ReNew

Technology for a sustainable future

Issue 135

WATER SAVING SPECIAL

WIN

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*Australian and NZ residents only; see page 73

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Water wise wicking

PLUS

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Home battery choices & more

Issue 135 April-June 2016
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DIY double glazing: glassy results

Sophie Thomson's dry garden tips

Waterless toilets: a mini guide

Heating Buyers Guide

Heat pump & hydronic

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Q Why do PV solar owners love the Sanden Eco® Heat pump so much?

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Issue 135, April – June 2016

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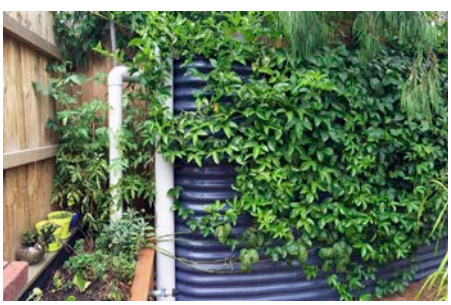
Wise water ways
Water-efficient gardens, no-water toilets and more

↑ Currently the world's largest offshore wind farm, the London Array is about to lose the crown to Hornsea One, off the coast of Yorkshire. Page 24.

↑ Noisy polluting generators go off; solar system lights up at a remote Indigenous rangers station in northern Queensland. Page 32.

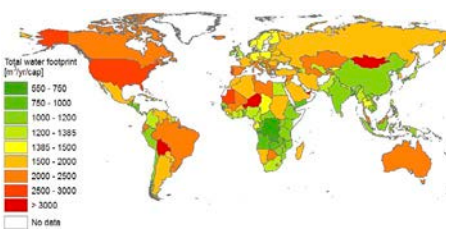


↑ This rain garden in the inner city is providing food, cooling shade and preventing stormwater runoff into local rivers. Page 54.

Features

↑ Sophie Thomson's thriving vegie patch in a dry climate, using wicking beds, 'measured' irrigation and low-pressure sprinklers. Page 46.

Special feature: water saving



↑ Yes, Australia has an above-average water footprint. Find out what that comprises. Page 70.

← **Cover image: A water-efficient home and garden in Castlemaine, Victoria. Photo by Calan Stanley.** With an extensive vegie patch (supplying tomatoes to the *ReNew* office!), this garden in Castlemaine is watered purely from a 7200 L rainwater tank, using drip irrigation and wicking beds. Two other tanks are plumbed to the home. Given the dry conditions over the last year in many parts of Australia, water efficiency needs to be back on everyone's agenda, so this issue we cover ways to achieve water-efficient homes and gardens, starting on page 40.

Guides

Efficient heating Buyers Guide

DIY

↑ We look at both reverse-cycle air conditioners and hydronic systems for heating. Page 74.

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

Sanctuary magazine

The ATA also publishes *Sanctuary: modern green homes*, providing inspiration and practical solutions to make your home or build more sustainable. The current issue of *Sanctuary* looks at ways to make sustainable housing accessible to more people.
www.sanctuarymagazine.org.au

Advocacy and projects

The ATA conducts research and consulting projects as well as advocating on issues of importance to our members.

The ATA is currently working on a number of policy and research projects in the energy space, including an analysis to help advise consumers whose premium feed-in tarrifs are set to expire at the end of 2016. In addition, we are making enhancements to the ATA advice service to enable us to serve more people needing individualised help on adding solar and making their homes more energy efficient.

The ATA is also working to advise the Victorian Government on a project to provide solar for all the surf lifesaving clubs throughout Victoria.
www.ata.org.au/what-we-do/advocacy

Alternative Technology Association

The Alternative Technology Association (ATA) is a not-for-profit organisation that exists to connect, inspire and assist people to make sustainable choices 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 6000 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 privileges to help you achieve your sustainability dreams. Your ATA membership provides you with benefits such as our free 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.

Not only does your ATA membership provide you with independent, practical advice on sustainable living but, with your support, the ATA will remain at the forefront of the next wave of innovative sustainable solutions that will define our homes and communities in the future.
www.ata.org.au

International projects

Kate Greenwood, ATA's new International Projects Group manager, has just returned from East Timor where she met with government representatives, our project partners and local groups. Hundreds of solar-powered lighting installations using the ATA's updated village lighting system (VLS) are planned for later this year as part of the Google Impact Grant.
www.ata.org.au/ipg

Publisher: ATA
Editor: Robyn Deed
Technical editor: Lance Turner
Advertising: Trish McLean, Olivia Wykes
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Design templates: SouthSouthWest
Cover design: Subgreen Design

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Contributions are welcome; guidelines available at www.renew.org.au or on request. Next editorial copy deadline: 22 April 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.

Next advertising deadlines:
Booking: 13 May 2016
Advertising copy: 20 May 2016

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Distributed in Australia and New Zealand by Gordon and Gotch.

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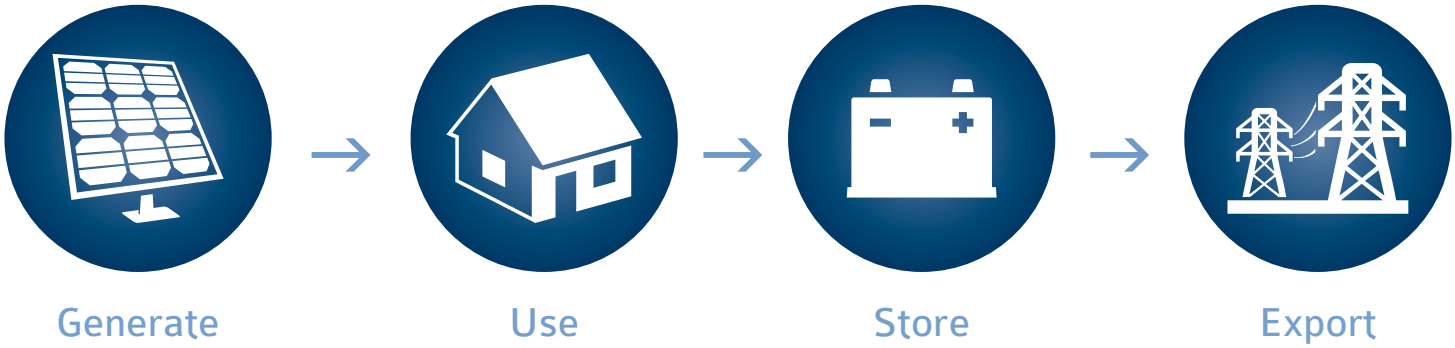

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Editorial

Water inside and out: monitor, measure and mete out

IN SOPHIE Thomson's Adelaide Hills garden, indigenous plants that survived under a 'no watering' scheme for several years have struggled this year, with some dying. In Victoria, we're seeing reservoir levels dropping, street trees struggling and many gardeners dismayed over just how dry the soil is. It's a similar story in many parts of Australia, with the tinder-dry bush causing devastating fires such as those in the Tassie wilderness.

If we don't want to abandon our gardens, critical as they are in providing shelter, cooling and habitat, as well as food, what do we do? In this issue, we explore some of the approaches that can help gardens thrive with efficient and effective use of water.

Sophie Thomson issues a challenge to rethink our gardens into watering zones, with most of the garden given to 'no water' and 'low water' plants—think local indigenous planting and choosing plants appropriate to the site and conditions. But that doesn't mean abandoning the higher water usage plants altogether, such as vegies; instead, we look at more efficient ways to water, including drip irrigation—potentially regulated according to temperature and rainfall—and wicking beds, where the water is delivered to the plant roots and wicks up to where it's needed. We've previously covered rainwater and greywater use in detail (see *ReNew 125* and *130*) so this time we shift attention to using stormwater via rain gardens, a way to reduce polluted runoff into our rivers and water the vegies at the same time. We also visit Melliodora, the Australian permaculture co-founder's property in Victoria, and find out how permaculture principles meld with water efficiency.

In the tropics and subtropics, the problem is slightly different—coping with deluges in summer and relatively dry winters. Two northern Australian gardening experts give advice on what to plant and ways to use water effectively in these regions.

It's not all about gardens. We also look at where households can save water, inside and out, and compare water usage around Australia. Our mini guide is on waterless toilets, definitely worth considering as a water- and pollution-saving measure.

Our main buyers guide is on heating. We often get queries about hydronic heating, so we've updated our guide to include both reverse-cycle air conditioners and hydronic.

And amidst all the talk about batteries and going off-grid, we take a look at what's available in all-in-one battery systems, and where the market is heading. We also examine the sustainability benefits of solar and solar + battery systems. If you've ever wondered just how much effect your solar system can have on the grid—can it really affect the output of a coal-fired power station?—this article is for you.

Plus there's lots more: a DIY on double glazing, a mini hydronic system, reviews of 10 water-saving books, where wind farms are heading and the Pears Report on how different the approaches to energy policy can be.

As we head into a disturbingly hot start to autumn, an election year and post the Paris climate talks, we welcome your feedback and input. We hope this year we can see action on climate change rather than just words.

Robyn Deed
ReNew Editor

In *ReNew 136*, out mid June

Australian-made, Passivhaus + more.

THE year 2015 ended with an historic agreement at the United Nations Climate Change Conference in Paris to limit global warming below 2°C. As a signatory to the agreement, Australia is now part of the push for a net zero emissions world.

At the ATA we are at the forefront of advocating for, encouraging and advising on sustainable technology and practices in Australian homes and communities to make a big impact on reducing carbon emissions. We are continuously researching and investigating new and emerging technology for a more sustainable future.

As an example of putting knowledge into action, we were very excited to team up with the Centre for Appropriate Technology (CAT) to install an off-grid solar system at the Oriners ranger base in far north Queensland. We have been admirers of CAT's work installing solar systems in remote Indigenous communities for many years and have profiled some of their work in *ReNew* previously. After funding cuts to their Bushlight program, the ATA was more than happy to work with CAT to trial a project reducing the costs of installing a system, with ATA members volunteering skills and labour.

A big thankyou to David Tolliday, John Dickie, Olivia Laskowski and CAT's Andre Grant for their work and dedication on a successful first project. We look forward to collaborating again in our goal for a net zero-emissions world.

Donna Luckman
CEO, ATA

Up front

Recycling app for Australia

Following a successful launch in Victoria in August 2015, the Sustain Me recycling app is set to go national early this year.

Developed over two years by young social entrepreneurs Stephen Halpin and Eleanor Meyer and their team of volunteers, to date the app has supported more than 1340 users to recycle around 3200 kg of waste and answered 7000 questions about recycling.

It provides localised information about what people can recycle and where they can do it. It also includes a personal recycling tracker, 'bin night' reminders and information on recycling centre locations and what they accept. So far, four councils around Melbourne have provided recycling information specific to their municipalities, and Sustainability Victoria has provided information for other regions; schools and businesses have also started coming on board.

The app's success has spurred Sustain Me's creators to continue their quest to "positively impact sustainability and recycling trends" and they're seeking crowd-funding to do it. www.sustainme.com.au

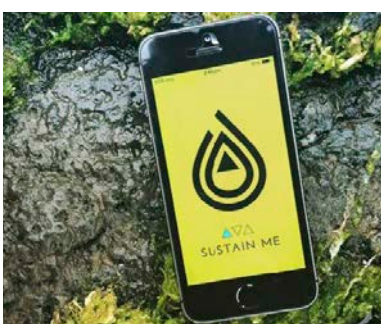


Image courtesy Stephen Halpin

Oz solar breakthroughs in brief

Australian company Vast Solar has taken the next step in the development of its concentrating solar thermal technology (which uses stored and then heated sodium to produce electricity when it's needed) with the commissioning of a 6 MW plant at Jemalong, NSW. In 2012, the company constructed a one-module pilot plant, which comprised a solar field of 700 mirrors (heliostats) focused on a 27 m tower with a thermal energy receiver, to which the sodium is pumped. The plant now has five such modules and will feed into the grid via Essential Energy's West Jemalong substation. This system's big advantage is that storage costs are just $25/kWh, compared with $300/kWh for conventional lithium ion battery storage. www.arena.gov.au

AGL and First Solar have together completed Australia's two largest solar PV plants at Nyngan (102 MW) and Broken Hill (53 MW). Combined, the plants will produce 360,000 MWh of renewable energy annually, enough for 50,000 Australian homes. The challenges in design, construction and commissioning of these large-scale projects will inform the development of further such projects that should help Australia transition to renewable energy sources more quickly.

An internationally unique solar project saw NSW alternative energy service provider Self Sufficiency Supplies recently win the Clean Energy Council's award for a stand-alone solar system with their three-phase system on a 120 V battery bank running a crematorium and chapel in Collombatti, near Kempsey, NSW. The backup generator has not been required since the system was commissioned six months ago. www.selfsufficiencysupplies.com.au

Darwin's Casuarina Square shopping centre now boasts Australia's largest rooftop solar system. The 1.25 MW system, completed in December 2015 by the GPT Group, comprises 4190 PV panels generating some 2030 MWh of electricity, powering about 20% of the centre's building and common area needs. The installation also has approval to connect to the electricity network powering local homes and businesses. blog.gpt.com.au

Photo courtesy of The GPT Group

↑ As of December 2015, Australia's largest rooftop solar PV system is this 1.2 MW system atop Darwin's Casuarina Square shopping centre.

New, easy test for airtightness

Air leakage in a building means draughts and reductions in energy efficiency. If you're serious about living in an airtight home, a blower door test is the usual way of determining air leakage. In conjunction with a smoke puffer, infrared camera or simply hand-feel, you can pinpoint where the leakages are occurring, so these can be addressed. A blower door test is a high-pressure air test that can only be conducted on a fully constructed building, as it won't work if there are gaping holes where windows and doors should be. A

STUDENT WATER PROJECTS

Rainwater savings confirmed by Swinburne study

New research into the cost-effectiveness of fitting rainwater tanks, by a team of final-year Swinburne University of Technology students, has found an average household water saving of 137 L (22.7%) per day.

Comparing water consumption data (from Yarra Valley Water) for 6390 households in the greater Melbourne area that had installed rainwater tanks and received government rebates between 2005 and 2008, with 5116 that had not, and using Google Earth to measure garden area and roof size of the houses in the study, their analysis further revealed a payback period of between 12.5 and 16.8 years, and that water from a 5000 L tank used in the garden, laundry and/or toilet had the shortest payback.

This research won the team the Australian Water Association's Victorian Undergraduate Water Award; they are in the running to win the national award, to be announced in May.
www.swinburne.edu.au

Water filtration workshop

Engineers Without Borders (EWB) Australia is a humanitarian organisation that aims to create a positive social impact through applying engineering knowledge to crucial issues, such as access to fresh water and renewable energy. Well known for their international projects, EWB also works within Australia.

EWB is currently running workshops in schools. The EWB team, drawn from university engineering students, talks to the students about issues surrounding water access in poor countries. Irina Halmagiu, coordinator of EWB's School Outreach Program and Regioneering Road Show, says, "We teach kids where they get their water from and how it is cleaned. Then we divide them into groups with each given a country; we use Australia, New Zealand, India, Ethiopia, Vietnam and Indonesia as the examples." Each of these countries is markedly different, from both economic and literacy perspectives so, for example, the kids in the Ethiopia group get instructions about how to build a water filter, but they are mostly in gibberish to mimic the low literacy rate in that country. "This teaches kids that you need knowledge as well as money," says Irina.

Photo courtesy www.ewb.org.au

Each group has a different amount of money to build their filter, based on average weekly earnings for their country (e.g. Australia $400, Ethiopia $20). The wealthier countries can donate to the poorer ones. The children are given materials for their filter—a bottle cut in half, sand, charcoal, woodchips and gravel—and compete to filter some dirty water; the group with the cleanest water at the end wins. The program opens children's eyes to water resource issues and how the sciences can provide solutions.
www.ewb.org.au

new invention, called the low-pressure Pulse air test, however, is set to change the game.

Developed by a consortium of specialists and academics in the UK energy efficiency industry over the last 14 years, the Pulse air test offers a number of benefits over the blower door test; chiefly, that the test can be done at different stages of a building's construction, offering the opportunity to make required changes as the building progresses, rather than trying to fix them once it's completed.

Other benefits reportedly include more accurate testing of air infiltration, lower-cost and more portable equipment, speedier testing (at the touch of a button, in minutes rather than an hour or more) and, working as it does with low air pressure, it can be used in occupied buildings.

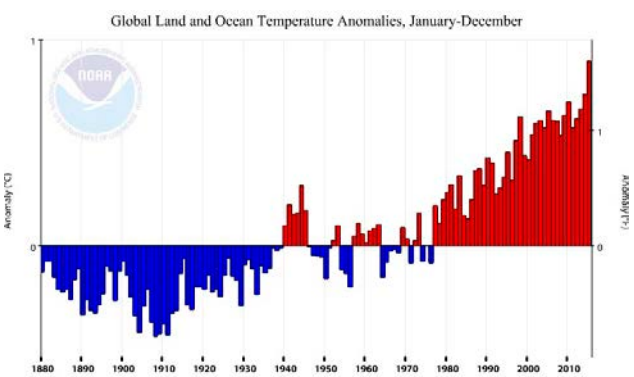
Following the safety testing and validation of a number of prototypes, production models of this new technology could be available in the UK from mid-2016. The developers are also in early talks with parties across Europe, the USA and Canada, with hopes to be able to make it available worldwide.
www.pulseairtest.com

'Hottest year' records keep tumbling

On 21 January, the US-based National Oceanic and Atmospheric Administration (NOAA) confirmed that 2015 was the hottest year on record, with the global average temperature climbing to 0.9 °C above the 20th-century average of 13.9 °C. This follows the previous record, in 2014, of a 0.74 °C increase. And, for the first time on record, December 2015 saw a global monthly temperature anomaly exceeding 1 °C (in fact, 1.11 °C).

Last year was the 39th consecutive year of above-average annual temperatures, and 2015 saw 10 months exceeding previous records for those months. An El Niño event developed also, one of the three strongest on record. And in May, CO_2 concentrations (one of the principal human contributors to global warming) reached 403.9 ppm—the highest ever recorded.

Breaking records is great in the sporting arena, but continually breaking 'hottest year' records will be catastrophic for us all. The stats are clearly showing that local, national and global action to reduce emissions is more urgent than ever.
www.theconversation.com



← 2015 is officially the hottest year on record, but it comes on top of previous such records in a continual increase in above-average global temperatures.
Source: www.ncdc.noaa.gov

Up front

Image: Landcare group Macquarie 2100

Where's Australia in the Top 10?

The answer is, it isn't. What Top 10 are we referring to? The 10 countries leading the world in the shift to renewable energy.

1. Sweden: With increased investments in solar, wind, energy storage, smart grids and clean transport, it aims to become the world's first 100% fossil fuel-free country.
2. Costa Rica: 99% of its electricity in 2015 came from renewables—primarily hydroelectric, solar, wind and geothermal.
3. Nicaragua: Renewable energy investments over the last eight years saw 54% of its electricity needs by June 2015 met by renewable sources; the goal is 90% by 2020.
4. Scotland: 97% of household electricity needs were met by wind power.
5. Germany: Up to 78% of electricity demand can be met by renewables, and it is the world leader in solar PV capacity.
6. Uruguay: Wind and solar investments in the last 10 years have seen 95% of electricity needs met by renewables in 2015.
7. Denmark: Wind power provides 42% of its electricity and it's aiming to be 100% fossil fuel free by 2050.
8. China: The world's largest carbon emitter, but also the largest wind energy capacity installed and the second-largest solar PV capacity; it's committed to phasing out coal and cleaning up its air.
9. Morocco: A combination of the world's largest concentrated solar plant, and wind and hydro plants, will provide 50% of this country's electricity by 2020.
10. USA: Fifth-highest solar PV capacity, second-highest wind power capacity; renewables accounted for only 13% of electricity needs in 2014 but potential to reduce emissions by 80% by 2030.

www.climaterealityproject.org

Global investors mobilising the billions needed to counter climate change

United Nations Secretary-General Ban Ki-moon, speaking at the 2016 Investor Summit on Climate Risk that followed the international climate talks in Paris, urged the gathering of 500 global investors (collectively managing assets of more than $22 trillion) to help significantly increase clean energy investments by 2020, so that the Paris climate accord's goal of limiting global temperature rises to below 2°C might be met.

Although clean energy investments hit a record high of $329 billion in 2015, he said, at a minimum, the level of investment would need to double, "to prevent excessive global warming that would trigger profound economic disruption and human suffering".

Other speakers at the all-day meeting, organised by non-profit Ceres, the United Nations Foundation and the UN Office for Partnerships, talked about the progress made to date in facilitating a shift in the global economy towards more clean energy and far less carbon, and the further commitments they would make in pursuit of this. Delegates also explored the growth areas for clean energy investments; for example, in India and China, and in solar and wind power, and therefore where it would make financial and environmental sense for capital to flow.

Michael Liebreich, chairman/founder of Bloomberg New Energy Finance, noted that the level of investment required over the next five years "will not be delivered by business-as-usual; closing the gap is both a challenge and an opportunity for investors".

Reinforcing this move towards much greater investment in sustainable operations, a recent report by AXA Investment Managers stated that responsible investment would move from being a specialist area to a must-have by institutional investors in 2016, as environmental issues, divestment and impact investment become more pervasive.

www.3blmedia.com
www.ethicalinvestor.com.au

ATA Gas Preferences Survey

The ATA (*ReNew*'s publisher) has been collecting information about gas preferences to facilitate consumer advocacy. The findings will be variously submitted to and discussed with state and federal governments, regulatory bodies and other advocacy organisations to raise awareness about gas usage trends and highlight concerns regarding extension and regulation of gas networks around Australia.

So far, around 1000 people have responded to our survey (thank you!). Of these, 65% are ATA members, 90% are homeowners and 54% are from Victoria (the state with the highest demand for residential gas).

Initial survey results have revealed that gas is significantly less the energy source of choice than it was 5 or 10 years ago, with nearly two-thirds saying they would now opt for electric appliances. Of the nearly one-third of households using less gas than three years ago, reasons included installing electric appliances and more efficient appliances, improving their home's thermal efficiency and installing solar hot water.

When it comes to space heating, 43% of respondents heat their homes using mains gas ducted heating. Interestingly, 36% of these also have a reverse-cycle air conditioner (RCAC) that they could use to heat their home instead. Mains gas is used for heating water in about half the surveyed households, with 41% of these being existing systems when the house was bought and 37% chosen partly for environmental reasons. Of the 8% who replaced their HWS in the last year, most replaced it with something different.

The Gas Preferences Survey is still open so if you want to help influence the industry and its regulators, share your opinions and experience (and feel free to encourage others to do so) at www.surveymonkey.com/r/LPLZKF5. And for a full overview of the survey results, keep an eye out on the ATA's website www.ata.org.au.

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Letters

Energy assessors

Thank you for highlighting in *ReNew 134* the opportunities for householders to engage professional assessors to advise them on how to use energy efficiently in their homes.

The role of the Thermal Performance Assessor (TPA) and House Sustainability Assessor (HSA) were defined as being quite separate roles but this is not quite the case, as the role of TPAs has evolved from its traditional role of issuing compliance ratings for new work to now include the provision of home sustainability assessments for existing homes.

TPAs are qualified and must hold the Certificate IV in NatHERS Assessment qualification. Assessors with this nationally recognised qualification can undertake compliance ratings for new homes and also carry out home sustainability assessments for energy, waste and water usage of existing homes.

Whilst not mandatory in all states and territories, many TPAs choose to be accredited with ABSA or BDAV, hold professional indemnity insurance and complete professional development training each year to maintain their accreditation.

Householders should look to engage accredited Thermal Performance Assessors who hold this qualification for home sustainability assessments as well as for new homes. They can be confident of receiving quality advice from a qualified person that meets their objectives.

Michael Plunkett

Avoiding waste

Following on from your waste articles in *ReNew 133*, I have been looking at how to downsize my housing, getting rid of years of hoarded goods and family heirlooms without hiring a skip.

My first attempt was to book a hard-waste collection and put stuff on the grass in the hope that people would take stuff. To our surprise, a local man, Anthony Deicmanis, was passing by and offered us cash for various items. We have since sold him quite a lot of goods. He sells on eBay as lustintherust2014, and on Instagram as lustintherust, or at the Camberwell Market.

Hard waste can be publicised on Facebook in the Hard Rubbish Melbourne page.

I then sold a beautiful solid wood wardrobe on eBay, and got twice as much as I originally asked; eBay is good when you are not sure of the value of something. The buyer sent around a truck to take it, which solved the moving problem.

Various councils run differing recycling programs. Yarra has a very comprehensive recycling drop-off point in Roseneath Street, Clifton Hill (see www.bit.ly/21bv5mt).

Yarra also runs a Bright Sparks program that repairs electrical goods and passes them on to low-income people, as well as a clothing recycling program. There's also an app called Sustain Me that looks at your locality and lists the services available.

For general resale, I found Gumtree, either to sell or give away free, as the best. The app is easy to use and got a good response. Freecycle is more difficult, in my opinion. There is also Craigslist, which I did not try.

In addition, Darebin and Casey run tip shops where stuff is rescued and resold.

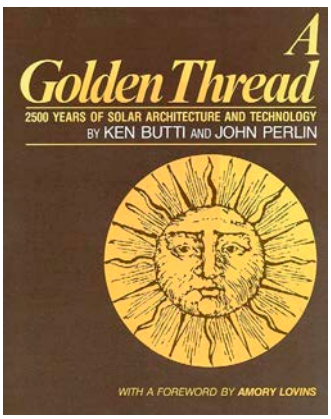
There are many other initiatives, which I don't know enough about. Op shops vary a lot depending on what resources they have, but goods must be saleable. However, goods refused by the Brotherhood of St Laurence went in a few hours on Gumtree, when offered for free. However, op shops use the money they raise for charitable works, so it can be worthwhile to use them when possible. One of my op shops had a tool store and took a lot of my gardening tools even though they were old and worn. I'm sure that there are more initiatives around.

Chris Moss

An interesting read

In *ReNew 133*, page 11, under the heading 'Back to the future' there was an interesting article on the Terrajoule Corp in the USA and a small-scale steam engine for use with parabolic trough solar collectors. There is an interesting book, written in 1980 titled *A Golden Thread—2500 Years of Solar Architecture and Technology* by Ken Butti and John Perlin, and in one of its chapters it goes into this topic with the story of an American company using this technology in the 1890s. The book is written with the layperson in mind and I would recommend it to anyone interested in small-scale solar energy history and use. Keep up the good articles.

Matthew Thomas



Solar thoughts

These are just my speculations, but from what I read, electricity will be totally solar in a few years time—utilities will be competing to find places to install PV panels and batteries near to the demand. Thermal power generation will disappear abruptly very soon, partly because of global warming but mainly expense. High-voltage transmission lines and solar farms will be fading away, again because of expense. Hydroelectric and wind power will stay, especially where they are reasonably close to population centres, because the power is cheap.

To get an idea of what this will mean to our cities; I estimate that the average person will use ~7 kWh/day which requires 20 m² of PV panels and, to allow for cloudy days, 10 kWh of battery storage, which needs 0.1 m³ storage space. For an Australian city of a million people this means 2000 hectares of panels

A cool fireplace

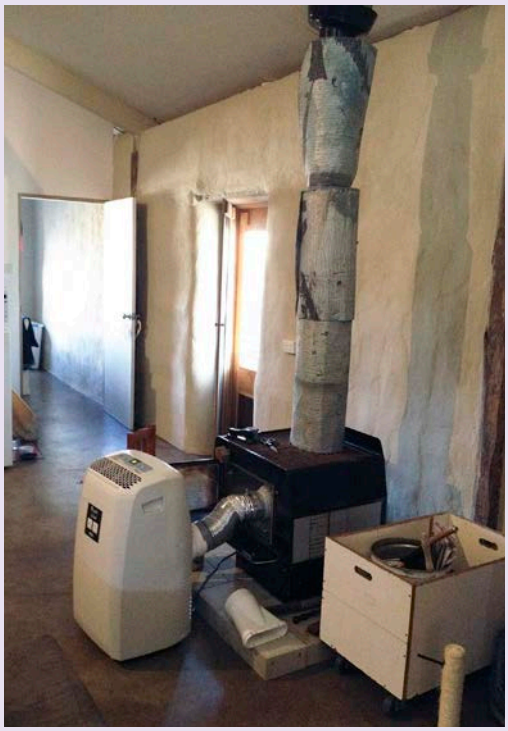
I thought I might share a little project with you. Hopefully it may help someone else as well.

Having owner-built a strawbale 'shouse' (shed/house) to live in while we build our main house, I didn't want to spend too much money on heating and cooling. Fortunately we were given a used wood heater just before winter this year which fits in well with our reuse/recycle beliefs.

We purchased a portable refrigerated air conditioner for summer use, but I couldn't figure out a way to exhaust the hot air. We custom-made our windows and they just didn't work with the air-con exhaust fittings, and I didn't like the idea of cutting a new hole in the roof or through the strawbale walls. As I was pondering this dilemma, my gaze stopped at the fireplace chimney and the proverbial 'tonne of bricks' hit me...use the hole I already had!

With some old Aircell offcuts to double-wrap the chimney (blocking the radiating heat), an old shirt to fill the gaps between the chimney pipe and exhaust tube, a piece of old perspex cut to size to stop any escaping hot air from the fire box and a couple of fittings from the hardware store, I had converted my wood heater into a 'cooler'. As it was the festive season, all I needed was a bit of Christmas wrapping paper and some fairy lights to finish it off!

Pete Sharpe



and 10 hectares of storage one metre deep. My estimate of the size of this city is 1000 km² or 100,000 hectares. There should be ample room.

Take a vantage point over the city—suitable roofs are everywhere! Good ones are carparks; a utility provides a roof covered with panels—sun and rain, gone! Others such as churches will gain some extra income by renting their roof. In my suburb a local supermarket has installed panels on the roof with no storage simply to reduce electricity costs during the shoulder and peak periods.

And there are plenty of places for batteries; a cubic metre will hold 100 kWh. Think of basements, inspection pits in footpaths, substations, etc.

Householders will find renting out roofs and storage space much better than installing panels and batteries. A good project for *ReNew* would be an article about suitable contracts for this.

Installing panels on the roofs of businesses will have a dramatic effect on electricity prices.

Utilities will raise prices at their peril, as it will just encourage more panel and battery installations.

Imagine a world where people only worked when the sun was shining—weekends and all.

Jim Jacobs

Poor tap design

This letter is to suggest an alternative use for existing technology, and perhaps ATA could make it happen.

Modern swivel mixer taps have cold to the right and hot to the left. They look best on 'warm', with the swivel pointing forward lined up with the tap. That's how cleaners line them up in the bank of basins in supermarket toilets and the like. When the tap is used for the normal 10 seconds, hot water flows into the pipe and cools down before it reaches the tap—over and over again.

However, the taps can be installed at 90 degrees, so that cold is to the front, warm is to the left hand side and hot is further to the back.

Cold then normally gets used, unless warm or hot are specifically chosen. This all sounds trivial, until you notice how very common it is. There are many thousands of these taps, wasting energy unnecessarily, with unnecessary energy costs and no winners.

I don't know any way to change plumbers' normal practice? Can you think how to do it?

Margaret McKenzie

This should work on some installations at least, depending on the sink design (some sinks don't have a simple hole, but rather a shaped hole, designed to allow the tap to mount in one position only).

However, there are taps already available to address just this issue. The Mora ESS is one such unit, see (www.moraarmatur.co.uk). They used to be available here from Rye Australia, but they seem to have disappeared and I haven't found another supplier. Perhaps a reader knows of a similar alternative?

Lance Turner

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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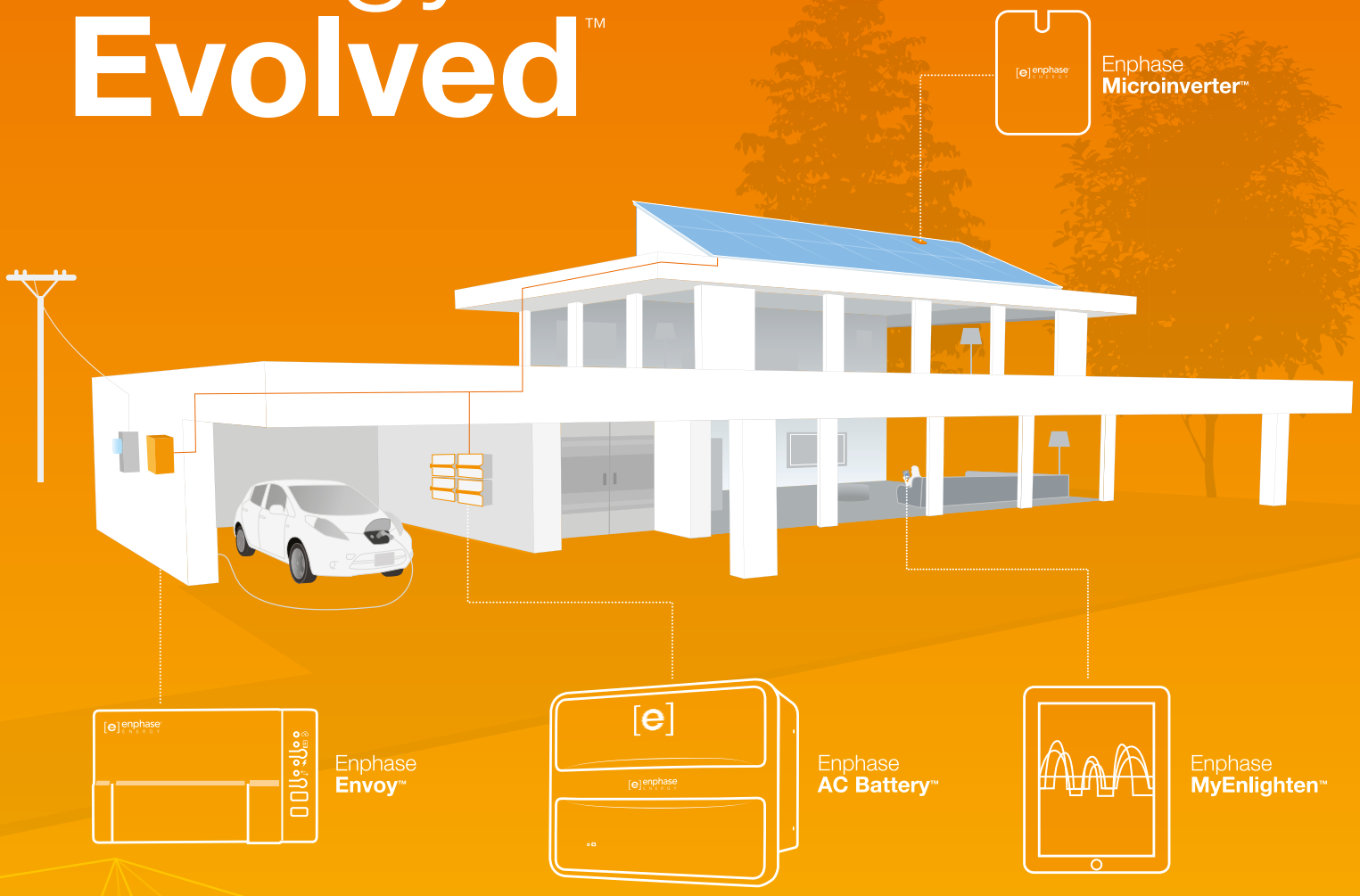

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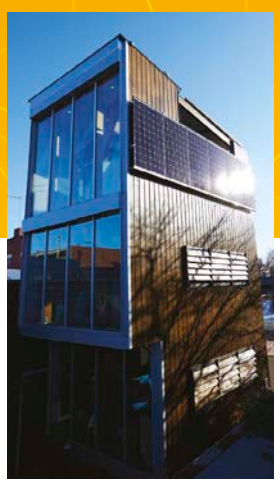

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Products

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

Simple water saving in the garden

Sometimes ideas are so simple you wonder why they weren't thought about before. When it comes to the Greenwell water saver, it actually was!

The Greenwell was developed around 15 years ago and has been used extensively by councils to reduce water wastage when watering street and park trees. However, you can also use them at home as they are readily available from Bunnings and other stores.

As you can see from the photo, the Greenwell is a simple plastic surround that you place around a tree, digging it into the ground as much as desired or required. When installed it not only holds mulch in place, it acts as a water reservoir—just fill it up and the water will slowly soak into the tree's root ball without any water loss due to runoff. It can also be used for tomatoes!

The Greenwell is a single piece of UV-stabilised recycled polypropylene plastic with a slide seam, so you slide the seam apart, wrap it around the tree and slide it back together. This allows installation on existing trees and shrubs without disturbing the plant.

Available in black, green and terracotta colours, and in two sizes—regular (495 mm diameter by 195 mm high) and large (670 mm diameter by 250 mm high).

RRP: around $10. For more information contact Greenwell, ph: (08) 8338 3124, brian@treenet.com.au, or see www.greenwellwatersavers.com

02

Protect your house from battery fires

There's no denying the advantages of electric vehicles of all sizes and shapes, but in recent months there have been some battery fires associated with small EVs, particularly 'hoverboards', but also with electric bikes.

Even hoverboards that are compliant with Australian standards have experienced fires, so it's not just the cheapies that can be a problem. The issue is the use of lithium battery chemistries that are not fire-resistant. The fire risk is one reason electric cars tend to use lithium iron phosphate cells, as they are far more resistant to fire.

However, given that there are many small EV batteries using the higher risk lithium formulations, Homescreen Media Pty Ltd is releasing a fire-resistant woven fibreglass bag called the Hovervault to help prevent property damage or destruction from lithium battery fires.

The Hovervault is like a large version of bags used by remote-control vehicle enthusiasts when charging their lithium polymer batteries to contain any fires. You just place the entire hoverboard inside the bag for charging. Should a fire occur, it will be contained inside the bag.

Of course, the Hovervault will also be perfect for charging electric bike batteries, or any other small EV batteries that will fit inside the Hovervault's 220 x 220 x 620 mm dimensions.

RRP: $59.95. For more information and to buy, go to www.hovervault.com

03

DIY SHW controller

For the solar hot water DIYer, wiring a mains-powered pump and controller is usually not an option, but there is an alternative—use a DC pump. Of course, you need a suitable pump controller, and Art Tec Solar has just the solution.

Their range of solar-powered differential temperature DC pump controllers don't even need a battery to operate—they run the pump straight from a photovoltaic solar panel.

The controllers are designed to improve system performance by preventing the pump from running if the water heating collectors become cooler than the storage tank, which may occur on overcast days and early and late in the day—when there is enough sunlight on the solar panel to power the pump, but the collectors have not yet become hotter than the storage tank.

There are three models of controller. The DTC-1 is the simplest and most affordable and ideal for SHW experimentation. The mid-range DTC-AT has adjustable differential and maximum temperature settings, while the DTC-D includes an LCD, selectable pump modes, freeze protection and temperature logging. It will also display the temperature in degrees Celsius (the other models only display in Fahrenheit).

RRP: from US$98 for the DTC-1 to $210 for the DTC-D. For more information and to buy, contact Art Tec Solar, guy@ArtTecSolar.com, www.arttecsolar.com

04

Double glazing for everyone

The benefits of double glazing are well known, yet few new homes in Australia are built with it. The reason is partly cost, and partly that it is still seen as a bespoke solution and builders may be reluctant to include it in design specs.

Paarhammer is aiming to improve the uptake of double glazing by developing a range of domestic windows and doors, called the Builder's Range, that will assist builders to achieve improved energy ratings with ease.

The windows and doors are supplied with bare wood frames, sanded and ready for painting, aimed at providing a substantial saving for the builder while suiting their workflow and contractor arrangements. This range is limited to domestic sizes and double glazing, but includes features such as secure locking, restricted tilt opening for child safety, a six-year manufacturer's warranty and a 10-year warranty on the glass. A 17 mm ply reveal is available at extra cost.

The range includes European style tilt-and-turn windows, fixed windows, French doors, bi-fold doors and lift-slide doors. Fly screens are available to order.

Paarhammer is also providing installer training.

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

05

A fairer phone

The original Fairphone was released to address the ethical issues in the supply chain of electronic products like mobile phones. Materials used in many phones can come from questionable sources (known as conflict minerals as mining them finances conflicts in the Congo), but the Fairphone 2 is made from FairTrade-certified materials, making it the most ethical phone out there.

Of course, with so much competition, it also needs to perform, and the new Fairphone 2's specifications allow it to compete in the mid-range phone arena quite well. Running on Android 5.1 Lollipop, the Fairphone 2 is powered by a 2.3 GHz quad-core Snapdragon 801 processor, with 2 GB RAM and 32 GB internal storage, plus a microSD slot. The 5-inch LCD has 1920 x 1080 resolution (441 ppi), 4G, wi-fi and Bluetooth connectivity, and dual SIM card slots.

Another interesting and ethical aspect of the Fairphone 2 is that it is designed to be modular. The individual components are easily replaced by the user, allowing it to be repaired or upgraded instead of being discarded.

While not the fastest phone out there, it is certainly the most environmentally sound and ethical smartphone we've seen. Note that the Fairphone 2 is currently only available in European countries, although it is expected to be available outside Europe this year.

RRP: €525. For more information and to buy, go to www.fairphone.com

06

Go MPPT without blowing the budget

Maximum power point tracking (MPPT) charge controllers let you make the most of your solar array on battery-based systems. However, most MPPT charge controllers are expensive as they are designed for larger systems. But what if you have a smaller off-grid system, but still want the benefits of an MPPT unit?

Well, you could take a chance on a cheap unit from eBay, but most of those are actually not MPPT charge controllers at all.

Another option is to go for one of the nice little units from the Victron BlueSolar MPPT range.

There are quite a few units in this range, from the 75/10, which has a maximum battery charge rate of 10 A and a maximum PV input voltage of 75 V, through to the 150/85, with a maximum charge current of 85 A and PV input of 150 V.

System voltages catered for are 12, 24, 36 and 48 V, depending on model. Features vary depending on model, and efficiency for all models is 95% or greater, depending on the battery voltage being charged to.

RRP: From around $165 although prices vary. Available from many renewable energy equipment suppliers. For more information, contact Victron Energy, mleeftink@victronenergy.com, www.victronenergy.com

Products

07

Store that heat

Whether you are looking at installing a hot water system or even a DIY hydronic system, you need a good-sized, well-insulated tank to store your heat.

The Tivok Energy Bank is a 420-litre grade 304 stainless steel tank designed to operate at atmospheric pressure. It uses a corrugated coil stainless steel heat exchanger inside the tank that transfers the stored heat to mains pressure water, without the need to store the hot water at mains pressure. Eliminating tank pressure eliminates the need for PTR valves and increases tank life.

The tank has multiple ¾" BSP water fittings for solar collector and heat pump connections, as well as hydronic heating connections. The heat exchanger's potable water connections are on the top of the tank, and maximum mains pressure for the heat exchanger is a huge 1650 kPa.

The tank features 60 mm of polyurethane insulation, surrounded by an aluminium-plastic composite case, which is available in silver or black finish.

The Energy Bank measures 665 x 665 x 1764 mm and weighs 71 kg.

RRP: $2428 + GST. For more information, contact Tivok Energy Pty Ltd, 4/51-53 Bourke Rd, Alexandria NSW 2015, ph: (02) 8084 7905, info@tivok.com.au, www.tivok.com.au

08

Lighter wood composites

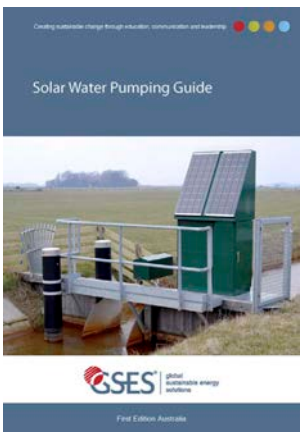
We have looked at numerous wood/plastic composite building materials over the years, but many were simply solid extruded sections, making them quite heavy, requiring greater materials use to make them and increasing transport emissions.

Biowood Australia has a range of wood composite materials for domestic and commercial use, including decking, flooring, lining, battens, cladding, louvres, fence posts and panels, and even roofing.

What makes the Biowood range interesting is that most of the profiles are designed to be hollow, greatly reducing the material content and weight. The materials are nevertheless strong and durable, are termite- and mould-resistant, and won't splinter, crack or rot—although for outdoor use, a UV-resistant coating is recommended. The material is also rated as non-combustible and self-extinguishing.

Standard colours include spotted gum, red cedar and weather wood, although other colours are available on special order, as are other profiles (minimum quantities apply).

For more information, contact Biowood Australia, Unit 2, 74–80 Helen St, Sefton NSW 2162, info@biowoodaustralia.com.au, www.biowoodaustralia.com.au



09

Solar pumping guide

Reliable water pumping can be critical in many areas, and where no mains power is available, the task often falls to solar power. However, creating a reliable solar pumping system is not as simple as it might seem.

The Solar Water Pumping Guide from Global Sustainable Energy Solutions (GSES) is a PDF eBook that guides you through the setting up of a reliable and correctly designed solar water pumping system.

The book covers systems from basic solar-only systems, solar with battery and even solar/generator and solar/grid hybrid systems. The book covers system components, such as PV panels and array sizing, controllers, motors and pumps. It looks at site assessment, water storage, system layout, flow rate calculations, pipe sizing and selection—all aspects of system design and implementation are covered.

Electrical wiring is also covered, as is system maintenance. Appendices include a design checklist, dynamic head calculations and solar system rebates.

RRP: $25. For more information and to buy the eBook, go to the GSES website at www.gses.com.au/shop

10

A Big Ass light

We've looked at the huge ceiling fans from Big Ass Fans in the past, and now they have turned their attention to another area of workspace fittings—lighting.

The Big Ass Light 122 watt Garage Light is rated at 13,000 lumens, with a colour temperature of 5000 K and a CRI (colour rendering index) of 70 or greater. Lumen maintenance is rated at 70% after up to 150,000 hours, so the light will pretty much last forever.

The lights are made from extruded aluminium profiles for good heatsinking and feature removable 'lumen maintenance trays' (LMTs)—basically slide-out covers that protect the LEDs from dust and bugs.

A optional occupancy sensor is available for improved energy savings, and the lights come with a huge seven-year warranty. The Garage Light measures 587 mm long x 233 mm wide x 118 mm high including hanging loops, and comes with a three metre cord and plug.

RRP: POA. For more information and to buy, contact Big Ass Light, ph: 1300 244 277, www.bigasslight.com.au

11

Non-plastic electronics

We all know plastics are an environmental issue, but their use has allowed electronics to evolve to what they are today.

However, while plastics are cheap and quick to manufacture, there are alternatives suitable for some electronic devices at least.

iBark has a range of electronic devices and accessories with cases primarily made from natural materials such as wood and bamboo. The range includes radios, portable speakers, iPhone cases (which can be customised with your personalised message, brand or custom design laser engraved onto the case), wooden watches, sunglasses and clocks, and on the non-electronics side there's a wooden yoyo!

For the office, there's even a wooden stationery set, with each piece hand-crafted from sustainably sourced wood. The set includes a stapler, letter opener, tape dispenser, stationery holder and blade holder, all packaged in a light wood box.

RRP varies of course, but shipping is free Australia-wide on orders over $20. For more information and to buy, contact iBark, PO Box 970, Byron Bay NSW 2481, shop@ibark.com.au, www.ibark.com.au

12

Garden vertically

As high density living becomes more commonplace, many people are missing out on the joy of having their own garden and growing some of their own food. However, you don't need a lot of space for a garden if you garden vertically.

The Foodwall from Biofilta is a wicking vertical garden consisting of self-contained garden beds that stack two or three high, saving space and allowing for much easier access, especially if you have trouble bending over.

The beds feature an adjustable water level system to suit both seedlings and established plants, and an internal aeration system to separate most of the soil from the water which maintains the health and productivity of the root zone and promotes high plant productivity and vegetable or herb yield.

Being modular, you can connect multiple bays and water from a single point, so you won't end up with a mess of hoses. The units are ideal for connecting to a rainwater tank, or mains water of course.

For more information and to get a quote, contact Biofilta, Unit 2/49 Bertie St, Port Melbourne VIC 3207, ph: (03) 9673 0320, marketing@biofilta.com.au, www.biofilta.com.au

Wind in the works
Wind farm round-up

Wind turbines are getting bigger and better. Alicia Webb takes us on a tour of the latest wind turbine tech and wind farms worldwide.

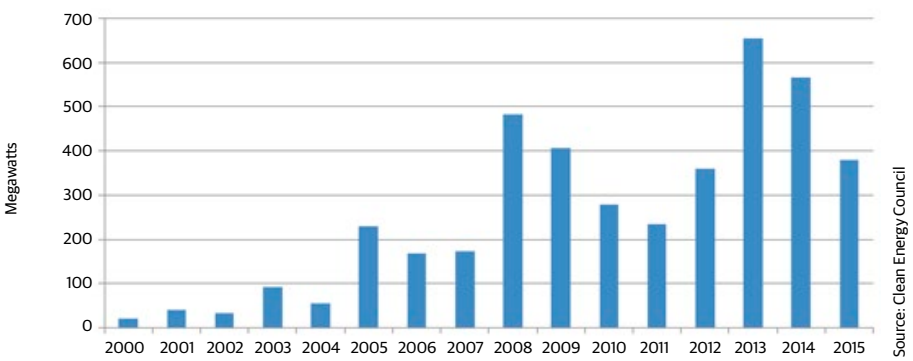
WHILE the world pushed on with ever-increasing wind farm installations, the Australian wind industry had another quiet year in 2015. The most significant change was that the large-scale component of the national Renewable Energy Target (RET) was revised down and legislated to remain in place without further changes to 2020. While the downwards revision of the target was disappointing, the industry is looking forward to getting back on track and spending the next four years delivering the projects that are needed to reach the target.

While confidence slowly returns to the sector, the activity levels behind the scenes are encouraging. Wind farm developers are working hard to ensure their sites are ready to go, with many development permits being revised to allow for larger, more modern turbines.

State-based renewable energy schemes were a lifeline for the industry during 2015. The Australian Capital Territory's first reverse auction scheme for 200 MW of wind capacity awarded contracts to three wind farms.

The low prices awarded for these contracts (the lowest was AU$81.50/MWh for the 20 MW Coonooer Bridge wind farm) surprised everyone and demonstrated how much progress the wind industry has made in bringing costs down. All three of these projects are currently under construction, creating jobs in rural Australian communities.

A second round of the reverse auction has also been awarded in two 100 MW lots. Hornsdale wind farm in South Australia, which won 100 MW in the first reverse auction, also secured a second stage (for a bargain price of $77/MWh), and a wind farm in the New England region of NSW won the other half.



↑ Annual installed wind capacity in Australia over the last 15 years. The graph shows increases overall, though with considerable fluctuation. While 2015 was a slow year for wind farming, prospects for the future are looking better due to the final resolution of a (reduced) Renewable Energy Target and friendlier state governments.

Australia's total installed wind energy capacity was 4187 MW at the end of 2015, made up of 2062 turbines spread across 76 wind farms. New capacity totalling 380 MW was added during the year. The graph below shows how the industry has ebbed and flowed in line with policy and funding.

Wind farms around the world

The world is blazing ahead with installing renewable energy and transitioning electricity systems away from fossil fuels. Compare Australia's 380 MW installed in 2015 with China, which installed 30,500 MW, about 80 times as much as us! Globally, the market grew 22% in 2015 with a total of 63,013 MW of new installations. Following China, leading countries included the 8600 MW installed by the USA and Germany's record 6000 MW of new projects, including 2300 MW of offshore wind power.

The country generating the most wind energy as a proportion of total electricity is Denmark. In 2015 Danish wind turbines generated enough electricity to provide 42% of the country's electricity consumption, a world record.

Steve Sawyer, Secretary General of the Global Wind Energy Council, said that 2015 saw China edge past the European Union in terms of total installed capacity, with 145.1 GW in China and 141.6 GW in the EU. The Chinese government's drive for clean energy is motivated by the need to reduce dependence on coal—which is a major source of the choking smog strangling China's major cities—as well as growing concern over climate change.

According to Bloomberg New Energy Finance, China's huge wind installation numbers were good news for Chinese

manufacturers as well, with nearly all of the capacity installed in China during 2015 being supplied by Chinese manufacturers.

Wind turbines keep growing

The wind industry in Australia kicked off in earnest in around 2003. That year, the largest wind farm in Australia was Challicum Hills, near Ararat in western Victoria. The wind farm consists of 35 turbines, each with a capacity of 1.5 MW, a rotor diameter of 64 m and a total tip height (tip height is the total of the tower height plus one blade length) of around 100 m.

Since then, wind turbine technology has made remarkable leaps forward. Costs are coming down while turbines can generate more energy using taller towers and longer blades.

The largest wind farm in Australia (and the southern hemisphere) is Macarthur, also in western Victoria. It has 140 turbines, each with a capacity of 3 MW, a rotor diameter of 112 m and a tip height of around 140 m.

The largest turbines in Australia are being constructed right now, at Coonooer Bridge wind farm in north-west Victoria. There will only be six turbines, but they're massive, with a capacity of 3.3 MW, rotor diameter of 117 m, and a tip height of just under 150 m.

The largest wind turbine in the world (in terms of generation capacity) is the Vestas V164, with a capacity of 8 MW, a rotor diameter of 164 m and a tip height of 220 m. It is intended for offshore use, but a land-based prototype was installed in 2014 in a Danish test centre.

The Clean Energy Council is expecting a big 2016 for the wind industry, with new projects signing deals and construction getting into full swing. Wind energy enjoys broad support across Australia, including in the regions in which wind farms are situated. And the newly revised Renewable Energy Target will mean almost doubling the existing amount of wind power in the next four years.

Alicia Webb is a policy manager at the Clean Energy Council. Her background is in engineering and she's been in the renewable energy industry for over 10 years.

More info: Articles on increasing tower heights and new blade designs: www.bit.ly/1oCbE4x, www.bit.ly/1R3e7Md

Image courtesy Vestas Wind Systems A/S

↑ The Macarthur Wind Farm is located across 5500 ha in the Western District of Victoria. With a capacity of 420 MW, it is currently the largest wind farm in Australia and the southern hemisphere. It has been operational since 2013.

Image courtesy Londay Array Ltd

↑ The London Array is currently the world's largest offshore wind farm. It has a capacity of 630 MW and has been operational since 2013. However, just announced, construction of Hornsea One is set to proceed. Sitting off the coast of Yorkshire and with a capacity of 1.2 GW, this will take the crown from the London Array, and will power more than a million homes.

Image: Papolon, reprinted under CC BY-SA 3.0

↑ On completion—estimated to be in 2020—China's Gansu Wind Farm Project, collectively located over a number of localities in the deserts in the west of the country, will have a capacity of 20 GW. Construction began in 2009. When finished, it is likely to be the biggest wind farm in the world.

Store and deliver
Energy storage market heats up

The energy storage sector is heating up. Lance Turner takes a quick look at where the industry is heading.

A DECADE ago, seeing solar panels on homes was a rare occurrence, yet now you will find them on more than one million Australian homes. Indeed, solar has become completely mainstream, no longer just for greenies and those living remotely.

While solar power works well to reduce dependence on the grid at peak times, the recent or pending removal of decent feed-in tariffs for many solar owners has meant that many are now looking at energy storage. A battery system means that system owners can reduce their low-valued exports to the grid and instead store the energy for later use, offsetting expensive grid imports, and potentially saving money, or at least shifting the balance towards greater self-sufficiency.

Traditionally, solar battery systems have been designed to suit the individual installation, but for grid-connected storage that is no longer a requirement. All you need is a system that can store an appropriate amount of energy and be able to supply that to your house when needed—it doesn't need to cover all demands of the home at all times.

To this end, we have seen a proliferation of domestic-oriented energy storage systems (ESS) of late. They vary in size, shape and features, but all are designed to allow the homeowner to take better control of their energy generation and use, reducing bills and, in some cases, providing a degree of backup against grid failure.

Not all systems are designed for grid backup, but this is becoming more common as manufacturers realise that customers want their systems to be as flexible as possible, even potentially allowing them to eventually go off-grid altogether.

↑ The UltraFLEX (right) and the smaller soon to be released UltraPOD (not shown to scale) use the CSIRO-developed lead-acid based UltraBattery for energy storage.

Even if you don't have a solar energy system, but are on a time-of-use tariff, you can make a battery system work for you. You can charge the battery during off-peak hours when there is a glut of electricity and low prices, selling that stored energy back into the grid at peak times. However, to get a decent price for the energy you export, you need to be able to tap into the National Electricity Market (NEM) system and get the current going rate. While domestic generators traditionally have been excluded from the NEM, this may be changing. Reposit Power is trialling a product that allows you to access the NEM, provided you are using a compatible battery system. So far, three systems are Reposit Power compatible—the Tesla Powerwall, LG Chem's RESU 6.4, and the Magellan RES1. However, you must also have a participating electricity retailer. So far, only Diamond Energy has a Reposit Power compatible plan—which will pay customers extra when there's a grid credit event, once the trial starts (see www.diamondenergy.com.au/reposit-GC100).

Battery types

Before we go too much further, we should cover the different battery chemistries available.

The traditional chemistry for energy storage has been the lead-acid battery—and for good reason. Lead-acid batteries are robust, reliable, well understood and, if treated correctly, can last a decade or more, especially in standby and low discharge

↑ The Enphase AC battery is a modular AC system—just install as many as you need.

depth applications. Despite them being an old technology, work is still being done to improve efficiency and lifespan of lead-acid batteries. A good example is the CSIRO-developed UltraBattery, which combines the best attributes of lead-acid batteries and ultracapacitors (capacitors are electronic components that store energy and can provide very high charge and discharge rates, while lasting many thousands to millions of charge–discharge cycles).

So far, the UltraBattery has been aimed at the utilities market, used in projects such as the Hampton Wind Farm in NSW and the King Island Renewable Energy Integration Project (KIREIP, see www.kingislandrenewableenergy.com.au). Smaller-scale UltraBattery systems are available, with the UltraFLEX available in 8.4, 12.6 and 17 kWh capacities and the 4.2 kWh UltraPOD system planned for a mid-2016 launch.

However, by far the most dominant technology in self-contained battery systems is lithium ion. One of the main reasons for this is that lithium batteries are much more energy dense than lead-acid, which results in smaller and lighter storage systems, allowing battery systems to be placed in tighter spaces or even hung on walls. Also, lithium batteries are expected to have longer lifespans than lead-acid batteries, while being able to undergo deeper discharges, reducing the actual capacity required for a particular daily cycling capacity—lead-acid battery lifespan reduces more rapidly than most lithium chemistries as discharge depth increases.

It should also be mentioned that there are several lithium battery chemistries in use. The dominant one for large-scale storage is lithium iron phosphate ($LiFePO_4$, or LFP for short). This dominance is due to the longevity and robustness of this chemistry, as well as its resistance to battery fires.

Lead and lithium are not the only games in town. Other chemistries include sodium ion, effectively a saltwater electrolyte battery, such as the units from Aquion Energy, which are available for domestic installations. Another chemistry is zinc bromine (such as the Redflow flow battery); Redflow's domestic model (a 48 V DC battery-only system) will be launched at the end of March 2016. We will take a closer look at it in a future issue.

AC versus DC batteries

We should also briefly discuss the different connection systems. There are both AC and DC storage systems available. As you might expect, AC systems connect to the mains grid side of a renewable energy system. They can charge via the mains grid or from solar panels that connect directly to the storage system, or via a separate external inverter. This makes them particularly useful for adding storage to microinverter based solar systems, or where an existing grid-interactive inverter is to be retained. The Enphase AC battery is an example of such a system.

DC systems contain no embedded inverter. Instead they use a bi-directional DC–DC converter to charge the batteries from the solar, as well as allowing the batteries to discharge into the existing inverter. The Tesla Powerwall, which is designed to connect between a solar array and its grid-interactive inverter, is an example of a DC system.

The actual internal configuration of systems varies somewhat, as does the included capabilities and features. It's important to select the unit right for your situation, so make sure your installer understands what you need.

The state of play

So that's enough about the systems, let's look at what's available, what will be available, and how you can go about installing an energy storage system.

There are two ways to go when looking to install an energy storage system (ESS). The first is to find a system you want and then get the local dealer to organise installation. The other option is to talk to your energy company. It has become clear to the more forward-thinking energy companies that storage systems will become commonplace withing the next few years. As a result, several companies have started offering systems for installation at good prices. For example, AGL is now offering four different ESS units (the AUO PowerLegato, Sunverge SIS 11.6 and 19.4 and the Tesla Powerwall) for solar systems between 3 and 5 kW, making them suitable for the majority of existing grid-connected PV installations, and starting at just under $10,000, or $13,000 when bundled with a new solar system.

Indeed, AGL seems to be moving wholeheartedly into the ESS market, recently announcing a US$20 million investment in US ESS manufacturer Sunverge Energy, part of a US$36.5 million investment in

What's available

There are actually quite a few systems available now, or soon (most will be available later this year). We have included a brief list below (including battery chemistry and whether the unit is AC or DC coupled) but it should not be considered exhaustive.

Lithium-based systems

- Alpha Storion ESS ($LiFePO_4$, AC)
- Bosch BPT-S 5 Hybrid (Li ion, DC)
- BYD DESS ($LiFePO_4$, AC)
- Enphase AC Battery ($LiFePO_4$, AC)
- Fronius Energy Package ($LiFePO_4$, DC)
- LG Chem RESU (Li ion, DC)
- Magellan power RES1 and RES3 ($LiFePO_4$, AC)
- Off-grid Energy Autonomy Unit (Li ion, AC)
- Panasonic Residential Storage Battery System model LJ-SK84A (Li ion, AC)
- Positronics ESS ($LiFePO_4$, AC)
- Samsung AIO (Li ion, DC)
- Selectronic myGrid Lithium ($LiFePO_4$, AC)
- Simpliphi OES2 and OES3 (modular batteries with BMS only)
- Sunverge (Li ion, AC)
- Tesla Powerwall (Li ion, DC)
- Zen Energy Urban and Freedom PowerBanks ($LiFePO_4$, AC)

Lead-based systems

- Ecoult UltraFLEX and UltraPOD (lead-carbon UltraBattery, DC)
- Selectronic myGrid (SLA, AC)
- AllGrid Energy WattGrid 10 and 12 (sealed tubular gel, AC)
- Giant Energy Hybrid Essential and Hybrid Grid Systems (SLA, DC)

Other chemistries

- Redflow (zinc-bromine, DC)
- Aquion Hybrid Ion (sodium ion, DC)

conjunction with ARENA, SBCVC, Siemens Venture Capital and Total Energy Ventures. Other energy companies are or will soon offer similar deals, such as Origin's offering of the Tesla Powerwall.

Energex is also launching a battery trial with a two-part trial in south-east Queensland over the next two years.

A pilot demonstration of residential and commercial ESS installations will commence at several sites, including the site at their EsiTrain facility at Rocklea. Energex has partnered with Sunverge, Tesla, Reposit and SolarEdge as part of the first phase of the ESS trials. The second stage will be a market-based trial in cooperation with vendors who are selling ESS to customers in selected areas in south-east Queensland. This trial will commence late in 2016.

Ergon Energy has their own trial of their Hybrid Energy Service happening in regional Queensland. The 12-month trial involves the installation of a 4.9 kW SunPower PV array and a 12 kWh/5 kW Sunverge battery storage and control system at 33 homes across Townsville, Cannonvale and Toowoomba.

Some systems may be available under a leasing arrangement from your energy company or other suppliers. While leases can be a false economy, especially for systems that are installed for long-term use, don't discount the possibility of leasing if it is available, as it lets you get into the solar storage market with minimal up-front cost.

Where is it heading?

Currently, the domestic ESS industry is in its infancy, much the same as the solar industry was 20 years ago. At this time, prices are still quite high and the number of systems available is relatively low, but projections indicate that we should expect to see a huge ramping up of the number of installations in the next few years, accompanied by a steady decrease in costs as competition grows and battery development and increased scale of manufacturing push cell prices down.

The World Energy Council estimates that energy storage costs will fall by 70% in the next 15 years. We expect that to be quite realistic, but that the drop in prices will come sooner than that, possibly in as little as five years. While for some people the economics already stack up, for most grid-connected users it will become economically advantageous to install an ESS by 2020 or so, and possibly before then.

Should I buy now?

With battery life expected to be around 10 years, it is generally not yet economically advantageous to install a battery system for most grid-connected homes, as reported in *ReNew 134*. However, economics is not the only part of the equation—many people install new technology to help progress it, seeing themselves as part of the push to advance that technology to the point of becoming mainstream. These early adopters are usually less concerned with the financial aspect and more with the move towards a more advanced, sustainable society, and have usually already undertaken energy efficiency measures to reduce their overall energy footprint, such as making their homes thermally efficient, choosing appropriately sized appliances with the highest energy star ratings and altering behaviour.

So the answer depends on your primary motivation for considering a battery system. If it's to offset electricity costs by making better use of your solar-generated electricity, then you are best to wait until system prices have dropped. Current estimates vary widely, but

What's on the horizon?

We have seen many battery breakthroughs come and go over the years, so it's hard not to be a little sceptical about some of the claims about upcoming battery technologies. But there are some interesting things happening to make us cautiously optimistic.

While flow cells, such as the Redflow units, are already available, other companies are working on them too. NanoflowCell AG are developing their own flow cells for EVs, with the aim that the EVs will be as fast to refuel as internal combustion engine vehicles, simply by replacing the depleted electrolyte with fresh electrolyte. However, they are also planning to apply their flow cell technology to stationary storage systems, according to the company. See www.nanoflowcell.com for more information.

While the Tesla Powerwall has been designed to shun the look of most battery systems on the market (i.e. it isn't a big box), other companies are looking to make storage even more of a feature of a home, rather than something to be hidden away.

The Orison Tower and Orison Panel are designed to be seen. Each contains a 2.2 kWh lithium battery and LED light and simply plugs into a power point to provide energy to appliances in the home. It's worth noting that the Orison has only just progressed past the Kickstarter stage at time of writing. Operation of some of the stated features, such as being able to isolate a home power circuit, seems to be a little unclear, given that it simply plugs into a power point, More information can be found at www.orison.energy.

There are numerous other battery chemistries currently being worked on around the globe, including lithium-air, zinc-air and an interesting zinc bromide gel electrolyte battery being developed by Professor Thomas Maschmeyer at the University of Sydney. This battery shows lots of promise, being able to be rapidly charged without damage, and having a long cycle life.

Reusing batteries

Some companies are looking at storage another way entirely. We have looked previously at using an EV as temporary storage, with vehicle-to-grid (V2G) systems such as Nissan's LEAF to Home system, but now automotive companies are looking to repurpose old EV battery packs into domestic and commercial energy storage. The advantage of such an initiative is that the cost of the system should be much lower than with brand-new batteries.

So far we have heard of several potential schemes for EV battery repurposing. Connected Energy and Renault are partnering to build second-life EV battery energy storage systems, the first being the 50 kW/50 kWh E-STOR, which is expected to be available for purchase in the UK starting in July. See www.bit.ly/1Tkhwei for more information.

Nissan is working with energy storage supplier Green Charge Networks (www.greencharge.net) to redeploy the used batteries for commercial and industrial customers.

Other companies who have reused their vehicle's batteries for stationary storage include General Motors, BMW (in conjunction with Bosch) and Daimler, who have used reclaimed EV batteries for large trial stationary storage systems. Toyota is also in the game, installing a battery bank made of 208 batteries from Camry Hybrids in a system at Yellowstone National Park. It also sells a similar product to dealers in Japan.

we expect to see system prices halve in the next three to four years, at which point the financial equation should be more attractive.

And while you are waiting for prices to come down you can get to work on improving the efficiency of your home to minimise energy use and hence the amount of storage required.

Incentives

If you are keen on installing a battery system, there may be financial assistance to do so. If you live in Adelaide, the City of Adelaide is providing up to 50% of the ESS cost (up to $5000) for the installation of energy storage systems. See www.bit.ly/1QiPElv.

State and local government incentives vary, so contact your local council to see if they offer any incentives for ESS installations. Also talk to your electricity company as they may have current or future trials or rebates planned. ✱

For more on the financial status of solar and solar + battery systems, see *ReNew 134* or the full ATA report at: www.bit.ly/ATAGCBEA

For more on environmental factors, see p. 34 this issue.

For more details on types of installations, see 'Going Hybrid' in *ReNew 132*.

For more information on solar leasing, see 'Solar Financing' in *ReNew 130*.

For more on energy storage systems, see the Energy Storage System Buyers Guide in ReNew 128 (and other articles in that issue), and the Battery Buyers Guide in ReNew 130; the latter concentrates on individual battery systems rather than all-in-one storage systems, but has more information on the different technologies.

Other resources:

Australian Energy Storage Council: www.energystorage.org.au

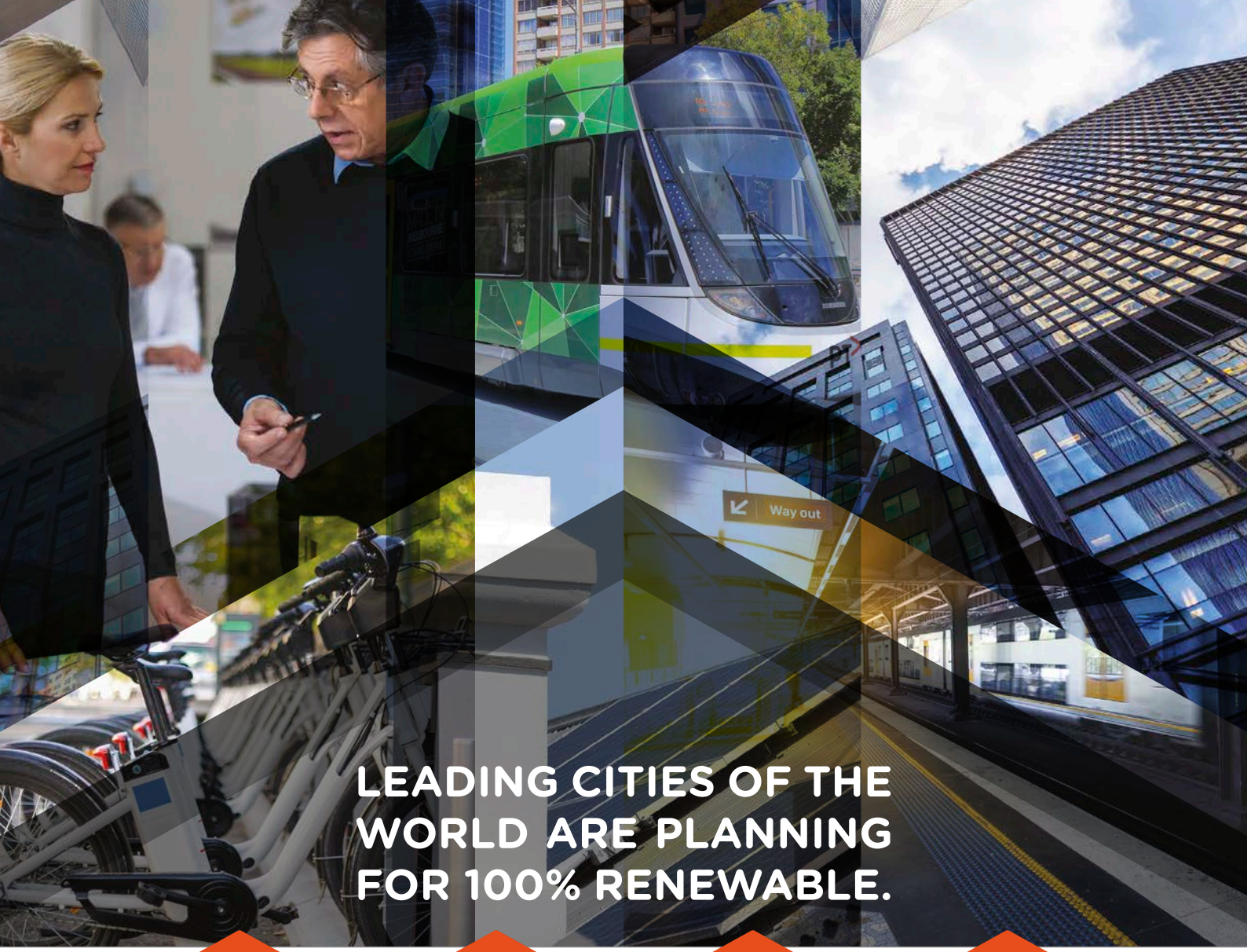
Australian Solar Council: www.solar.org.au

New Zealand and Pacific Solar and Storage Council: www.nzpssc.org.nz

One Step Off The Grid: www.onestepoffthegrid.com.au

Image: Lindsay Edwards Photography

↑ Lithium storage systems can be quite compact, allowing them to be installed in spare spaces not much use for anything else. This Panasonic unit was installed in January as part of a CitiPower trial.



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A light in the bush
A powerful collaboration up north

A pilot project at an Indigenous ranger station in northern Queensland has shown how collaboration can help bring low-cost sustainable power to remote bush locations—and turn off the polluting generators. By David Tolliday.

Image courtesy Andre Grant

↑ 24-hour reliable power for the rangers station—a job well done! (Left to right) Local electrician Jared Warren, land and sea manager Chris Hannocks, ranger and traditional owner 'Brolga' (Philip Yam), ranger Garry Hudson and ATA volunteers John Dickie and David Tolliday in front of the new solar PV array installed at the Oriners Ranger Base.

FOR many years now, volunteers with the Alternative Technology Association (ATA, *ReNew*'s publisher) have been working with other organisations to provide solar lighting and improve quality of life in East Timor. Last year, ATA's volunteers were called on to similarly help power up Oriners Ranger Base in Cape York, northern Queensland.

A seed is sown

In 2014, the Kowanyama Shire Council's Land Office invited the Centre for Appropriate Technology (CAT) to visit their Oriners Ranger Base (160 km west of Laura, on the Cape York Peninsula) to look into the power and water situation there. In particular, the base was in need of a new, reliable stand-alone solar energy system to replace the old 12 V system that had, sadly, been stolen from the site a couple of years earlier.

The land office hoped CAT's experience and design knowledge would help them find the best way to set up a system, maximising the use of very limited funds (from their own income sources) to achieve a high-quality, durable remote-area solar power system. Looking at the challenge, CAT considered a collaborative model that would incorporate pro-bono installation by experienced solar industry professionals combined with 'sweat equity' from the community. This model would use key elements of their highly successful Bushlight Program (see box), along with the pro-bono partnerships.

A project is born

In early 2015, after discussions with the ATA (whom CAT considered a natural partner for the project), CAT's pilot proposal was accepted. The ATA had agreed to support the pilot by sourcing two volunteers with the appropriate technical expertise and experience to take care of the installations. The ATA put out a national call for suitable volunteers and, after a selection process, I was chosen to be the lead installer, with John Dickie assisting. I'm from Melbourne and John's from Canberra, and we are both electricians and Clean Energy Council (CEC) accredited solar installers.

After months of planning, we arrived in Cairns to meet CAT's Project Manager, Andre Grant. We then spent two days checking and loading equipment, and purchasing last-minute supplies before heading off for the seven-hour 4WD trip to Oriners Ranger Base.

After meeting the Indigenous rangers—'Brolga' (Philip Yam), Garry Hudson and John Clark—along with land and sea manager Chris Hannocks and local Kowanyama Shire electrician Jared Warren, we surveyed the existing power setup. It consisted of an array of petrol generators, extension leads, portable lights and power boards, mostly laying across the ground. In anticipation of the arrival of the truck and container the next day, we headed to bed early.

As with all good plans, things didn't go *quite* right—the truck had to turn back because of a leaking radiator; two days later, it arrived. The days were very hot and the humidity high, so work was limited to early morning and late afternoon. (You know it's hot when not even the Indigenous rangers will work in the midday heat!) At one point we realised

we had miscalculated the required quantity of array cable. Some frantic telephone calls later, we had the parts on a plane to the local town—a three-hour round trip away.

We had a time limit of two weeks, which sounds plenty; however, wiring the ranger station made our job more involved, and we also installed the container we shipped up with our solar equipment as a new secure kitchen/storage area, to help prevent thefts when the rangers were away.

Early in the second week, we were finally able to test and commission the stand-alone power system, and so turn off the noisy, polluting generators. Oriners Ranger Base now had a reliable, sustainable 240 V power supply—for light, power and, importantly, refrigeration, for maintaining food for the rangers over the wet season, when access is severely restricted.

We finally broke camp on the Tuesday to head back to Cairns. Taking two days, we checked out the next possible project at a 'nearby' Indigenous-owned cattle station. Back in Cairns, we had a night out to celebrate a successful project before boarding our planes home the next day.

Highlights (and challenges!)

It was challenging, not only because we were miles from any suppliers, but also because it was hot: very, very hot. It was a great experience, however, and the team worked well together. Having the opportunity to share my solar knowledge with John, Jared and Andre was very rewarding. The Indigenous rangers really appreciated our efforts, and they were also great—sharing their knowledge and stories, and taking us 'red claw' (freshwater crayfish) hunting for our dinner. I can highly recommend volunteering.

For John: "As well as a fantastic experience working in a remote location and meeting some sensational people, it was great to be able to contribute, albeit in a small way, to the installation of sustainable, clean, quiet technology that provides more reliable power for essential items such as refrigeration, lighting and communications, and which should have a long lifespan. This, in turn, allows the traditional owners and rangers to more effectively look after and manage their country."

Technical details

The project was to design and install a reliable and robust stand-alone power system that would provide at least 10 kWh per day of 240 V supply to the ranger's house and shed, to replace aging generators that were not only noisy and unreliable, but also produced considerable pollution.

The design was based on a DC-coupled PV array stand-alone configuration; however, with changes in industry practices and thinking, we would consider an AC-coupled system for future installations.

One issue that became apparent in designing this system was the change in the requirement of power conversion equipment (inverters and charge controllers) in AS/NZS 5033, which came into effect in July 2015.

Image: David Tolliday

↑ Solar-powered lights go on; noisy generators go off.

Many of the tried-and-true charge controllers used in stand-alone power systems for years no longer complied, and the newer, approved models were not readily available.

Finally, reliability and redundancy were major considerations in this design. In line with CAT's experience, the system was robustly designed to ensure the realities of remoteness and poor access to service and support would not lead to system breakdown or failure. ✱

David Tolliday is a senior instructor in renewable energy training at Holmesglen Institute in Melbourne. He holds CEC accreditation in grid-connected PV and stand-alone (off-grid), small wind and hybrid power systems.

About CAT

Governed by a majority Indigenous Board, the Centre for Appropriate Technology is a not-for-profit technology innovation company that works with remote Indigenous communities to design, build and manage technologies that support self-reliance and economic independence.

CAT is well known for its Bushlight Program, which designed and installed 130 solar systems (stand-alone and hybrid) to provide reliable, affordable 24-hour power to small communities across Australia. Bushlight systems near Kowanyama include Fish Hole, Scrubby Bore and Baas Yard.

The Bushlight approach ensures that system design is based on community planning processes that benchmark current and future energy needs, and provides community-based training in monitoring and managing the systems to maintain optimal loads and performance. This project provided the opportunity to develop a new model for delivering solar power with limited funding, while incorporating the sustainability and reliability delivered by the Bushlight approach. It hopefully benchmarks a process that will be of benefit to other remote ranger bases and homelands.

Key specs:

- PV modules: 24 x BenQ model PM060P00-255 (total 6.12 kW)
- PV mounting frame: Clenergy PV-ezRack® SolarTerrace II-A
- Inverter: Selectronics SP-Pro SPMC481-AU 5 kW
- Charge controller: 2 x Studer Vario Track VT80 MPPT charge controllers
- Batteries: 24 x Hoppecke 8 OPzV Solar 1000Ah VRLA (50 kWh)
- Surge protection: 2 x MidNite MNSPD DC Type 1 devices
- Capacity: Minimum 10 kWh per day from 50 kWh battery bank

Energy flows
How green is my solar?

How long does it take to pay back the energy used in the production of solar + battery systems and how much of an effect do they have on the greenness of the grid? The ATA's Andrew Reddaway investigates.

↑ Many people are considering adding batteries to their solar systems as prices come down and more all-in-one systems become available. It's a good time to examine greenness of solar and solar + battery systems. Image: Fronius International.

BY GENERATING clean electricity, solar systems reduce the amount of coal and gas that's burned in power stations. This reduces pollutants and greenhouse gases released into the atmosphere, which cause disease[1] and man-made climate change[2]. Fossil fuels also require extractive processes such as fracking and open-cut coal mining, which have led to negative effects on the environment such as land degradation, water contamination and mine fires.

It seems clear that installing a solar system will have a positive effect on the environment. But with several different types of system now available, including systems with batteries, how do they compare in terms of the environment?

Grid-connected without batteries

The vast majority of existing solar systems are connected to the grid and have no batteries. Your solar panels' electricity is first used by on-site appliances, and any excess is exported to the grid to be consumed by your neighbours. Any shortfalls are supplied from the grid. This setup is relatively cheap and efficient, using a simple inverter that relies on the grid for its stability. However, it's not very self-sufficient, because if a grid blackout occurs the inverter will switch off. (Although not always; some rare grid-connect inverters can use direct solar generation to supply household appliances in a blackout, even without batteries; for example, the Nedap PowerRouter.)

Since the grid has minimal energy storage, whenever your solar system is operating, a centralised power station will reduce its output to compensate. Each kilowatt-hour of solar generation reduces power station generation accordingly. In fact the benefit is even greater, as the power station must supply not only the end-user demand but also the losses incurred in the power lines, which can be over 20% for remote locations. Some people argue that because coal-fired power stations are inflexible, they'll keep consuming coal at the same rate regardless of solar generation. Actually they are responsive enough; for example, Loy Yang A in Victoria can halve its output in less than an hour. Spread out over a geographically large area, solar systems' overall impact is relatively gradual even when a cloud front arrives; this is forecast and managed by the grid operator in five-minute intervals.

With enough panels you can generate more electricity than you consume over a whole year, with your night-time imports more than compensated for by your daytime exports.

Grid-connected with batteries (hybrid)

There are a variety of reasons to include batteries in a grid-connected solar system. Some of these systems are quite self-sufficient as they can supply your appliances during a grid blackout. With enough batteries and solar panels, imports from the grid can become rare events. However, adding batteries doesn't increase your net impact on fossil fuel generation. Sure, you're importing less from the grid at night, but on the other hand you're exporting less during the day. Batteries also incur losses when charging and discharging, so your house will consume slightly more electricity than it would have without batteries.

Off-grid

As battery prices come down, many people are now considering severing their grid connection. This is certainly the most self-sufficient option, but its uptake will be limited by expense—a full off-grid system might cost $50,000 for a typical household. Severing a grid connection has drawbacks from an environmental point of view. At current prices it makes sense to install a relatively large number of solar panels, to help supply the house during a cloudy week in winter or the wet season. Excess generation during sunny periods will be wasted as the off-grid system can't export to the grid. Off-grid homes typically use diesel generators to get through the worst weeks, or to cover additional consumption such as guests. This small amount of fossil fuel use should also be considered.

Where the grid is available, a grid-connected solar panel is greener than an off-grid one.

RURAL OFF-GRID HOMES

Although it takes a lot of energy to create an off-grid solar system, estimating the overall green credentials of a rural off-grid home is not a simple matter. The ATA has many members living off-grid in the country. Most commonly, extending the grid to their house would have been prohibitively expensive and would have consumed a lot of energy to construct and erect the poles and wires.

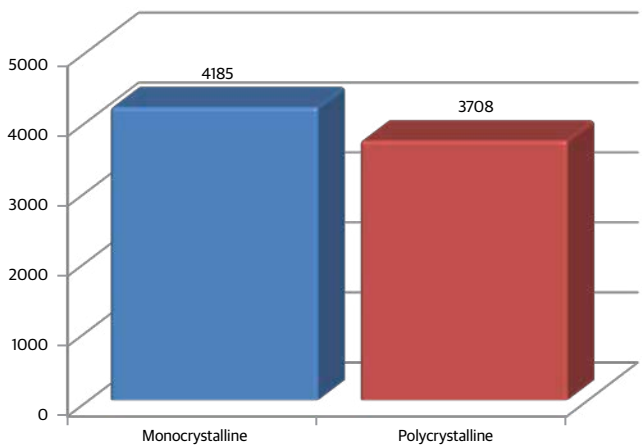
Electricity is only one aspect of an off-grid rural lifestyle. Families living this way tend to have very low electricity consumption, for example 5 kilowatt-hours (kWh) per day. They are often rehabilitating the landscape and locking up carbon in vegetation. Other environmental impacts are typically also low, depending on travel patterns.

Embodied energy

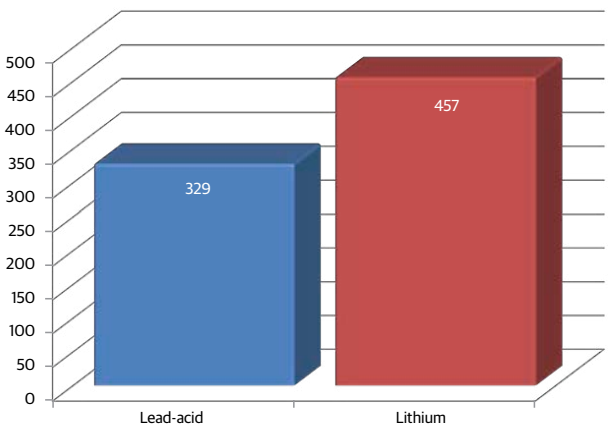
Manufacturing a solar system involves melting silicon for the panels and refining aluminium for the frames, among other things.

Estimating the energy use is tricky, but the best information we can find indicates that creating a one kilowatt (kW) grid-connected solar system with monocrystalline panels consumes about 4200 kWh of energy, including an allowance for transport. Polycrystalline panels are more frugal in their use of silicon; producing a 1 kW polycrystalline system consumes about 3700 kWh. These embodied energy estimates include energy used far upstream, such as mining of raw materials.

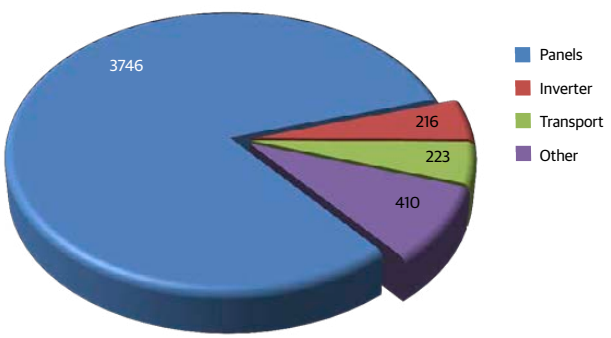
Creating a battery requires quite a lot of energy too. The best estimate we can find is that manufacturing one kilowatt-hour (kWh) of lithium battery storage uses about 454 kWh of energy. Lead-acid batteries require less energy to create (321 kWh), but more storage than lithium is typically required to deliver the same performance.



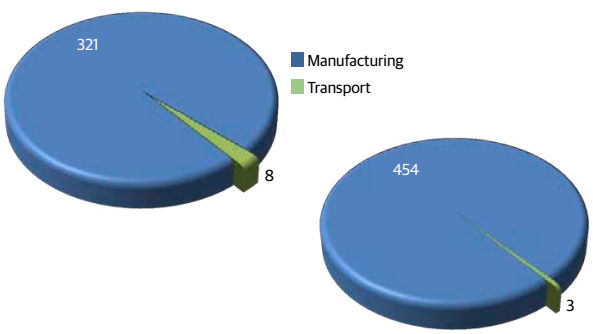
↑ Embodied energy for monocrystalline versus polycrystalline in kWh per kW (lower is better).



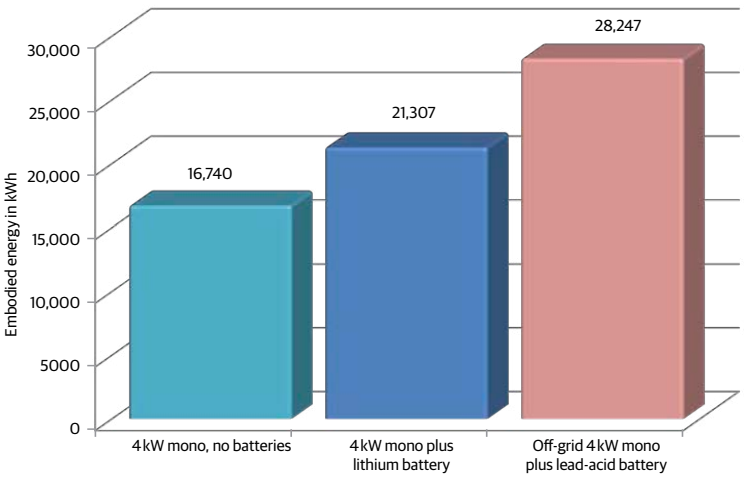
↑ Embodied energy in kWh per kW of battery capacity (lower is better) for lead-acid batteries and lithium batteries.



↑ Individual components of embodied energy for monocrystalline in kWh per kW.



↑ Individual components of embodied energy for lead-acid (left) and lithium batteries (right) in kWh per kW.



↑ Embodied energy of three different solar energy systems.

For comparison, we totalled the embodied energy of three different systems:

- 4 kW monocrystalline solar panels (say 16 typical panels), grid-connected, no batteries
- 4 kW mono, grid-connected, with a lithium battery, rated storage capacity of 10 kWh
- Off-grid 4 kW mono, with a lead-acid battery, rated storage capacity of 35 kWh.

We calculated the embodied energy of these three systems as about 16,700 kWh, 21,300 kWh and 28,000 kWh respectively.

Energy payback period

Although solar systems generate energy, they first require energy to produce them. This is like an energy debt that must be repaid. After it's paid back, all further generation can be counted as positive for the environment.

We used Sunulator to estimate annual generation of a north-facing 4 kW solar system in 10 Australian locations; it was found to range from 5300 kWh in Melbourne to 6900 kWh in Alice Springs. We then estimated how much power station primary energy this solar generation displaces; for example, the thermal energy in coal. This is consistent with accepted practice in life cycle analysis. Burning fossil fuels to generate electricity is inherently inefficient; based on data from the Office of the Chief Economist, we assumed that each kWh of solar electricity generation displaces 3 kWh of primary energy. This is conservative as it doesn't consider extra fuel burned to make up for losses in powerlines.

Payback periods were then calculated. The system without batteries had an energy payback period ranging from 0.7 years for polycrystalline panels in Alice Springs to 1.1 years for monocrystalline panels in Melbourne. Since solar panels have an expected lifespan of at least 25 years, solar systems have a couple of decades of 'green' generation after achieving energy payback.

Adding a lithium battery with a rated storage capacity of 10 kWh results in a longer energy payback period, ranging from 0.9 years to 1.3 years. This is slightly optimistic, as it doesn't include extra grid electricity required to make up losses in the battery.

The energy payback period of the selected off-grid system with 35 kWh of lead-acid battery storage varied from 1.3 years in Alice Springs to 1.8 years in Melbourne. However, this is also optimistic, as it assumes all generation is used. As noted above, much electricity generation potential in an off-grid system is wasted. If only half the generation is used, then the energy payback time would be doubled. Also we haven't included the embodied energy of the diesel generator as we couldn't find data on this.

Greenness of the grid

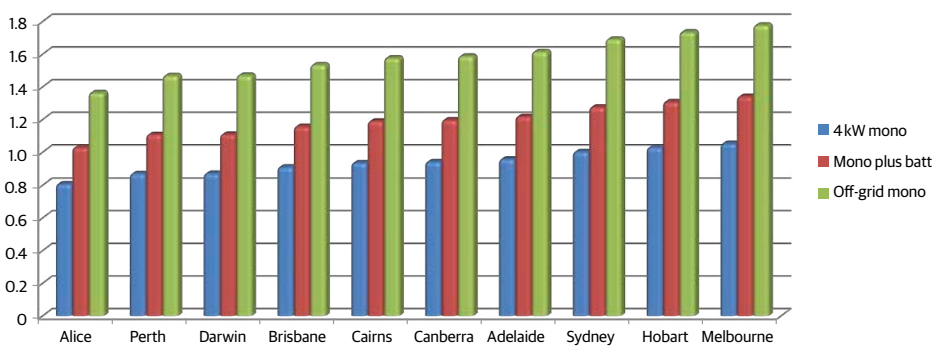
If centralised generation in your grid is particularly polluting, your solar system's environmental benefit will be correspondingly larger. On the other hand, if your system's components were manufactured using very dirty energy, its embodied energy will be greater.

Although the dirtiness of electricity generation varies around Australia, from Tassie hydro to Victorian brown coal, most states can share electricity via powerlines going over state borders. Due to these interconnections, it's appropriate to consider Australian grid electricity as an average. WA's grid is separate but similar in carbon intensity. NT is considerably cleaner than average, as it mostly relies on natural gas, but small disconnected grids (e.g. Coober Pedy or Esperance) are generally dirtier, as they often rely on diesel.

These days, most solar system components are made in China, which, like Australia, predominantly relies on coal for energy. Since China's grid is approximately as dirty as Australia's, the embodied energy comparisons used here make sense. However, if your solar system is manufactured in a greener part of the world, its embodied energy will be reduced; for example, it will be about one-third lower in Germany.

Will batteries result in extra panels?

It's possible that when installing batteries, people will install more solar panels than they otherwise would have. Solar systems are frequently sized to meet daytime electricity consumption, a strategy that avoids large amounts of export and speeds economic payback. However, if a battery is included, it may then make economic sense to add extra solar panels to supply night-time consumption as well. If batteries prompt solar



↑ Energy payback time in years for three different systems using monocrystalline panels (lower is better).

"If centralised generation in your grid is particularly polluting, your solar system's environmental benefit will be correspondingly larger. On the other hand, if your system's components were manufactured using very dirty energy, its embodied energy will be greater."

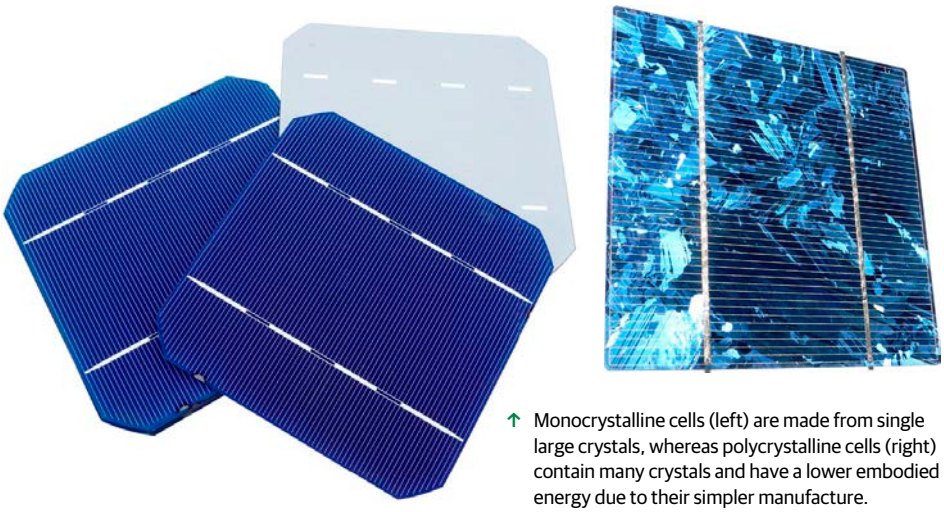


Image: Georg Slickers/CC-BY-SA-3.0

↑ Monocrystalline cells (left) are made from single large crystals, whereas polycrystalline cells (right) contain many crystals and have a lower embodied energy due to their simpler manufacture.

installations to increase in size, more fossil fuels will be offset.

To me, it seems unlikely that this effect will be large, at least in the next few years. Current solar installations are already quite large, averaging 4 kW, or about 16 typical panels. Bigger systems are more likely to be constrained by roof space or restrictions imposed by the local electricity distributor. And due to limited budgets, some people may reduce the number of panels so they can include a battery in their new solar installation.

If you're not constrained by roof space or budget, batteries can make oversized solar systems more attractive. An oversized system has a panel power higher than its inverter power, e.g. 6 kW of panels on a 5 kW inverter. Good inverters can cope with this, and it's a useful way to maximise generation if the distributor has restricted your inverter size to 5 kW. Most of the time weather conditions won't be perfect so the panels will generate less than 5 kW anyway. But some of the time the panels will be able to generate above 5 kW, and without a battery this generation is 'clipped' and wasted.

If we add a battery to an oversized system some of this clipped energy may be stored instead of wasted, increasing overall generation. This requires the ability to charge the battery separately from the inverter—not all systems can do this. Sometimes clipping will happen when the battery is already full, in which case the clipped generation is still wasted. To maximise the green effect of oversizing, rules can be setup to prioritise spare battery capacity during the best generation times, which may require a trade-off against bill savings.

Will batteries spur people to consume less electricity?

Many people have found that once they install solar, they are more conscious of their electricity consumption and so use less. On the other hand, some people's energy consumption increases after a solar installation because it provides cheap electricity for air conditioning etc. The impact of home batteries on energy consumption behaviour is yet to be seen.

Will my battery help to close coal-fired power stations?

Solar systems take business away from fossil fuel generation, especially in the middle of the day when the sun is strongest. Along with improved appliance efficiency and other factors, this has meant that Australia's grid electricity consumption has declined since 2008. This has already resulted in the closure of some smaller coal-fired power stations.

Residential batteries reduce solar's impact on power stations in the middle of the day, shifting it into the evening instead. Power stations receive a slightly better price for their electricity in the early evening peak, so their business will suffer a little more if batteries become common. However, this effect is quite minor; I don't expect it'll do much to speed up power plant closures.

People also install batteries to make a statement expressing dissatisfaction with large energy companies. If enough households and businesses joined in, could they force policymakers to accelerate the grid's transformation away from fossil fuels? My guess is that battery uptake will intensify the political effects of the solar boom that's been underway since 2009. Politics is unpredictable; it's hard to tell when a tipping point might be reached.

Will my battery allow more renewables on the grid?

Storage can contribute to a future 100% renewable grid, but it's hard to attribute this 'green' effect to batteries installed today. The current crop of batteries can really only time-shift solar generation from times of excess to the evening. This does help the grid to digest solar exports, but in most states this is not yet a problem as solar generation is still minor compared to fossil fuel generation. And time-shifting is not very reliable. For example, while you're away on holidays your battery will be sitting near 100% full and having very little effect on the grid. And if the grid's peak day occurs in winter, many home batteries will have already been depleted by the peak time.

In a renewable future, the main challenge is a cloudy, calm winter week. Battery storage to cover a whole week is prohibitively expensive, so it didn't figure heavily in either AEMO's or BZE's 100% renewable reports[3, 4]. Instead they planned to over-size renewables, store energy in the form of hydroelectric dams and tanks of molten salt and also generate some electricity from biomass (crop stubble etc).

Household batteries can help to plug gaps in the renewable grid's electricity supply, but first they would need to get smarter. To make a reliable contribution, the battery would need to be remotely controllable, for example by the grid operator AEMO. Say an electricity shortage is predicted for Monday evening; AEMO could direct home batteries to charge up over the weekend, then discharge during the shortage.

Image: PV Cycle (https://youtu.be/81-MEpcA-Rc)

↑ While PVs have considerable embodied energy, some of this is recovered at the end of their useful life by recycling. PV Cycle, Europe's largest PV recycler, has achieved a 96% recycling rate in real-world performance for silicon-based PV modules.

Households would forgo savings from time-shifting solar during such times, but would be compensated, perhaps via subsidies to the price of grid-controllable batteries.

Note that South Australia already has a high level of solar (up to 30%) and wind generation (up to 100% of grid demand). SA's coal-fired power stations will all be closed or mothballed by 2017, as they have not been able to compete with renewables and Victorian electricity imports. However, natural gas still remains a major fossil fuel for electricity generation.

Embodied energy of the grid

When building a new house on a block with no grid connection, it may be greener to go off-grid, because much energy would be required to construct and erect the new poles and wires, concrete footings etc. The embodied energy of this new infrastructure should be considered against the embodied energy of the alternative off-grid system. This also applies to entire new housing developments.

It's also possible for a grid-connected battery to avoid embodied energy in the grid. If the local electricity network is nearing its capacity at peak times, home batteries could be remotely controlled to discharge at peak times. This would reduce the peak and avoid an infrastructure upgrade.

Can I help speed up battery development?

Industries cannot be developed in a laboratory. Technologies to generate electricity from coal and nuclear fuel were nurtured by governments for decades before growing to their current scale. Relatively minor subsidies for solar panels spurred consumer uptake, creating economies of scale that developed the current solar industry. Home batteries seem poised to follow a similar path.

Technology enthusiasts purchasing home batteries today should be encouraged, because they are helping battery manufacturers and installers to build capability and experience. This will help speed up the rollout of batteries in the future.

Recycling

Recycling schemes already exist for lead-acid batteries, so the figures in this article assume some of their materials have come from low-energy recycled products. On the other hand, recycling is not included for solar systems or lithium batteries. Schemes are under development for these (see 'Waste Not Want Not' in *ReNew 133*). The figures don't allow for energy consumed in the disposal of solar systems, but we expect that by the time a system sold today reaches the end of its life, facilities will be available to recycle it, reducing the energy consumed to create a new product.

Small Technology Certificates

Another factor in the 'greenness' of a solar system is Small Technology Certificates (STCs). These have assisted nearly all solar systems installed in Australia—their effect is to reduce the upfront price of a solar system. These were set up as an industry development scheme and reflect the value of a solar system's green electricity generation over 15 years.

Some people consider that STCs cancel out a solar system's environmental impact for the first 15 years of its generation. This argument held some weight in the early days of the scheme, but not since it was reformed in 2010 to ensure 'additionality'. When you install a solar system you are increasing total renewables, so we can consider its generation as green.

Conclusion

A grid-connected solar system without batteries is a very green option because excess solar is fed into the grid, reducing the damage caused by fossil fuels. It only takes around one year to generate the energy required to produce it.

Installing a grid-connected battery generally doesn't benefit the environment directly, but does help to develop economies of scale in battery manufacturing and installation which will assist our longer-term transition to a 100% renewable electricity system.

In specific situations, batteries may have a direct environmental benefit if they assist an oversized solar system, avoid grid infrastructure construction or upgrades, or if they enable an off-grid lifestyle that helps the environment.

If you're looking for the greenest solar system, polycrystalline solar panels are a better choice than monocrystalline because they take less energy to manufacture. You could also consider components sourced from a country or company with a relatively clean electricity supply, as these will have a smaller fossil fuel impact. Also you should plan to recycle the battery and panels at their end of life.

Finally, solar systems should not be considered in isolation; we recommend looking at energy-saving measures at the same time as they're definitely green and often more cost-effective.

The ATA acknowledges research for this article provided by John Weir, an ATA member, principal consultant at Engineering Essentials and Honorary Fellow at the University of Melbourne in the Department of Mechanical Engineering.

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Wise water ways
At home with water efficiency

Eva Matthews looks at the gadgets, habits and tools that can help you make the most of our precious H_2O.

THE water account for 2013–14 from the Australian Bureau of Statistics reveals some useful facts about our water use at home. Household water consumption for the year totalled 1872 GL—equivalent to just under four Sydney Harbours. And the Sydney Harbour analogy is particularly relevant, as NSW was the highest-using of the states and territories by almost double that of the next-highest, partly because of its larger population. Per capita usage was highest in WA (361 kL) and NT (416 kL) per person per day; Victoria was the lowest at 175 kL and NSW, ACT, SA, Tasmania and Queensland were all in the range 200 to 220 kL (see graph overleaf).

In the same time period, this water use cost households around $5 billion, and prices are rising (up around 25% on the previous year in NSW and Vic). And then there's the fact that, despite Australia's average rainfall being well below the global average and likely to remain so, we are the greatest per capita consumers of water, not even including the water embodied in the production of the food and products we consume. These stats make it pretty obvious that we are not, as a nation, living sustainably or smartly enough when it comes to this precious natural resource.

So what can we do to improve this situation? Primarily, use less water and make the most of the water we have! There are also national and state/territory-based rebates and incentive schemes (such as showerhead swaps, rainwater tank and greywater system rebates, appliance upgrades, toilet replacement and leak fixing services) to help people become better water savers. Check out www.yourenergysavings.gov.au/rebates for basic info and useful links.

How can you save water in the home?

APPLIANCES

The Australian Water Efficiency Labelling and Standards (WELS) scheme requires products such as showerheads, toilets, washing machines, dishwashers, taps and flow controllers to be rated and labelled for their water efficiency. The Star rating system (up to 6 Stars, more stars means more water efficient) and data on actual water consumption will help you make the most water-efficient choice for your budget.

LEAKS

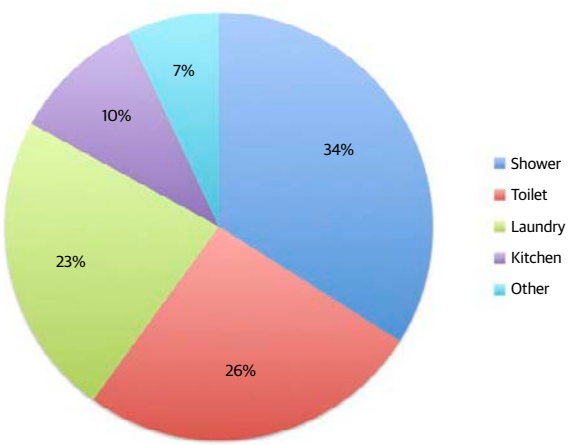
Dripping taps and leaking toilets and pipes are the 'stealthy saboteurs' that can undermine your other water-saving measures.

A slight leak in your toilet can waste more than 4000 L/year; a more significant leak, up to 96,000 L. A significant leak will be fairly obvious, but you can check for a smaller leak by placing a few drops of food colouring in the cistern; if the dye comes through into the bowl within 15 minutes of flushing, you have a leak.

A tap dripping once per second wastes around 7000 L/year (that's 7 m³!). Leaking pipes are harder to detect, but the losses here could be enormous. You may be alerted to a problem if you notice your water bills increase significantly (or, if you're on tank water, your supply dwindling more rapidly than normal). Alternatively, you could install an Australian invention called the Aqua Trip Leak Detection System (from $139 plus plumber installation costs, www.aquatrip.com.au), which is able to differentiate between normal water use and a plumbing problem, and can switch off the water supply before it becomes a big problem.

The key to water saving here, of course, is to fix the problem—be it in the tap, the toilet or the pipes—as soon as it's detected.

→ Average percentage of water used indoors in Australian homes for each water-using activity. By following the water-saving tips described, these figures could reduce by 50% or more. Data source: www.yourhome.gov.au



← The new Kiri SatinJet ultra-low-flow showerhead is perhaps the most efficient on the market, with a 3 Star WELS rating and using just 5 L/min. You can order it from the ATA shop for around $30 less than elsewhere.

→ The Hughie Sink helps reduce water consumption and also encourages reuse of water in the garden.

BATHROOM

The shower is the biggest water guzzler in the home, accounting for around 34% of indoor water use, on average. There are a couple of simple things you can do. Replacing an old inefficient showerhead with an efficient one (3 Star, using 6–7 L/min) will mean you use about 40% less water (there are programs available in many states to provide free or low-cost replacements; see www.yourenergysavings.gov.au/rebates).

Take shorter showers (set a timer!) and, possibly, fewer showers—the benefit of fitting a waterwise showerhead is reduced if you don't. As well as conserving water, more-efficient showers can save on energy bills as less water needs to be heated.

You could also go one step further and retrofit an award-winning Australian invention called The Every Drop Shower Saver (www.showersaver.com.au). This could reduce your water use in the shower by up to 50%. A flick of a paddle quickly switches the water flow off while soaping or shaving; another flick returns the water at the same temperature and flow rate. (Note: this gadget may not be suitable for instantaneous gas hot water services as it can take a few seconds to restart heating after the water has turned off, which may lead to cooler water coming through at first.)

By installing low-flow taps or tap aerators, you can reduce your tap water use in the bathroom from 18 L/min to just 2 L/minute. Again, behaviours can maximise the benefits here—for example, don't leave water running for longer than you need to wash your hands or clean the basin, and turn it off while brushing your teeth.

TOILET

The toilet is the second-biggest user of water inside the home (around 26%). Older single-flush toilets use around 12 L/flush. Replacing these with water efficient dual-flush cisterns (another Australian invention) will save around 60% of this water—of course this means you'll need to be using the half-flush as often as possible. If you're not able to replace your toilet, you could have a plumber reduce the flush volume of your cistern, or you could place a water displacement device into the tank. You can purchase these, or you could simply use a two-litre bottle filled with water.

You could go one step further and install a low-water or waterless toilet. This will make water use in the toilet negligible or non-existent, and has other environmental benefits besides (see more on waterless toilets on p. 62 of this *ReNew*).

LAUNDRY

The laundry is also a high water-use area of the home (23%), so wait until you have a full load of washing before turning the machine on, and/or adjust the water level to match the load size. Use any 'eco' functions your washer offers. If you have an old washer, consider replacing it with a minimum 3.5 Star WELS-rated model, and note that front-loading washers are more water-efficient than top-loaders in general. Although a combination washer/dryer might be space-saving, the condenser technology it uses means that quite a bit of water is used in the drying process, so, before purchasing one of these, check the WELS rating and water-use data of different models.

If you need to use a basin for hand-washing items, install a low-flow tap or one with an aerator, and only use the minimum amount of water required to wet and rinse the items.

KITCHEN

Kitchens account for up to 10% of water use in the home. Water-saving strategies here include scraping food remains off dishes into the compost bin (rather than rinsing) prior to washing, and always using a plug in the sink (if hand washing dishes or vegetables) instead of having the tap run continuously. One step beyond this is to use a Hughie Sink (another Australian invention, www.hughie.com.au), which is a removable bucket moulded to fit most sinks, the watery contents of which can easily be tipped onto the garden after each use. Water savings can also be made by installing a water-efficient dishwasher (minimum 3.5 Stars) and using it optimally—fully load the dishwasher and use the economy cycle if you have one (may not be suitable for heavily soiled loads). A dishwasher will use between 10 and 16 litres per cycle; water usage when washing by hand varies enormously, from less than 10 litres for those who don't rinse, to 30 or more for those who rinse well.

↓ Tap aerators and flow restrictors are great ways to save water, reducing water flow without any action required once installed. Aerators are usually also flow restrictors, but if you just want less flow without aeration then use flow restrictor discs. You can get flow restrictors with different flow rates for different taps. Restrictor discs fit inside the tap and aerators on the end, but both are DIY installs.

Images: Aquaclic aerator (left), aerator/restrictors from Reduction Revolution (middle) and Flexispray restrictor disc (bottom right).

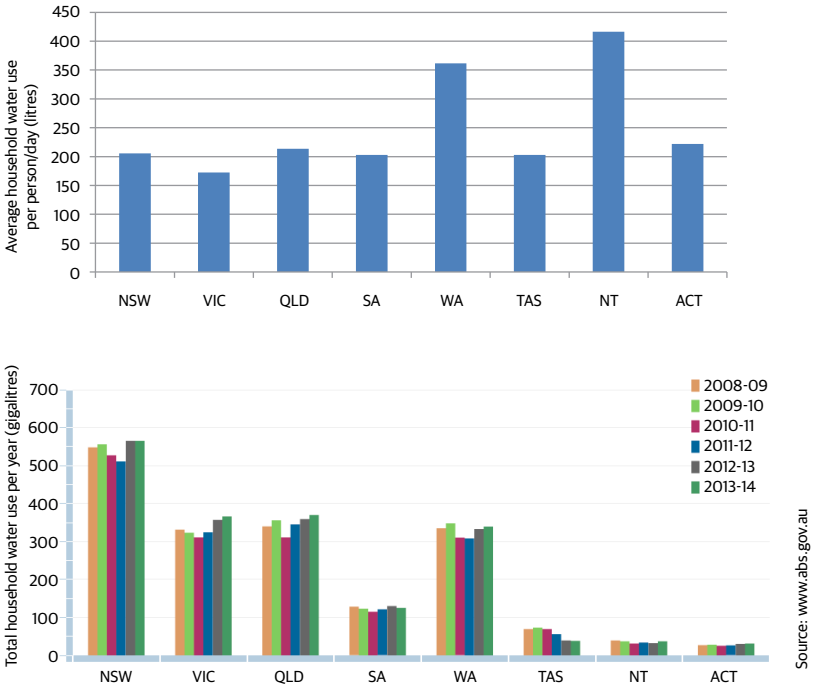
Saving water outdoors

Water use outdoors can be up to 40% of total household water usage—mostly used in the garden, but also washing cars and filling swimming pools. There are a number of articles in this *ReNew* looking at ways to be more water-efficient in the garden, but briefly:

- Choose indigenous plants suited to the local growing environment.
- Mulch around plants to improve moisture retention and improve soil condition.
- Use water-efficient irrigation systems and products—look for those labelled with the Smart Approved WaterMark, which have been assessed by technical experts to ensure they achieve water savings.
- Only water the garden when it needs watering (moisture sensors can be helpful if using irrigation systems) and only at optimal times of the day (before 10am or after 4pm, to reduce evaporation), preferably at ground level rather than over leaves and flowers, so it gets to the roots where it's needed.

Other outdoor water-saving measures:

- Clean paths and driveways with a broom, not a hose.
- If you wash your car at home, do it on the lawn so the waste water is put to good use (use biodegradable, low-phosphate detergents to minimise impact); use a bucket of soapy water and a sponge to clean, and a trigger-nozzle hose to rinse.
- If you have a swimming pool, use a pool cover to reduce evaporation (and save up to 30,000 L/year). ✱



↑ Differences in water use around Australia. The top graph shows average household water consumption per person by state/territory in 2013–14, and the bottom graph shows total household water consumption per state. Although NSW has the highest usage in total, the less-populous WA and NT have much higher usage per person.

Eva Matthews is a semi-regular contributor to *ReNew*, when not busy trying to finish building her sustainable home in the Yarra Valley.

Calculating and monitoring your water use at home

The first step in home water conservation is to understand how much water you are using, and where. Once you know that, you can take steps to implement water-saving measures most effectively. There are a number of online tools to help:

- www.watercorporation.com.au has a water use calculator that gives green/amber/red light results, then an action plan for steps you can take to improve your result. It's based on averages, rather than specific consumption per household, but is still a useful tool to alert you to what needs attention and steps you can take.
- www.hunterwater.com.au provides a similar calculator, and offers comparisons between estimated water usage figures for your home and the 'typical customer'; it also provides water-saving tips for each major water-use zone.
- www.taswaterinteractivehouse.com.au is similar, but a bit more flash. It has a column graph showing daily use for different areas in each major zone, as well as comparison to the average; final results show average yearly use per zone, and comparison with the average.

For homes connected to a reticulated water supply, you can monitor overall usage by reading your meter or looking at the stats on your water bill—and then assess subsequent savings by comparing to post-action readings.

To monitor your actual water use at home in more detail, and therefore more accurately target your water-saving measures, pp. 34–35 of *ReNew 125* reviews how smart water meters can help.

One such device is the award-winning Australian-designed GreenStar Monitor by Aquamonitor (www.aquamonitor.com.au). A compact digital display wirelessly connects to a sensor that is easily self-installed on your water meter. Water-use data is regularly updated to the unit and can be downloaded via USB as a .csv file for detailed analysis. An alternative stand-alone version, the MeterProbe, can be used if a wi-fi network is unavailable; data can be downloaded via Bluetooth to a free app. Both monitors have alerts if abnormal water usage (i.e. a leak) is detected.

WATER REUSE AND HARVESTING

GREYWATER

Reusing the water that normally goes down the drain from showers, basins and taps is a great way to save potable water for drinking, reduce water bills and ensure future water supplies for all. Greywater is fine to use on the garden (except for vegies) if low-sodium and low-phosphorus detergents are used in the home, but it must be applied sub-surface via a lilac irrigation pipe.

Treated greywater can also be reused for toilet flushing and clothes washing. Collecting greywater can be as simple as capturing water in a bucket (e.g. in the shower, or in the sink when washing vegies) and depositing it straight after around the garden. There are more integrated systems, where a valve in the laundry/kitchen/bathroom pipes diverts greywater to the garden. And there are more advanced systems that treat the greywater and divert it to the garden or back indoors for reuse in the toilet and laundry. The Greywater Buyers Guide in *ReNew 130* has more on this, and the ATA's *Water Efficiency eBook* features an article—from *Sanctuary 22*—on using plants to treat greywater for the garden. Note that diversion/treatment systems may require council approval, so check with your local authority first.

BLACKWATER

Waste water from the toilet requires biological or chemical treatment and disinfection before reuse; it can only be used outdoors, often only as sub-surface irrigation, and is not an option for all households—systems can be expensive and require a certain amount of space. However, they provide significant water-saving and environmental advantages. Blackwater system types include aerated (the most common), microfiltration and worm-based. Council approvals are required for all types, and regular inspections are also required in some areas or for some types, so check with your local authority.

STORMWATER

In most urban developments, stormwater—all the rain that falls on the roof or garden (plus anything it carries with it, such as oils, fertilisers, soil, litter)—is carried away down a network of drains and pipes and ends up in our natural waterways. As well as minimising environmental pollution, capturing stormwater before it drains away represents a great water-saving opportunity for the home. Water-sensitive landscape design is the key, and can be planned for and implemented during new-house construction, or you can certainly transform an existing garden with these same principles in mind. Strategies include diverting stormwater from downpipes into the garden, having water-permeable paving, swales and soakwells that detain water and increase percolation into the soil, garden beds or vegetation that arrest water flow down an incline and 'rain gardens' that utilise the stormwater before some of it eventually makes its way into the drainage system. (See p. 54 of this *ReNew* for a rain garden example, and *ReNew 125* to explore Josh Byrne's water-smart garden.)

RAINWATER

Rainwater can be collected via roof gutters, stored in tanks, and filtered and pumped (or gravity-fed) through pipes so that it can be used in a variety of ways around the home and garden, significantly cutting down on mains water use. Tanks come in many different shapes and sizes, and can be located above- or underground. Typically, government authorities recommend (particularly in an urban setting) that indoor use be limited to clothes washing and toilet flushing (and possibly showering), rather than use for drinking and cooking. First-flush diverters, leaf-shedding gutters and rainheads can improve the quality of rainwater entering the tank, and in-built filters further capture sediments before use. There may be restrictions on the size, number and placement of rainwater tanks, so check with your local council.

If you want to harvest your rainwater, the ATA's Tankulator (www.tankulator.ata.org.au) can help you assess the size of tank you need based on your average water usage and your household water catchment capacity (as well, it provides a wealth of information on tank options and considerations), and *ReNew 125* has a Rainwater Tank Buyers Guide to take you the next step.

Images: Josh's House supplied by Josh Byrne & Associates

↑ A Grey Flow greywater system directly diverts bathroom and laundry water to Josh Byrne's waterwise garden via a drip irrigation system, shown here before being covered with mulch. More details at www.joshshouse.com.au.

Image by Calan Stanley

↑ This home has three 7200 L Polymaster rainwater tanks, two plumbed to the home and one used to supply a dripper system in the garden. They've just bought an Irrigatia solar-powered watering system and have been pleased with the results so far. "The grapevine has gone nuts!" says the owner.

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Drop by drop
Measuring it out

Robyn Deed talks to *Gardening Australia*'s Sophie Thomson about her measured approach to watering in Adelaide's challenging dry climate.

SOPHIE Thomson is not a fan of hand watering, in general: "No one does it deeply enough—often you'd need to stand there with the hose on each plant for 20 minutes to do it properly." She sees many trees and shrubs in water stress due to hand watering. "Hand watering can work well for pot plants and vegies, but not for the general garden."

More water, less often

To get the required level of watering for trees and shrubs, she's a fan of low-pressure sprinklers (for example, Lo-Flo an Australian invention, WaterMark approved), which produce big drops rather than mist, or drip irrigation systems that can be turned on for the required period. The watering system might need to be on two hours once a fortnight to get the deep good soak the plants need—more water, less often is the mantra.

But how do you know how much water is needed? Sophie advises that the best way is to look at what you're doing now and adjust from that. "Start by watering as you normally do and then dig down next to the plant to see how deep the water has gone; it will often be just a couple of centimetres, but trees and shrubs need the water at their root zone, 20 to 30 cm down." Adjust the watering time and volume to do this and so encourage strong deep roots.

↑ Sophie's driveway uses plants needing no or little water once established. Here you can see an angophora tree on the right with Poa labillardieri 'Suggan Buggan' grasses in the foreground, and new plantings of Angophora costata behind. On the left are local indigenous native species designed to provide food or shelter for wildlife.

Read your plants

"You also need to read your plants," Sophie says. Watering needs will vary depending on such things as rainfall, heat, humidity, soil type and root competition. You can "read" the leaves, for example, as these are a plant's 'air conditioning' system. With citrus, you can feel the leaf on a hot day and, if it isn't cool to touch, then the plant is too dry; the leaves should also be vibrant and shiny. With vegies, it's slightly different—"We need to acknowledge that many soft, tender vegies are being grown outside of their climate zone, so we need to accept a bit of wilt in the heat, so long as they pick up overnight and when watered."

Water zones: challenge yourself

The most important thing is to create watering zones, grouping together plants with similar watering requirements—you'll save water by only applying the required amount for that zone. These zones include 'no water' zones that survive on the natural rainfall alone once established; 'low water' zones that survive on infrequent watering (once a fortnight to once a month) once established; and 'moderate to high water' zones that require more frequent watering.

Sophie says, "Challenge yourself to transform your garden so that the ratio of 'no water':'low water':'moderate to high water' is 50%: 25%: 25%."

Plants in the 'no water' zone may still need a year or two of irrigation to establish, and might even need one or two waters over summer in harsh years. In Sophie's garden, the garden beds on either side of the driveway, where she wants a bold statement but cannot fuss, are part of the 'no water'

↑ As well as wicking beds and low-pressure sprinklers, Sophie uses measured irrigation in her vegie patch. Invented by Bernie Omodei, an Adelaide-based mathematician, the gravity-feed dripper watering system adjusts watering based on evaporation of water in a container, and thus adjusts for rainfall and temperature.

Above: a small solar panel powers the system to turn watering on and off. It sits above the flow splitter which splits the incoming water supply into gravity-feed flows for multiple watering areas.

Top right: dripline being laid in a garden bed.

Right: Bernie and Sophie in front of the thriving patch.

zone. By contrast, her vegetable garden is in the "moderate to high' water zone.

She adds, "With plants that have a moderate to high water requirement of once a week or more, make sure that they are growing in the right position, and try to grow them where they are sheltered from harsh sun and hot winds." And, by harvesting your own rainwater, you can water the plants as often as they require it, not governed by mains water restrictions.

It is easier to design watering zones when planting a new garden from scratch, but even if you have an existing garden, often just by removing or relocating a few plants, you can rezone areas to take them from high to low water usage.

This year in the 'no water' zone

So how has the 'no water' zone around the driveway worked? Sophie planted this in July 2014 as a wildlife corridor with local indigenous plants, which have had no supplementary watering after planting. Most plants have survived but some haven't, particularly given the last, very tough, season.

Usually the Adelaide Hills has a classic Mediterranean climate with rains from late April till late October, then six months without rain. This year, though, they had no significant rains from August, with a very hot December (seven days over 40 °C). In late January, they were fortunate to get three patches of rain. Sophie says, "It was a blessing, as a number of my local indigenous plants were really struggling, and a number have died after surviving for several years." She's had to occasionally water even in the 'no water' zone because of this.

A thriving vegie patch

Sophie's vegie patch is thriving, however. She has flowers throughout the patch to encourage beneficial insects, and she uses a number of approaches to watering. She has 10 wicking beds which she built herself (for around $20 each) and she's found they need watering just once a week in general. One, however, needs much more frequent watering (similar to a normal raised bed) as she put in a tomato stake and pierced the plastic liner. She says it's an open question how long the soil will last in them. With her beds, she's expecting to change the soil completely every three years, because the water she uses is salty bore water. She's hoping for more research and experiments to inform wicking bed use, but she likes the approach and says that they have been very successful for her.

Measured irrigation in Sophie's Patch

Elsewhere in the vegie patch, Sophie uses gravity-feed drip irrigation, using a system invented by a local Adelaide mathematician, which controls watering based on rainfall and temperature.

Designed for developing countries without power or pressurised water systems, the system is called measured irrigation. It can be completely unpowered, just relying on manual monitoring of a watering gauge and turning the system on/off based on water level, or powered using a small solar panel to turn the system on/off as required. It's the 'as required' that is particularly interesting—it uses evaporation of water in a container to indicate when watering is required. For more on the ins and outs of measured irrigation, see the box at right.

Sophie's system was installed by the inventor, Bernie Omodei, two summers ago. It's been successful for her, though there have been a couple of teething troubles due to the salty bore water blocking dripper system hoses, so she's learnt that there is some monitoring required to check on it—plant reading is always required by gardeners, as she notes! If it was using filtered water or mains water, that shouldn't be a problem, she says.

Sophie notes that mulch is another important ingredient to reduce water use. "We need to look at the mulch we use, though," she says, "to look at its carbon miles and whether pesticides have been used in growing it." She suggests choosing local, where possible; in South Australia, for example, lucerne and pea straw are often locally grown, though some lucerne crops do use pesticides.

Her comments on mulch are just another indication of Sophie's thoughtful approach to garden creation and maintenance. Sophie's Patch is an inspiration for those considering how to have a productive, beautiful and sustainable garden with low water use. And even better, she shares her results with all of us via *Gardening Australia*!

See more about Sophie's garden at sophiespatch.com.au. Some of the information in this article is adapted from Sophie's book *From the Ground Up—A Complete Guide for South Australian Gardeners*, with permission.

Measured irrigation—what is it?

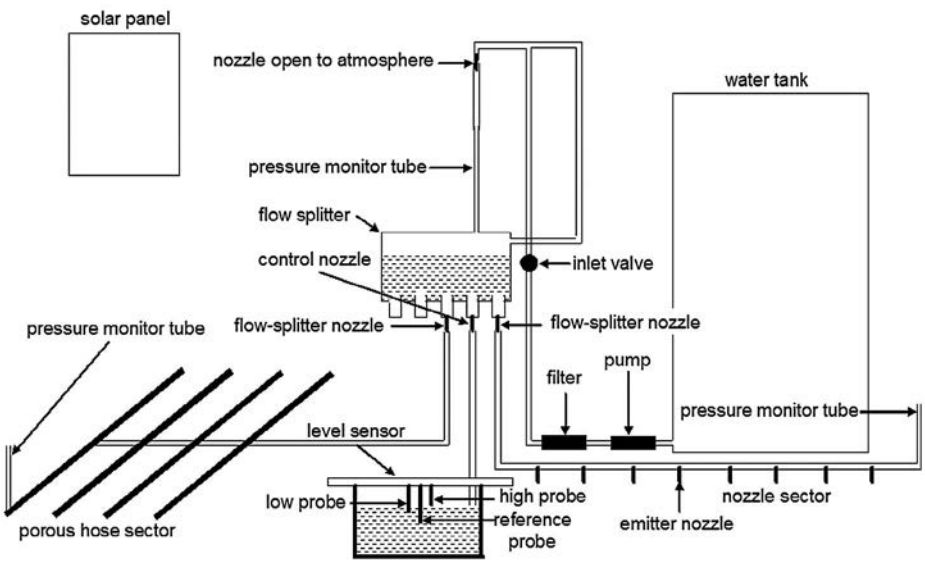
Measured irrigation was invented in 2011 by Adelaide-based mathematician Dr Bernie Omodei to enable low-cost water-efficient irrigation in developing countries without mains power or mains water. He's been refining the system ever since, leading to it also finding a home in private gardens, such as Sophie's, and in many community gardens.

The first community garden to install the system was Fern Avenue Community Garden in Adelaide. They are still using it five years down the track.

The system can be installed by Bernie or DIY, using a kit provided by Bernie. The diagram below shows how the system works. It uses a fall in the level of water in an evaporation container (which can be simply a bucket) to switch on or off the watering system, either automatically, powered by a solar panel, or manually. Thus the system is responsive to rainfall, heat and humidity.

It's a gravity-feed system rather than pressurised, a conscious decision to cater for areas without power or mains pressure water. Most automated irrigation systems are pressurised, but in many remote areas or when using tank water, that's just not possible without expensive pumps requiring additional power. Pressurised systems can also cause problems with leaking around pipe joins. The system can be used with mains pressure water by diverting mains pressure water to a tank or flow splitter (as shown in the diagram) from which it drains by gravity.

The drippers and lines used with the system are non-pressurised too, so you need to consider that if replacing an existing system.



↑ The system consist of a water source (your water tank) that feeds a flow splitter via a small 12V inline pump, filter and a flow control valve. The pump is powered by a small solar panel and battery and is controlled by a pump controller connected to a set of three sensor electrodes fitted above an evaporation container. As water evaporates from the container, the low probe is uncovered, triggering the pump. Most of the water from the tank flows via the flow splitter nozzles to the watering zones. Water flow in each zone is controlled by the size of the flow splitter nozzles and the dripper nozzles in each zone. The pressure monitoring tubes allow you to equalise the pressure in each sector by adjusting nozzle sizes to balance the pressures (see the video at youtu.be/4A2I-U2HG4g for an overview of the system). A smaller control nozzle drips water back into the evaporation container until the water level in the container reaches the high water electrode, which turns off the pump. In this way, the system is completely automated and only waters when necessary. Most of the materials required for a system are included in a kit, including the flow splitter, the pump, filter, controller and sensor electrodes, various nozzles, drippers and soakage hose. Extra nozzles, hose etc are available when you order the kit. For full details, see www.measuredirrigation.com.

Case study: Yarrawonga Community Garden uses measured irrigation

In mid-2014, Yarrawonga Community Garden in Victoria's north installed a measured irrigation system themselves to water a herb garden, seven citrus trees and 22 garden plots ranging in size from 7.5 to 12 m². The total garden area measures 2300 m². The system has seen two summers now and they are very happy with it, says Thomas Hutchison, a committee member.

Thomas found out about this "amazing self-regulating system" on the internet. He says that convincing the committee wasn't easy at first, as many people wanted to go with a more traditional 240-volt pressurised system. However, he was able to convince them of the benefits, particularly given their environmental objectives to minimise electricity use.

It took them about 100 hours work to set up the system—a reasonable amount of work as they decided to bury the main feeder pipework. They dug 60 cm trenches to bury 420 m of 19 mm poly pipe to supply the weeper hose used in the beds: 520 m of 13 mm cross-piped porous weeper hose, made in Melbourne from recycled car tyres. The system is 'multi-sector' with a flow splitter to divide the water from the header tank into separate flows for each sector. This is only needed for larger watering systems like this.

The system has been relatively maintenance-free, "aside from the rare fork entry into a hose or an innocent tampering finger on the inlet valve, which has now been isolated from reach".

Key to the system is setting up the evaporation container correctly. Bernie's website includes calculations based on net evaporation (evaporation minus rainfall) and the amount of water needed for each dripper during the hottest, driest month of the year. The system also works better on a flat site, but instructions for sloping site setup are included.

Yarrawonga had initial teething problems to regulate the flow, but they found a 'try, fail, succeed' approach worked well. Thomas says, "With Bernie's always-willing guidance we have a good, reliable irrigation system and a thriving garden."

Thomas notes that the system maintains average soil moisture and certain crops may need more: for those, additional hand watering at key times works well to ensure a better harvest. "It's not a problem, just something to keep an eye on if you've got tomatoes about to set fruit which may need more water than the average."

Beyond being self-regulating, one advantage of the system is that they didn't need to install clamps on any connections because the gravity-feed pressure puts very little stress on push-on poly connectors. Thomas adds, "You can also add liquid seaweed fertiliser to the header tank and supply that to all the plants in one go!"

↑ Left: the irrigated herb garden in the Yarrawonga Community Garden. Centre: trenches dug and poly pipe being laid to the beds. Right: The flow splitter and poly pipe feeding underground to the beds.

Another self-regulating system

The Irrigatia is another solar-powered self-regulating watering system designed to water smaller garden beds or groups of planters or pots. It consists of a small solar-powered pump unit that is programmed to switch on and run every three hours, at a total flow rate of approximately 100 to 120 mL/min. The runtime of the pump depends on the amount of sunlight the unit has received in the preceding three hours and the pump settings—there are five different settings—and in very sunny conditions the pump can run for two hours during every three-hour cycle. The units come in kit form with filter, poly tubing, drippers and Tee fittings, and can be used to water small garden beds, groups of potplants or hanging baskets, vertical gardens, greenhouses and the like. Complete kits start at $159, with extension kits and maintenance kits (which include a new pump and batteries—stated battery life is 12 to 18 months) also available. See www.irrigatia.com.au for more information.

Wicking beds
Irrigation from the ground up

Seven years ago, when permaculture design consultancy Very Edible Gardens began, they had no idea what a wicking bed was. After repeated queries from clients, they started to research and experiment. Dan Palmer, co-founder of VEG, shares the fruits of their labour.

PRIOR to our foray into wicking beds, all of our raised vegie beds were either unirrigated or set up with drip irrigation. But then someone whispered these words to us: "Wicking beds… We want wicking beds." So we started setting up wicking beds in old bathtubs, and using plastic liner in standard raised beds. We set out to learn by doing, our initial intention to prove to ourselves that wicking beds didn't work. We gave it a pretty good shot, learned a lot in the process and refined how we went about them—a good example of iterative design, where you keep doing what's working and improve what isn't, then repeat.

What is a wicking bed?

Invented by Australian Colin Austin, the wicking bed idea involves the prevention of water loss from your garden bed through the use of a waterproof liner or layer. This creates a reservoir of water beneath the soil and means that, instead of watering from above via drip irrigation, a hose or a watering can, the water wicks up into the soil from below.

This keeps the soil nice and moist. You prevent the weight of the soil from squashing all the water out by having the water sit in a layer of small stones, sand or similar, which can accommodate the water while bearing the weight of the soil. You prevent the soil from dropping down into gaps between the stones or sand particles with a layer of something that lets water wick up, but stops soil moving down. The last essential piece of the wicking bed puzzle is that you need a designated overflow point so that the soil layer doesn't get flooded and kill the soil life and plants by rotting their roots.

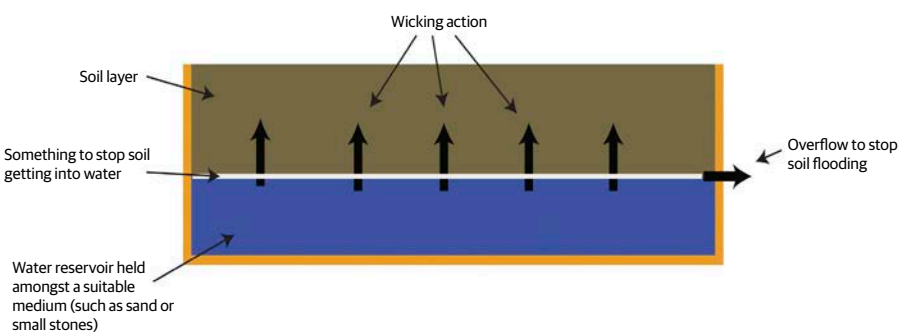
Water efficiency

The water held in the reservoir can only leave the bed by wicking up through the soil profile, to be sucked up and incorporated or transpired out by the plants. With ordinary raised beds, most of the water you apply drains straight out of the bottom and is lost to your precious vegetables forever. This is not possible in a wicking bed. Every drop is forced to stick around, at least until the reservoir is full.

With many irrigation systems, water is lost into the atmosphere as evaporation, before it even has a chance to drain through. Much of the remainder can be lost by leaching out of the bottom. The water storage and application solution embodied in a wicking bed eliminates water loss through evaporation and leaching. If set up just right, the zone of moist soil starts about 5–10 cm down into the soil, meaning the plant roots can easily reach it, but the sun's rays cannot.

Wicking beds maintain a more constant desirable soil moisture profile than other irrigation approaches. So long as the reservoir is kept topped up, the soil around your plant roots is always just right. Excess or deficiency of soil moisture is almost never a factor. Gardeners don't need to group particular groups of plants (i.e. 'similarly thirsty') together in the same wicking bed; the beauty of this concept is that plants just take the moisture that they need.

These days we install more wicking beds than not. We have to admit that, despite our initial scepticism, they have proven themselves.



↑ The essential ingredients of a wicking bed.

The be-all and end-all?

We don't necessarily think wicking beds are a panacea. There are still times when we think non-wicking beds, whether in the ground or raised, are more appropriate. For example, they may not work in large-scale applications (e.g. market gardens), in situations where wicking beds wouldn't be properly installed or the setup budget is very low, or when the managers are very happy to manually water

regularly, or when it is possible that some current or future users won't understand how wicking beds work and hence be able to manage them well.

Wicking as an irrigation solution is most relevant where there are long dry periods during the growing season, water is scarce, or the gardens will be neglected for long periods without watering—e.g. at schools. Nevertheless, beyond these special circumstances, wicking beds are appropriate to most home gardens across most parts of Australia. [*Ed note*: Some people suggest regular raised beds may be preferable where there is regular rainfall.]

Management and maintenance

The main thing is to check the reservoir water level regularly and top up as required (by shoving a hose into the inlet pipe and turning it on until the reservoir overflows).

You should also keep in mind not to go as hard as you otherwise might on nitrogenous nutrients (such as blood and bone). Still use them, but not in excess, as you don't want them leaching down and making the reservoir stagnant. Take care not to pierce the liner doing things like bashing tomato stakes into your bed. (It is safest to use a support system anchored to the outside of the bed instead.)

On average, it is advised to water every two weeks in summer. If you let it dry out, the bed becomes just like a normal non-wicking bed until you top it up again.

Common mistakes and concerns

FORGETTING TO INSTALL AN OVERFLOW PIPE

A common error for first-time wicking bed builders is forgetting, or just not knowing, to put in a designated overflow pipe, or at least a hole where water can safely exit the bed. The pipe should be at the point of transition from soil to stones, which should be about 30–35 cm down into the soil profile.

CREATING LEAKS

Be gentle with your liner. Double it up. Lay it down on some soft sand or old carpet. Place a layer of sand on top of it so the stones don't accidentally pierce it. Water cares not for a 'she'll be right' attitude, and makes a beeline for any hole. When this happens, you do not have a wicking bed—you have a leaking and drying out bed or, in other words, a conventional bed. If in doubt, apply silicone sealant. Before you add the soil, test the liner by filling with water. Then leave it overnight and check for leaks in the morning before moving on.

GETTING THE DIMENSIONS/RATIOS/MATERIALS WRONG

The soil depth really needs to be between 25 cm and 40 cm (ideally somewhere well within these two extremes). Too shallow and it will get too wet. Too deep and it won't get wet enough. The water layer needs to be at least 15 cm deep to justify the effort of building the thing, and ideally at least 20 cm deep.

↑ The layers of construction are visible here in one of VEG's recent wicking-bed installations (Balaclava Railway Station Community Garden). The beds have a waterproof liner at the bottom, then a layer of stones topped with geotextile fabric, with the soil being added on top.

↑ Carey Priest unrolling potable-water grade liner in the VEG warehouse.

PLASTIC CONCERNS

Many wicking bed builders use builder's plastic (polyethylene, which is supposedly chemically inert so unlikely to leach, but it is hard if not impossible to get any statement about its suitability for lining wicking beds from any manufacturer) or synthetic rubber pond liner (which, though very strong, is even more of an unknown).

It has taken Very Edible Gardens a lot of experimentation and research to find a solution. Our breakthrough was prompted when we were asked to install about 40 large wicking beds for a Melbourne-area council community garden. As the beds were being raised due to soil contamination issues, the council wanted written evidence that the liner used in the beds was 100% safe for use in vegetable gardens and potable/drinking water certified.

We eventually found a solution—a liner that is not only certified potable-water grade and especially produced to line the likes of council drinking water reservoirs, but is tough and very hard to accidentally puncture when installing. Unfortunately, the smallest quantity you can buy this product in is 3.7 m-wide rolls that are 600 m long and weigh over a tonne! Fortunately, however, we have somehow wrestled one such roll into a dispenser contraption in our warehouse and are happy to share.

Assuming you go with a potable-water grade, high-strength liner, as it is out of reach of the sun's UV rays, it will likely last indefinitely.

Regarding the inlet and outlet pipes, PVC piping is not ideal. Poly pipe is much better

↑ Inlet and outlet pipes (visible at top of planter at back, and at ground level in front, respectively) are critical to keeping moisture levels optimal.

↑ Here are those same beds sprouting lush, healthy vegies.

from a toxicity perspective. We use 25 mm low-density poly pipe and fittings for both our wicking bed top-up pipe and our three-way water level indicator/overflow/bed drainage tap.

Stagnation

The main maintenance task is emptying out the reservoir every year or so, as a precaution to prevent stagnation. You can assess the state of the water in the outlet—whether it looks discoloured or smells, etc. When it rains, fresh water is pushed through the system, so, for the most part, stagnation doesn't happen. It may if you leave the system without draining and refilling for a year or two. If the water does stagnate, it is carrying excess nutrient and anaerobic microorganisms, but it isn't going to kill your plants suddenly. It may result in a drop in their vigour. We've installed hundreds of wicking beds and never had any reports of stagnation.

As mentioned previously, we recommend going a bit lighter on fertilisers like blood and bone than you might in a non-wicking bed, as excess will filter through and contribute to stagnation (not to mention being a waste). ✱

Very Edible Gardens, based in Melbourne, is directed by founders of the 'permablitz' movement, Dan Palmer and Adam Grubb. VEG exists to help grow healthy and abundant communities, landscapes and livelihoods by designing and creating regenerative human-supporting ecosystems. www.veryediblegardens.com

When wicking beds go right...

Rosalie Livingstone had two of her five (2.4 x 1.2 m) raised vegie beds at her inner-Melbourne home converted by VEG to wicking beds in 2014.

Prior to a four-week trip to the USA that September, Rosalie planted silverbeet in both a traditional bed and one of the wicking beds. On her return, she remarks "the difference between the two was amazing. The wicking bed was lush, the other just okay. This convinced me to convert the other three to wicking."

This season her garden has been a bit neglected, but "in a win for the wicking beds", what she did plant, has thrived.

As for water usage, Rosalie says, "they are a miracle". She has one 3000 L rainwater tank that she uses solely to water her garden and, previously, it would regularly run out in the first month of summer. However, despite slightly lower summer rainfall since installing the wicking beds, she has gone two summers without the tank running out.

She fills the wicking beds once a week, or twice if temperatures hover in the high 30s. It takes just a few minutes. Rosalie conditions the soil as she normally would, with "compost, worm castings and chook-run straw, and that has been fine".

Rosalie's final word on wicking beds: "They are perfect for a neglectful gardener like me. I haven't had lettuces bolt, I've had successful cabbages for the first time ever, and I can go away and not worry about the garden perishing."

Image: Rosalie Livingstone

...and wrong

A couple of years after installing a "very successful" 5 x 1.2 m wicking bed at her home in Melbourne's inner northwest, the construction of which she researched via the internet and which she "loves to bits", Eileen Ray had someone help her install a second, slightly smaller one. After laying down the gravel and putting strong pond liner on top, she noticed too late her (inexperienced) helper standing on top of the liner in the bed. It wasn't visible at the time, but that pressure pierced a hole in the liner, which caused the wicking bed to leak. Rhubarb has been planted in it and is doing okay, but the bed has never performed as it should, and is a definite failure compared to her other one. Eileen's preventative advice: lay a plank over the top of the bed if you need to walk over it to reach your plants or do some weeding.

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A project for a rainy day
Put your stormwater to use

Even dense inner-city housing can easily hold back most of its stormwater runoff—saving water, cooling cities, reducing flooding problems and protecting rivers. Chris Walsh's inner-Melbourne house shows how.

OUR little Richmond house needed renovating. In the process, I wanted to take the opportunity to practise what I preach in my work on urban stream ecology and show that a densely developed residential block can avoid contributing to the wrecking of my local river.

This would require two things: capturing runoff from all the hard surfaces of the property and using as much of it as possible. Ideally we would also allow some of the captured water to infiltrate into the surrounding soil, as rivers need groundwater flows, but as we are surrounded by constructions this wasn't possible in our case.

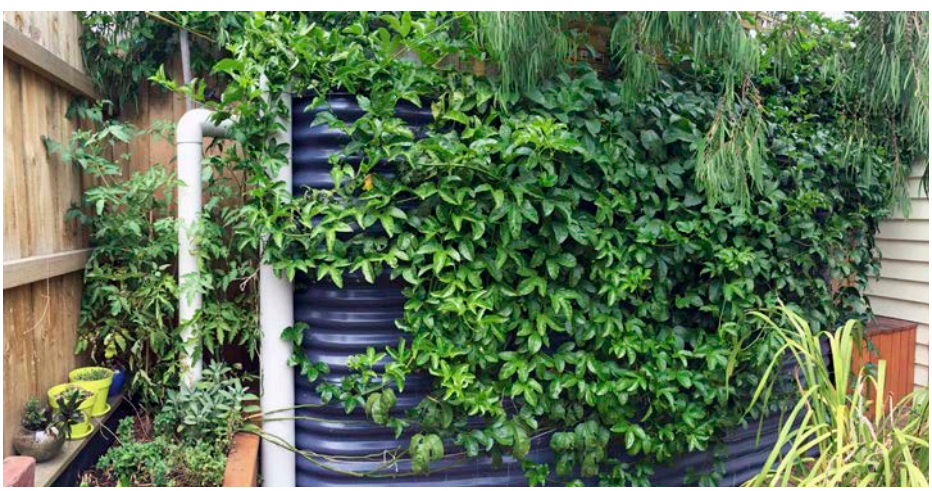
However, if all properties could successfully keep most of their runoff out of the council drainage system, as we are doing, then it would become more feasible for councils to build infiltration systems that can cope with the large volumes of stormwater generated by roads. If this were done along all city streets, then our cities' streams and rivers could be truly healthy again—a revival of natural assets that for too long we have assumed must be lost from our urban landscapes.

Just a square metre of runoff

So about 18 months ago as part of our renovation (and at little extra cost), we constructed two small, productive 'rain gardens' that capture runoff that would otherwise go into the stormwater drains.

These garden beds keep our household in herbs and vegetables (and provide cooling shade) without the need for mains water or active watering. We also installed a small rainwater tank that takes up less than 1% of the property area and captures water for use in our toilets, laundry and another garden bed.

Only a square metre or so of brickwork at the front gate drains to the street. With our stormwater system, no runoff should leave the property from any surfaces other than this square metre of brickwork, except in large storms.



↑ Tank overflows to the rear rain garden and the rain garden plants grow over the tank and, eventually, the northern wall of the house!

The tank installation

Our house sits on a 160 m² block, with a roof area (post-renovation) of 118 m². To capture water from the roof, we installed a 2750 L slimline tank along the back wall of our courtyard. All the downpipes (draining about 114 m² of roof) except one (draining 4 m²) drain to the tank via a 'charged' system (also known as a 'wet' system, the downpipes are always full up to the level of the tank inflow).

Each of the downpipes has a rainhead with a flywire screen to prevent debris flowing down the pipe and to keep out mosquitoes. This was particularly challenging for two downpipes on walls along the boundary, where we only had 150 mm between the wall and the boundary. I managed to source two frogmouth filters—narrow enclosed filters that are no longer manufactured. [*Ed note:* A product called Superdiverta, which sits flat against the wall, may be an alternative solution, www.supadiverta.com.au.] The small amount of water that splashes out of these filters is directed through a second pipe into the small garden outside our kitchen.

The 100 mm sewer-grade downpipes (necessary for charged systems) connect under the house to the tank. This pipe system has a slight slope to a purge point at the front corner of the house; in case the system ever needs to be emptied, it can be drained slowly into the front rain garden.

← Tomatoes flourishing in the front rain garden. The large pipe is the inspection well for the outlet pipe; the small pipe is the inspection well for water depth in the garden.

The tank is plumbed into our two toilets and washing machine. We also use it to water our 6 m² of garden (normal garden beds, separate from the rain gardens described below), with a pump that switches automatically to mains water if the tank runs dry.

Productive rain gardens

The tank overflows to two connected rain gardens. It goes first to the 3 m² back garden, which fills with water to about 15 cm higher than the water level in the 2.2 m² front garden. When the back garden fills, it overflows to the front garden. When they were first connected, the back garden kept emptying to the same level as the front garden, because the pipe between them was acting as a siphon. A couple of small holes drilled into the top of the connecting pipe broke the siphon, and resolved this issue.

The rain gardens are essentially big planter pots, about 1 m deep, with a bottom layer of gravel separated from the top 60 cm of soil by geofabric. A slotted pipe, allowing water to pond up to about 40 cm depth, runs along the gravel layer connecting the higher inflow and outflow pipes. In a few places, the soil layer over the geofabric is sunk to the bottom of the garden to allow the soil to wick and keep the top soil moist when the water level drops. An inspection well (a capped, vertical 45 mm PVC pipe) in each rain garden helps us keep an eye on how much water they have over summer.

Because they are completely sealed at the bottom (with heavy-duty pond liner), the only loss of water from the rain gardens is from what the plants use. The current plants in these small rain gardens wouldn't lose a lot of water over a year, but we are encouraging the plants to grow out of the beds: we planted a passionfruit vine that covers the tank and will grow along our back wall, grapevines that will cover the pergola in the rear courtyard, and trees. These big plants should at least triple the effective area of the rain gardens, absorbing much more water and providing lots of cooling shade.

The results

Over 18 months of operation, the tank has collected about 60 % of our roof's runoff, and the rain gardens have used a further 10 %.

Why stormwater and not greywater?

In my opinion, the sewerage systems of Australian cities do an excellent job of transporting the wastewater from our toilets, sinks and showers to central treatment plants that result in generally small, localised impacts to coastal waters or large rivers. In contrast, roof and road runoff drains to pipes and gutters that ensure every drop of rain that falls on a roof or road, every drop of oil or soapy water that spills onto the street, every dropping from a bird or possum that lands on a roof—all of it—drains quickly to the nearest creek, river or beach. This runoff causes the many waterways of our cities to be sick, failing to provide the many ecological services that healthy streams could.

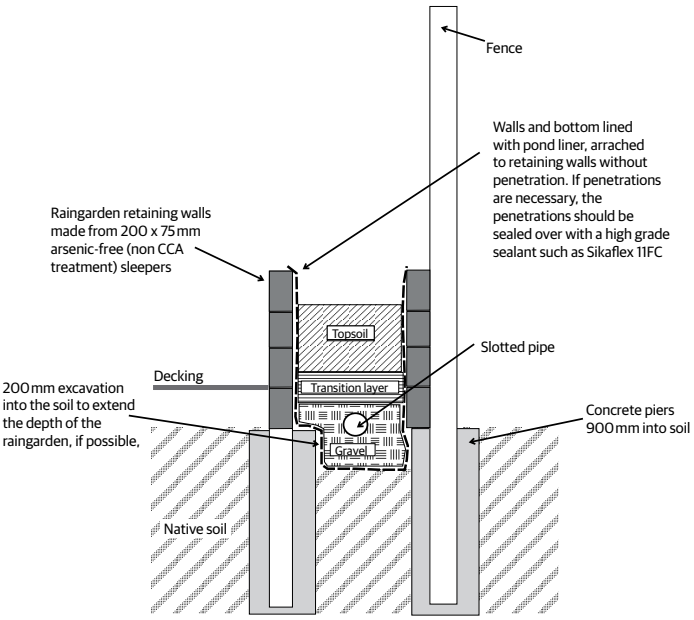
If we keep stormwater on our properties, we can help reduce those widespread impacts. Using soapy greywater instead of stormwater to flush toilets will have no effect on the performance of treatment plants, but using it to water gardens will increase the risks of loading your soils with salts or of allowing high-nutrient greywater to get into the stormwater system.

The economics

The tank, pump, extra piping and additional labour added about $8000 to our renovation costs, amounting to less than $400 additional mortgage payments each year.

Personal savings to us exceed this outlay. The 40 kL of water supplied by the system saves us $100/year; the supply of herbs and vegetables has saved us at least $350/year at the market. We greatly value the shading benefits, which are more difficult to put a dollar value on.

We pay $95/year for Melbourne Water to manage our stormwater drainage and waterways (a fraction of what we pay them to protect the environment from the wastewater we produce). Our system is providing the public benefits of greatly reducing our property's impact on our local waterway, and reducing our contribution to flooding. Arguably, a fair system of governance would compensate property owners who contribute to these services, making stormwater use even more economically attractive.



↑ Cross-section of the rear raingarden. The topsoil, transition layer and the gravel covering the slotted pipe are added after construction. Only sufficient gravel to support the slotted pipe needs to be added during construction.

Usage by the rain gardens should increase as the vines and trees grow. While our roof has produced runoff on 186 days over that time, the property has overflowed to the street only 44 times, usually releasing only a fraction of the volume running off the roof. On two days over that time, when flooding of Melbourne's streets has been reported in the papers, our property produced little or no runoff.

During the last summer, a healthy stand of tomatoes used all of the water in the front rain garden twice (the deeper, back rain garden is yet to empty). The charged downpipes proved a useful resource, as we were able to fill the front rain garden from the purge point.

All of the vegetables and herbs we have planted in the rain gardens have thrived without active watering. A gingko tree and two citrus trees have been less happy, perhaps not enjoying having wet feet. We raised them after the first year, and are watching their progress.

The benefits of water saving, of low-effort fresh vegetables and herbs, and of cooling shade have made our system well worth our while, without even considering the public benefits we are providing by reducing local flooding and protecting our local river. ✱

For more details of Chris's rain garden renovation and progress, see www.urbanstreams.net/index.php/news-2/my-raingarden-diary. The urbanstreams.net site also contains more general information about his research on urban stream ecology as principal research fellow in the School of Ecosystem and Forest Sciences, University of Melbourne.

Stormwater reuse on a larger scale

Historic, iconic and beautiful, the 26 acres of parklands on the eastern fringe of Melbourne's CBD known as the Fitzroy Gardens require around 117 ML of water for irrigation annually. Challenged to meet this need in the face of drought, water restrictions and impacts of climate change, the City of Melbourne decided to build a stormwater harvesting system, following the success of their trial project at nearby Darling Street (you can read about this in *ReNew 121*).

Completed in December 2013, the Fitzroy Gardens system is, to date, the city's largest, and captures sufficient stormwater to replace around 60% (i.e. 70 ML) of the potable water supply previously used on the gardens.

The water runoff is captured at a natural low point in the 67-hectare catchment area. The runoff first goes through a 'gross pollutant trap' to capture litter and leaves before moving on to the sedimentation chamber, which filters fine sands and oils. From there it flows into the primary 4 ML storage tank and gets pumped up to the biofiltration bed at the surface, planted out with native wetland grasses, where invisible pollutants such as nitrogen are removed. The treated water flows down to a 1 ML storage tank, from which the gardens' irrigation water is drawn, with any excess diverted to the stormwater system.

Similar systems also operate in the Queen Victoria and Alexandra Gardens to Melbourne's south, and Birrarung Marr on the banks of the Yarra River.

Indeed, local governments all around Australia are embracing Water Sensitive Urban Design practices to more effectively manage stormwater runoff in our urban landscapes. Water authorities are also encouraging rain gardens at the local level, providing step-by-step guides to designing, building and maintaining a rain garden (such www.healthywaterways.org, www.melbournewater.com.au/raingardens). South Australia's Environment Protection Authority (www.epa.sa.gov.au) has Rain Garden 500, which is a three-year grant program for councils, community groups and individuals around Adelaide.

Image courtesy City of Melbourne

↑ The 240 m² biofiltration bed used at Fitzroy Gardens has a footprint that's just 10% of a standard gravity-feed system. A slightly coarser sand was used to handle the regular pumped inundation of the bed; this also affected plant selection of Juncus procerus and Juncus gregiflorus.

Common sense meets design
Water efficiency at Melliodora

Sarah Coles speaks to Su Dennett and David Holmgren about water efficiency and permaculture.

THE first thing I notice on the journey from the city to Hepburn Springs is how dry the land is—the topsoil is blowing away from the farms even though it rained last week. Then I arrive at Melliodora and it's green.

David Holmgren and Su Dennett have been running this permaculture demonstration site on the edge of Hepburn Springs, about 120 km north-west of Melbourne since 1985.

David is co-originator of permaculture, a system of agricultural and social design principles grounded in the patterns observed in nature, and is well known for his book *Permaculture: Principles and Pathways Beyond Sustainability*. Su managed their business Holmgren Design for many years, but is now focused on work with the Hepburn Relocalisation Network, through which she coordinates a vegie box scheme, facilitates bulk food distribution, ride sharing, free-cycling, a tool library and bushfire preparation.

Melliodora is a one-hectare property on which there are three passive solar dwellings housing the family, WWOOFERS, workers and course participants. The main adobe house was designed to be bushfire resistant, with mudbrick walls and floor.

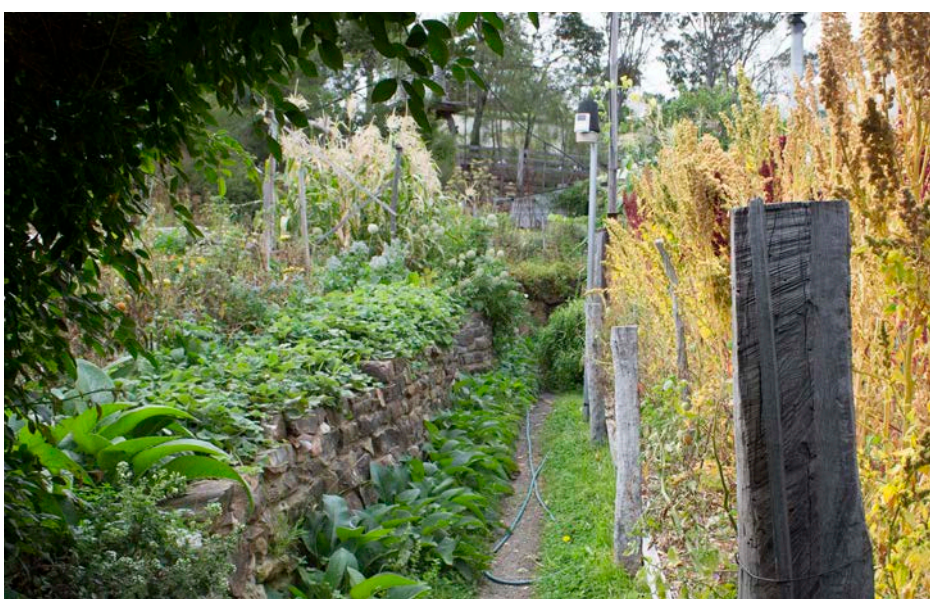
It is a hot day, but the main house in which we are sitting feels comfortable. It is a low-energy house, thanks in large part to the orientation, thermal mass, wood stove, cool cupboard (draws cool air from underfloor into an insulated cupboard) and grid-connected solar. On the north side of the house are a grapevine and a greenhouse which provides warmth in winter. It's currently full of kiwi vines, cucumbers, beans and pumpkins, which provide shade in summer.

Su says, "We use those plants as part of management of the house. The house is made of earth, so that is an extension of the garden." When I ask if the house was constructed from earth on-site Su laughs, "No. Bendigo. We decided we would have a relationship and not make mud-bricks!"

Quite a lot of food production takes place at Melliodora—150 fruit and nut trees are where the bulk of water is used. The overall garden design is based on a European mixed orchard. There are food gardens, livestock—including goats, chickens and geese—and a creek revegetation project on public land at the rear of the property. In the incredible orchard, fruit and nut trees (apples, pears, olives, fig, feijoa, peaches, walnuts, almonds, hazelnuts) are planted alongside tagasaste, an evergreen that provides food for the goats and mulch for the garden. There is a 'permaculture zone 1' vegie bed next to the kitchen, made of recycled timber and stone. Their small lawn, which they don't water or fertilise, Su says is "very good as part of a fire-prevention strategy." The property is an example of soil fertility, resilience, bushfire- and flood-resistant design and stormwater harvesting.

Su was water-conscious as a child: "We grew up with that way of looking at things. I was born in 1947. That is not long after the war and people were what we would these days call frugal. You took care not to waste things."

Water at Melliodora comes from three places: dams, town water and rainwater.



↑ I visit Melliodora on a hot summer day during the driest summer Su Dennett can recall. The vegie beds are productive, fed by the rainwater tanks and town water, and well mulched with eucalypt and wattle wood.

"70% of water goes on agriculture. That doesn't exonerate the household from saving water." Su Dennett

↑ One of the seven rainwater tanks on the productive property. This one is used by the house; Su is a stickler for minimisation of water use: "70% of water goes on agriculture. That doesn't exonerate the household from saving water," says Su.

Melliodora has two dams to capture runoff. It is a 40-hectare catchment. The dam water is pumped to tanks at the top of the property to irrigate and provide water in the case of a bushfire: water misting pipes are installed around the perimeter of wooden outbuildings, and the water storage tanks have good pumps.

There are seven rainwater tanks. The largest are 48,000 L and the smallest is 3000 L. Some are concrete and some are galvanised steel. The concrete ones are for garden use and the steel ones for the house.

Su points out that this has been the driest summer she can remember. "It seems like we're getting less and less rain in the summer, so we need to use more of the town water." Melliodora uses 150 to 250 kL a year from the town water supply. David estimates that 80% to 90% of this is used on the garden. Where households might typically use 250 kL per year, Melliodora uses 720 kL in total. But they have three dwellings and 150 fruit and nut trees. To put things in perspective David says, "Melliodora uses 1 ML over a hectare of land. Irrigated rice in Victoria uses 12 ML per hectare."

Melliodora has predominantly tree crops, which require less water. The permaculture garden design means that it is a sheltered environment, so less water is lost to evaporation. "But it's not permaculture magic"; David says they make conscious choices to use less. "We're not using as much water as crops could potentially use." He explains that farmers get paid so little for what they produce, but the cost of water, fuel and fertiliser is low so they use a lot of those inputs.

David estimates that the average indoor household water use at Melliodora is 50 L per person per day. When David started doing design work in the 1970s, 350 L per person per day was considered the norm: "That was before water-efficient technology." Since then, there has been a dramatic reduction in water use, "but the figures are still too high." David adds that calculating household water use is tricky because "if you recycle all that water, if you don't contaminate it with oils, fats and chemicals, then you get a second use out of it."

At Melliodora, some of the vegie watering is done by hand or by sprinkler in the evenings and early mornings. "At the same time, you can observe what's happening in the garden; you can weed and harvest," says Su, eating a home-grown grape and pouring me a glass of tank water.

Walking around the property, she points out the cut-off drains that go from the street to direct all of the water into the property. "We clean out the drains after every rainfall to make sure that water continues to flow in to the property. And we have drains on the bottom road reserve that bring water into the dam. You would lose a lot of water if you didn't do that." As Su points out the places on the property where water is being

"I don't have to think about climate change or peak oil or any of those things, because all of those things would be resolved if we cut our consumption. It doesn't take rocket science; you don't have to spend years doing a PhD to go 'that doesn't make sense, I won't do that'."

harvested, she tells me about Peter Andrews, creator of Natural Sequence Farming and his maxim 'Slow it. Spread it. Sink it.' Su notes that harvesting rainwater in this way is "something that everybody can do in the city as well; to intercept their gutters and make a bit of a change there. Clearly you can't do really big things, but that is part of Dave's *Retrosuburbia: A Downshifter's Guide To A Resilient Future*. (David Holmgren's forthcoming book due out this year). She adds, "We'd like to think that no water that we're using leaves the property."

Mulching cannot be underestimated. Su says, "Mulching is really good and it's not just for water saving. Bare soil is not a natural state; you can't keep the life in the soil if it isn't covered." Su is enthusiastic about woody mulches made using a chipper: "All the fungal life that we get through that woody mulch is a great complement to the other forms of life that you need in your soil."

As part of their fire mitigation strategy, they collect bark and leaves from the road reserves. The bottom road reserve has big eucalypts and wattles on it that make fantastic compost.

It seems strange to be at Melliodora talking about ways to be efficient with water when the next street over is full of people taking spas. Su says, "We have a huge demand on water here because of the tourist industry. We are promoted as 'Spa country'. People are profligate with water. It's disgraceful! The water restrictions are on garden use, but they can't monitor if you're filling up your spa bath."

David has created the 'Permaculture Principles' (see side box). When I ask Su if she applies these to water saving, she laughs. "I don't think about the principles. I just do things intuitively, because I come from the view of minimisation of everything. That meets all of the criteria—the environmental criteria—so I don't have to think about principles." She tells me about her showering routine: "People say 'Oh, I need a shower every day'. What they mean is 'I need to clean every day'. You can put three cups of water in your wash basin and scrub with a face cloth."

When I ask David the best way to save water (unlike Su, with her three cups of water and a face cloth) he comes at me with a macro angle: "Build a parallel system, because the other one is sending us into the climate cooker. Withdraw our support of the centralised systems. Create a degree of autonomy that constrains the monetary economy."

David has published extensively on this, the 'crash-on-demand' idea, that if just 10–15% of people reduced consumption, the effects would be massive. "Self-reliance is central." David points out that a third of the water use in typical households goes down the toilet. "A million compost toilets across Melbourne actually would make a difference. People can just start small. The biggest flexibility we have is actually in behaviour change. There's so much fat in the system...efficiency is not what the system is trying to do."

David gives the example of the sewerage system in Brisbane, which was built to require a large volume of water to run through it to run properly. David admits, "Our water use at Melliodora could be a lot lower. We don't represent some state-of-the-art efficiency. But it is a fraction of the water used to grow the food that is in supermarkets."

Su sums it up: "You must have regard for resources. What does it take to get that water? Where does that water come from? Where do these things come from? How do I get them? You must conduct that basic enquiry about how you exist in this world."

The philosophy at Melliodora is to minimise water use in the house so that the water saved can be used to grow food in the garden. Looking out across the lush orchard on the driest continent on earth, this makes sense to me. ✱

Melliodora guided tours: www.holmgren.com.au/melliodora/tours/
Hepburn Relocalisation Network: www.relocalisehepburn.blogspot.com.au
Australian Story about Peter Andrews creator of Natural Sequence Farming: www.abc.net.au/austory/content/2015/s4226139.htm

↑ Top: The property uses drip and micro-spray irrigation throughout.

Bottom: One of the dams is a goose pond. Su says, "We are in the process of pumping it out onto the land because having geese in it all of the time it has become a thick soup of nutrients. We will pump that out into the orchard before the autumn rains come."

The Permaculture Principles

1. Observe and interact.
2. Catch and store energy.
3. Obtain a yield.
4. Apply self-regulation and accept feedback.
5. Use and value renewable resources and services.
6. Produce no waste.
7. Design from patterns to details.
8. Integrate rather than aggregate.
9. Use small and slow solutions.
10. Use and value diversity.
11. Use edges and value the marginal.
12. Creatively use and respond to change.

Going waterless
The composting toilet

While flushing toilets have been the popular option for centuries, dry systems are a worthy alternative. Eva Matthews investigates.

FOR millennia people have been working on the problem of what to do with their poo. Essentially, there have been two basic approaches—the 'wet' and the 'dry'.

From as far back as the Bronze Age (3300–1300 BC), there is evidence that the Harappan civilisation of the Indus Valley, on the Indian subcontinent, used flowing water to wash away their business via brick-covered drains. Throughout the Roman Empire, from the first to fifth centuries AD, water-flushing systems were also prevalent. In the absence of flowing water, human waste has largely been deposited into a hole or pit and covered over. Over the centuries, these approaches have seen various developments.

A forerunner to the modern flush toilet, comprising a water-filled tank and bowl, was invented in England in the late 16th century. The Industrial Revolution saw the invention of the S-trap in 1775 (a crucial bit of plumbing, still used today) and the first modern toilet went into production shortly thereafter. Growing levels of urbanisation and wealth, and the development of more sophisticated sewerage systems, saw the flushing toilet become more widespread from the mid-1800s, not only in Britain, but also across Europe and into America.

There followed many iterations of the flushing toilet, but the next revolution came in 1980, when Bruce Thompson, who worked for Caroma in Australia, designed the dual-flush cistern as a water-saving measure (reducing a standard flush from 12 L to just 9/4.5 L; this has since further reduced to 4.5/3 L). This technology has now spread widely across the world, preventing many gigalitres of good drinking water going to waste.

The modern version of the dry toilet system—essentially a seat with a collection vessel underneath and requiring the addition of a covering material, such as peat or sawdust—was invented, again in England, in 1860. However, it didn't gain the same popular support as the flushing toilet (which so beautifully addressed our desire to have as little as possible to do with our waste once it leaves our body). Despite the commercial development of the Clivus Multrum composting toilet back in the 1930s, the waterless loo has largely remained on the fringe. Modern iterations have proven very useful in rural/remote areas that are short on sewerage infrastructure and/or water, and in places where disturbance of the environment needs to be minimised (such as national parks). And the suburban backyard dunny (basically a big collection bucket located underneath a bench with a hole in it to sit on, which was taken away during the night and replaced with an empty) remained in use in some parts of Australia even into the 1970s. But, where infrastructure has been available, the popular choice has always been the flushing system.

However, with the water crisis currently facing the planet, there is good reason to reconsider the waterless toilet.

There are also water-saving toilets, such as those covered in *ReNew 125* (urine-separating, vacuum and air-assisted), and water-treating and re-use systems (such as worm-based or aerated); however, the focus here is on completely waterless—you can't get more water-saving than that!

There are different definitions of what constitutes a dry toilet, but the most common type is the composting toilet. So let's find out more about it...

What is a composting toilet?

Basically, a composting toilet is one in which human waste is captured in a chamber and processed, over time, into a rich fertiliser—endearingly known as 'humanure'—that can be used to feed your garden.

The process requires a combination of air, heat (optimally 40–60 °C, to kill the pathogens) and the action of aerobic organisms such as fungi, worms, bacteria and insects, to break down the waste over a period of at least six months, and up to three years. Exactly how long the decomposition

↓ Looking at it in its slick and shiny setting, there is not anything obvious to differentiate this—a composting toilet—from a modern flushing unit with a hidden in-wall cistern. Just one of several good reasons to consider going waterless in the loo.

Photo courtesy Anthony Smith, 'The Water Wally'

takes depends on climatic conditions, the size of the collection chamber, the design of the system and how often it is used. Urine is often diverted or evaporated, as too much moisture means water-loving anaerobic organisms can start producing offensive-smelling gases, and decomposition takes longer.

There are a number of suppliers of off-the-shelf composting toilets in Australia, but some types you can also build yourself (*ReNew 125* features a DIY wheelie-bin composting toilet, if you're interested). Note, however, that state-approved designs may have a better chance of being allowed by your local council, and planning permission should be sought before purchasing/making and installing a composting toilet in your home.

Different types of composting toilet

The first differentiation in composting toilets is whether they are a split or self-contained system. Split systems require space directly under the floor of the room containing the toilet, as this is where the collection chamber is installed. Self-contained units require no underfloor space (and are therefore best suited for houses built on concrete slabs) and the collection chamber is inside the toilet.

The second differentiation is whether they are continuous- or batch-composting. In a continuous system, the waste moves slowly down a sloped container (which sits under the floor), decomposing as it does so, until it is removed as compost from an end-product chamber. The Clivus Multrum system, first developed in Sweden in the 1930s, is perhaps the best-known example. (*ReNew 128* featured a case study of a Clivus Multrum system, if you'd like a real-life story about how one performs—in short, pleasingly well!) Batch systems are ones that have two or more collection chambers. The waste falls directly into a container, where the decomposition process starts. Once a container is filled, it is replaced by an empty one, and left to continue the composting process until its contents are ready for use as fertiliser. Some, such as the Australian Rota-loo system, have multiple containers mounted on a turntable in a space underneath the floor, making the process of changeover and removal easier.

Things to consider

The type of composting toilet you go with will crucially depend on whether or not you have underfloor space to house a split system. You also need to consider the system's capacity—how many people will use it, and how frequently? A self-contained unit is fine for smaller households or for holiday homes, but a split system will have greater capacity.

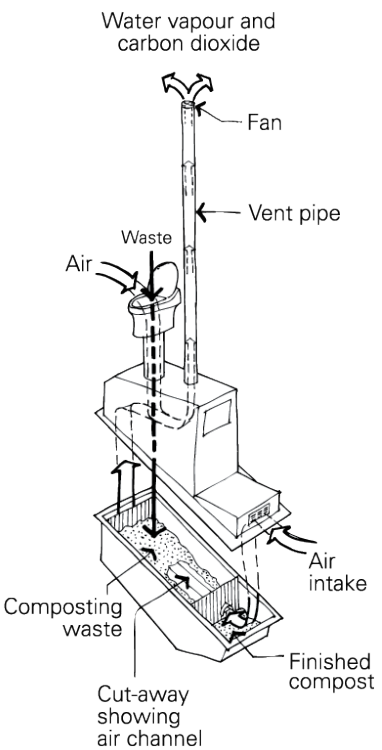
Climatic conditions are another factor—some systems come with a heater, to ensure optimum temperature is maintained in the collection chamber or to help evaporate urine, but you may not need this if you live in warmer climates and/or you situate the system on the sunny/warm side of your house.

Cost may also determine your choices, and this can vary significantly, depending on design and features. Design approval is also important in seeking planning permission—since 2004 all composting toilets have required certification to Australian and New Zealand standard AS1546.2—so check this with the supplier. Councils may not allow composting toilets in areas where sewerage is available, or may have different regulations and requirements, such as providing soil tests and site plans with your planning application, so it's best to check this early on in the process.

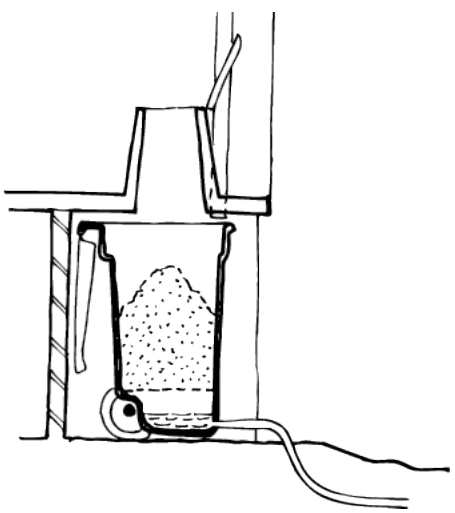
Maintenance may be something else you'll want to factor in—simpler designs may require more work to operate effectively (e.g. adding a bulking agent with each use to promote aeration; regularly changing a small container), but they also may be easier and cheaper to fix if problems arise, compared to more complex systems that have more moving parts and are perhaps more inaccessible.

Once installed, safety is also an important consideration. As there may still be residual pathogens in the humanure, even if the system is working properly (i.e. has adequate air, and pH and moisture levels are optimal), it is best to wear gloves and a mask when handling the fertiliser, and it should be buried under at least 10 cm of soil (but it's not recommended for your vegetables, due to the potential risk).

Finally, if you want (or need) to be completely independent of a sewerage system, you will need to invest in a greywater system to deal with the water that is being used in your bathroom, kitchen and laundry. (See *ReNew 130*'s Greywater Buyers Guide for help with this.)



← Examples, from left to right, of a continuous- and a batch-composting toilet. In the first, the waste decomposes as it works its way down a sloping chute to an end-product chamber. In the second, the waste drops straight down into a collection chamber (in this example, a wheelie bin with a perforated false floor to drain off liquid to avoid a too-wet mix), where it decomposes over time.



Source: Commonwealth of Australia (www.yourhome.gov.au/water/waterless-toilets) Department of Industry, Innovation and Science (2016]) 'Your Home: Australia's guide to environmentally sustainable homes'. Your Home is CCBY licensed under a Creative Commons Attribution 4.0 International License.

Benefits of a composting toilet

Over a year, having a composting toilet will prevent 35,000 to 60,000 L of potable water being flushed away, which is better for the environment, for water storage capacity and your hip pocket—the cost of water is rising yearly, as is the cost of sewerage connections for new homes.

Where an on-site wastewater management system is the only option (such as rural/remote areas), the initial and ongoing cost of a composting toilet is significantly lower than other systems, such as septic, aerated treatment and worm farm systems.

And with improvements in the aesthetics, function and cost of waterless toilets, it makes sense for people to consider this option for their home. Modern designs mean a composting toilet can look as much at home as a conventional toilet; plus, there are a range of types and models to meet different usage needs and structural limitations (see the brief buyers guide, below, to get you started).

You will also have free fertiliser to help your garden flourish! (Of course, if you don't have a garden, the fertiliser can be disposed of as per your local council regulations.) ✱

Eva Matthews is a semi-regular contributor to *ReNew*, when not busy trying to finish building her sustainable home in the Yarra Valley.

Image: Anthony Smith

↑ Anthony Smith runs his wastewater management business from Margaret River in WA. He has seen and used a variety of composting toilets in his travels around Australia and abroad, so it made complete sense for him to install one at his home/office (as seen above, the Clivus Multrum CM2), where it replaced a flushing toilet. This was around 18 months ago. It is used daily by himself and his wife and, occasionally, his three-year-old twins, as well as visitors to his Water Wally showroom—where it serves as a working example of a composting loo. Anthony has been very happy with the performance of the toilet—no odours, and lovely fertiliser for the garden. And while it serves their current needs well, he says that, when they build their home in the next few years, he will install a larger split system "for the simple fact that it's a lower maintenance option which, for us, is an important factor in long-term planning."

Image: Ruth Campbell

↑ Ruth Campbell runs Pine Rivers Yoga at her home studio in Cashmere (just north of Brisbane). To accommodate her students, she installed a simple split system—a Nature Loo Classic 650—inside a purpose-built 'privacy hut' next to the studio, in August 2010. Not being on mains water was a key consideration in her decision to buy a waterless composting toilet, as was ensuring no effluent runoff onto the land. The toilet gets regular use. It has three collection chambers, i.e. one in use and two extra, and these are changed over every three months. Ruth buries the humanure in the ground. She hasn't had any issues with the toilet in the five-and-a-half years she's had it; it meets her needs and she's very happy with it.

A brief buyers guide to waterless composting toilets

The following list outlines key suppliers of off-the-shelf waterless composting toilets in Australia. It is by no means exhaustive, and does not constitute any recommendation by the ATA; it is intended as a starting point for your search. Note: You should check with the supplier whether the system you're considering is certified, and with your local council as to whether it is approved in your state/territory.

A Better Way to Go
www.abetterwaytogo.com.au
ph: (03) 9421 4235
Supply marine/mobile and domestic self-contained composting and incinerating systems. Brands include Airhead, Villa and the Separett range.

Ecoflo Wastewater Management
www.ecoflo.net.au
ph: 1300 138 182
Supply domestic and commercial self-contained, mobile and split systems. Brands include their Nature Loo, Clivus Multrum CM and EcoLet range (www.clivusmultrum.com.au), and Sun-Mar Centrex, Excel and Compact ranges (www.sun-mar.com.au).

Ecosan Australia
www.ecosanaustralia.com.au
ph: (08) 9390 9382
Sole Australian distributor of the Ecosan split-system toilet.

Enviropro Alternatives
www.enviropro.com.au
Supply self-contained composting toilets, including the Nature Loo Classic and Excelet range, Sun-Mar Excel range and Nature's Head, and Sun-Mar Centrex split systems.

Kiel Industries
www.kielindustries.com.au, www.rotaloo.com
ph: (03) 5135 3900
Manufacture and supply domestic/public split system Rota-loo range.

Water Wally
www.waterwally.com.au
ph: 0407 247 844
Supply self-contained, split and mobile/outdoor systems, including the Nature Loo range, Sun-Mar Excelet range, Clivus Multrum Ecolet and CM range, Rota-loo, and the 'Loveable Loo' designed by composting loo guru Joseph Jenkins, author of *The Humanure Handbook* (Jenkins Publishing, 3rd edn, 2006).

Prices for domestic self-contained systems range from $745 to $3300; for split systems, $1795 to $5850. Generally, higher capacity means higher cost.

It never rains, but it pours
Gardening in the tropics

Rain in summer and lots of it, little rain in winter—gardening in the tropics and subtropics requires a different approach to water management. Emma Scragg explores the topic with two northern Australian gardening experts.

DIFFERENTIATED by summer rain rather than winter, the northern half of Australia requires a very different approach to gardening and selection of plants from the south. In the tropics and subtropics, there are longer periods of sunshine, and generally people talk of rainfall in metres rather than millimetres. Roof gutters, drains and rainwater tanks often can't keep up with the rainfall rate and valuable stormwater for the drier winter months is lost. The focus of successful landscape design and gardening in the north is not water-conservation but rather capturing the water effectively when it falls and selecting plants appropriate to the wet summers and dry winters.

Yungaburra garden designer and landscaper David Leech and Brisbane-based landscape architect and horticulturalist Arno King shared some of their knowledge to make the most of the abundance that these climate regions can offer.

Soil as storage

Arno suggests the most effective place to store stormwater is in the soil. Rainwater can be slowed and absorbed through the use of swales, terracing, vegetation and optimum soil structure.

Australia's soils are generally heavily degraded from fire, agriculture and compaction, leaving us with "some of the lowest levels of micro organisms in the soils," says Arno. "And minerals that rely on the organic matter to hold them in the soil have been flushed out." In high rainfall areas of the tropics and subtropics, it is critical to have good soil structure and biology. Fungal webs (mycelium) in particular, along with invertebrates and other microorganisms (bacteria and protozoa), are encouraged by high levels of calcium and organic matter. These aerate the soil: they make the soil more like a sponge and "plants can tap water immediately around them," Arno says.

Subtropical and tropical calcium levels are generally low on the east coast but are better in some areas near Darwin and in Western Australia, where limestone is the parent rock. To improve calcium levels, Arno suggests adding lime, dolomite or gypsum (refer box).

Another mineral additive that Arno recommends is humates, from humic acid deposits and fossilised plant matter, often associated with coal. These are economical and have huge impacts on soil and its water-holding ability. Diatomaceous earth and zeolite have a similar effect but also encourage and provide shelter for microbes which in turn transport mositure to plants. This is useful Australia-wide.

Image: Arno King

↑ Growth can be verdant in the tropics and subtropics! Above shows a thriving vegie patch in Arno's garden in August (late winter) with a mixture of salad greens: "so much better and so much more variety when you grow your own," says Arno.

Pests and diseases

Pests and diseases can be best managed Australia-wide through soil minerals and appropriate plant selection. "90% of pests are to do with poor plant nutrition," says Arno. A lot of pests and diseases are again a reflection of lack of calcium. "Calcium is essential for cell structure. Also, if you're getting pests eating your plants, it's often a lack of silica. Add them

→ Plant selection is critical in the tropics and subtropics to prevent disease and crop failure. There are many plants that thrive, provided they are planted in the right season.Top left: Poor Man's Bean (Lablab purpureus) a heritage Brisbane bean, originally from India.

Top right: Indian saag, a type of mustard with fleshy leaves, used like spinach, for example, in Palak Paneer in northern India, says Arno. "It grows profusely as a winter crop in the tropics, and is delicious, a little sweet, with just a touch of mustard flavour."

Bottom, minutina (a type of plantain) with Brazilian spinach in the background.

Images: Emma Scragg

"Some of the most productive places in the world are in the tropics and subtropics for growing vegetables. The key is to grow different foods with the season. "

in the right amounts and leaf-eating insects grind their mouth parts down so they can't eat." Fungal diseases can be a problem in humid climates but a strong epidermis, helped by calcium, offers improved resistance to spores.

Mediterranean plants (figs, olives, lavender, sage, rosemary etc) are some of the hardest to grow in the tropics and subtropics, says Arno—"they are so psyched into getting rain when it's cold and during the hot summer months being bone dry." They also love high levels of lime. Selecting a climate-appropriate cultivar can help. If olive fruit is wanted, St Helena Olive (Manzanillo cultivar), for example, is more suited to the subtropics.

Fruit fly is a notorious northern pest. It is better to grow fruit that's fruit-fly resistant during the fruit-fly season (late spring to early autumn) than to battle them. "There are more fruits that don't get fruit fly than those that do," says Arno. Jackfruit, grumichama, mangosteens, bananas, cherry tomatoes, paw paw, sapote, avocado, pineapples, jaboticaba, pomegranate, passionfruit, lychee, grapes, custard apple, citrus and blueberries generally have thicker skins which resist fruit flies. "In midsummer, I would be growing beans—snake beans and string beans—along with African cabbages, eggplants, chillies, zucchini and cherry tomatoes. Larger tomatoes are better in spring and autumn, outside fruit fly season. It's just planting things at the right time of year."

Arno adds that some of the most productive places in the world are in the tropics and subtropics for growing vegetables. The key is to grow different foods with the season. "Summer, it's Asian, African and South American. Autumn and spring, often Mediterranean and winter—your northern European vegies," Arno suggests.

Landscaping for a comfortable microclimate

In all climate zones in Australia, landscaping can improve microclimate. Thoughtful location of trees, trellises and shrubs can buffer undesirable sun and winds and promote cooler summer breezes. "These can also reduce heat absorption and reflection off structures," says Arno. "Shading areas of paving and even roofs shaded with climbers help with evaporative cooling, which works very well in most of Australia. When it is raining the plants are sucking up moisture

Applying calcium

Calcium is available in several forms—lime, dolomite and gypsum—each suiting different soil mineral and pH levels.

Lime is more alkalising and is good for the typically acid soils of the tropics and subtropics. Apply: 1 handful per square metre twice a year. Beware: lime will oxidise fertiliser if applied at the same time, making it inaccessible to plants. Apply separately.

Gypsum contains sulphur and calcium and can be good where soils are more neutral. Apply: 1 handful per square metre twice a year.

Dolomite lime is useful only in soils lacking in magnesium but in almost every one of Arno's soil tests for the east coast, he has found an abundance of magnesium. Apply: 1 part dolomite lime to 2.5 parts lime.

Arno's garden

Arno King's 10-acre (four-hectare) property faces north-west on a ridge on the outskirts of Brisbane. Soils vary from deep-red brown clays to sandy loam over rock and deep silt along the creek. Rainfall of 1.3 m is heaviest in summer and autumn but the property tends to miss the light coastal showers in winter and spring. Arno has created swales, dams and soakage areas to encourage greater infiltration and has increased rainwater storage from 23,000 L to 125,000 L. Soils have been improved by mulching and incorporating organic matter, humates, zeolite and diatomaceous earth, adding lime to bring pH from 4.5/5 to 6.5 and using biological fertilisers.

Arno tends 600 m² of vegetable gardens and a lush fernery of 300 m² that coolly shades his home from hot western sun and storms. His wide range of fruiting trees, vegetables, herbs and spices are focused on summer and autumn crops to maximise production during wetter months. "Many plants are Asian, African and South American and thrive in warm, wet, humid conditions. As I often run out of water during the cooler months I also focus on drought-tolerant vegetables—chaya, Surinam spinach, mustards, Ethiopian cabbages and tuberous crops."

Image: Arno King

↑ Terracing can be important on a sloping site, particularly in the tropics and subtropics with heavy rainfall. Here, Arno King has terraced and planted herbs on the slope and vegies on the flat. Arno says, "The slope drains well and it gets full sun, so sometimes you can even grow Mediterranean herbs (though not reliably!)"

Fertilisers in the tropics

"Nutrients need to be in exact proportions to one another for your soil type, so the idea that you can buy an ideal balanced fertiliser is untrue. Ideally do the soil tests, then get fertilisers made up to suit your soil type," says Arno. Fine and soluble fertilisers were developed for agricultural vegetables in cold climates, not for warm areas with heavy rain. "I prefer to use ground rock minerals because they aren't highly soluble and don't wash away and pollute nearby waterways with the first heavy rain. They last in your soil 20 to 30 years, 40+ years for many of them. And save so much money! They rely on the soil microbes to break them down and supply them to the plant."`

Useful tips from Arno and David

- Look at the site overall and identify where stormwater flows and how best to capture it.
- Do a pH test, soil texture test and ideally laboratory soil test to determine deficiencies in the soil.
- Open up the soils and add minerals and organic matter in proportions appropriate to your soil's needs.
- Tree mulch holds better than lighter mulches in heavy rain.
- In some particularly wet areas with heavy soils, mounding trees and garden beds can reduce risk of root rot but do increase surface area for evaporation.
- Choose climate-appropriate fruit trees which like wet summers, dry winters and resist fruit fly.
- Growth is verdant in the tropics, so avoid over-planting to reduce future pruning and thinning.
- Select and locate large trees carefully in cyclonic areas.
- Plant different vegetables and herbs according to the seasons to minimise pests, diseases and failure.
- If plants are diseased or eaten by pests, check soil health and if the plant is growing in the wrong season.

from the ground which is transpired, cooling the surrounding area very effectively".

Use of deciduous trees is beneficial in the tropics and subtropics but finding ones which lose or gain their leaves at the right time is less straightforward. "Most of the trees in the subtropics are semi-deciduous and drop their leaves according to moisture in the ground, which is less reliable with increasingly variable rain patterns. Whereas in temperate zones, more reliably, it's more about daylight". The few trees that are daylight-deciduous that will grow in the subtropics are: liquidamber (Liquidamber styraciflua), Indian crepe myrtle (Lagerstroemia indica), Chinese tallow (Sapium sebiferum), persimmon (Diospyros kaki) and swamp cypress (Taxodium distichum). Frangipanis are also an option and are quintessentially tropical.

Arno suggests, as another sunshading option, bushes which respond well to pruning for controlled seasonal shade and sun including Hibiscus mutabilis. For hedging, try Hibiscus 'Psyche', lemon myrtle (Backhousia citriodora), Acalypha capillipes, waterfall plant (Phyllanthus multiflorus), Fukien tea plant (Carmona retusa), scarlet fuchsia (Graptophyllum excelsum) and lilly pilly.

While summer shading to the north from awnings, overhangs and deciduous trees is beneficial in all warmer climates, north of the tropic of Capricorn, the midsummer sun shines in the south. "A lot of people don't shade on the south side of the house where you will, in the hottest time of the year, get the sun in." Arno deals with it by planting palms and light shady plants on the south side.

Cyclones

From experience of 50 years of living in the cyclonic tropics, David Leech recommends careful placement and selection of larger plants and trees to avoid damage to buildings in extreme weather events, remembering that many bushes and trees grow much larger in

Images: Emma Scragg

↑ Stone terrace and vegie garden in the distance at David Leech's property. Raised beds or fully screened gardens are essential protection against tropical wildlife.

↑ Water capture, natural stone and peaceful landscapes inspired by Japanese garden design are features of David Leech's own garden in the tropics.

the tropics. Some safer species suggested by Arno include frangipanis, most palms and African mahogany (Khaya senegalensis), poinciana (Delonix regia), paperbark (Melaleuca leucadendron) and Indian laburnum (Cassia fistula). Avoid eucalypts, fig trees, bamboo and fishtail palms.

Conclusion

The tropics and subtropics can be ideal regions for productive and lush gardens if soil health, water catchment and appropriate plant selections are made. Arno and David's gardens are successful examples of these.

Emma Scragg is an architect, writer, photographer and cycle adventurer who lives and breathes sustainability. She is enthusiastic about design of places and spaces which respond to their occupants' needs and the climate to minimise environmental impact.

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Arno King: gardendrum.com/author/aking/
Anne Latreille (2013) *Garden Voices—Australian Designers, Their Voices*, Bloomings Books
Annette McFarlane (2010) *Organic Vegetable Gardening*, ABC Books

David Leech and Bonne Terre

David Leech has lived in the wet tropics of Cairns and the Atherton Tablelands since 1963 and over that time has learned to create gardens which are not only beautiful but address cyclones, maintenance and local climate.

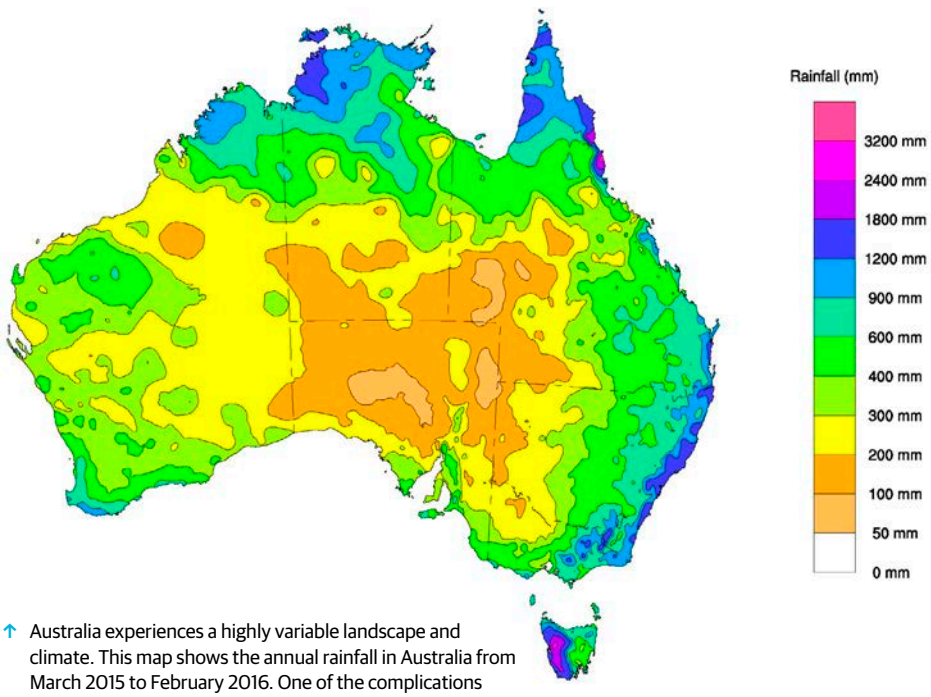
His travels to Japan and working with garden designer Ellis Stones strongly influence his designs. He blends rocks and beautiful stonework, small water features, terracing, ground covers, shrubs and carefully chosen trees to form restful gardens with framed views, pockets of interest and habitat for wildlife. David includes plenty of seats made from simple planks on natural boulders to rest in the tropical heat.

At his own home. Bonne Terre, he has transformed 15 acres of cleared farmland into a picturesque setting for his three stone buildings, blending large food gardens, ornamental house gardens, an orchard, open grassland and 600 m² of revegetated forest which attracts abundant wildlife including local tree kangaroos.

With an altitude of 600 m, the area has a far more moderate climate than neighbouring coastal Cairns, and the rich, fertile volcanic soil absorbs the 1.4 m of annual rain readily with very little runoff. Despite high annual rainfall, they rely on 90,000 L of rainwater storage and access to the adjacent Tinaroo Lake for the dry winters to maintain the household, vegetable gardens and new trees.

The hidden cost of food
The water footprint of what you eat

The relationship between water resources and our dinner is a complex one. Sarah Coles takes a look at the facts.



↑ Australia experiences a highly variable landscape and climate. This map shows the annual rainfall in Australia from March 2015 to February 2016. One of the complications of the water footprint concept is that it assumes that water that would be made available by reducing a high water footprint activity such as dairy farming would be available for use in a less water-intensive activity such as potato farming. In Australia this is often not the case, according to CSIRO researcher Brad Ridoutt, as a lot of livestock are farmed on land that is unsuitable for other purposes.

THE amount of water embedded in the food that we eat depends upon a number of factors including how the food is grown, processed, packaged, stored, transported and cooked. The water footprint concept shines a light on the total amount of water required to produce the food that we eat. The concept can help us to navigate the relationship between our consumption and increasing water scarcity, but it does have some limitations.

The water footprint concept originated with Arjen Hoekstra, Professor in Water Management at the University of Twente, the Netherlands. Hoekstra defines the water footprint of a product as the total volume of freshwater that is used to produce it. A water footprint comprises direct and indirect water use.

The direct water footprint refers to the freshwater consumption and pollution that is associated with the water used by the consumer. Indirect water includes three components: blue water, green water and grey water. The blue water footprint refers to the volume of surface water and groundwater, for example lakes and aquifers, evaporated as a result of production. The green water footprint refers to the volume of rainwater consumed. Grey water refers to a hypothetical volume of freshwater which would be needed to assimilate a load of pollutants.

In *The End of Plenty: the Race to Feed a Crowded Planet*, Bourne writes, "[Of] all the freshwater available for human use around the world, agriculture sucks down nearly 70%." According to WWF, "Australia has the 12th largest water footprint in the world. India has the first, followed by the United States and China." For the world's driest continent, currently in the grip of an El Nino drought, high water usage is of concern.

A 2001 Australian Bureau of Statistics report into embodied water intensities by Lenzen and Foran estimated the amount of water needed in litres to produce $1 worth of goods and services. They found that $1 worth of fruit and vegetables required 103 litres of water, $1 of beef required 381 litres and $1 of dairy products used 680 litres of water. David Holmgren, co-founder of permaculture (see article on p. 58) has studied the 2001 report and estimated that Melliodora, their permaculture property, used 20 litres of water for every $1 of fruit and vegetables produced and only two litres of water for every $1 of goat's milk produced.

The food that we eat accounts for about 50% of our total daily water footprint. Food requires a lot of water to grow, process, package, store, transport and prepare. A lot of this is 'virtual' or embodied water. It is hard to figure out how much water we are consuming when we sit down to eat a cheese and tomato sandwich; particularly because of the amount of virtual water consumed. According to a UNESCO report 'The Green, Blue and Grey Water Footprint of Crops and Derived Crop Products', when considered per ton of product, commodities with relatively large water footprints are: coffee, tea, cocoa, tobacco, spices, nuts, rubber and fibres.

The Water Footprint Network (WFN), based in the Netherlands, has come up with embedded water figures for a number of foods and drinks. According to the WFN it requires, on average: 3400 litres to produce one kilogram of rice ready to eat, 5000 litres for one kilogram of cheese, 120 litres for one glass of wine, 140 litres for one cup of coffee

"if you cannot measure it, you cannot improve it."—Lord Kelvin

and 30 litres for one cup of tea.

The WFN data states that it requires 15,000 litres of water to produce one kilogram of beef on average worldwide. A number of questions sprung to mind when I saw this number: What methodology did they use to calculate this figure? Is this data based on factory-farmed beef? How closely does northern hemisphere beef production mirror Australia's? Does the water footprint take into account the environmental condition of the soil where the cows are raised?

CSIRO researcher Brad Ridoutt has expressed concerns with the methodology the WFN used. In a 2016 article, 'An Update on Water Footprints', Ridoutt writes, "There have also been some rather outrageous statements made about the water footprint of livestock products, including claims suggesting the water footprint of any animal product is larger than the water footprint of crop products with equivalent nutritional value (Mekonnen and Hoekstra. 2012. Ecosystems 15:401-415). These claims are based on virtual water studies which, although bearing the name water footprint, are not compliant with ISO 14046." ISO 14046 is the only international standard for water footprints.

Small-scale organic agriculture has a lighter water footprint than industrial agriculture. There are many different ways to raise a cow and some of them, such as grass-fed organic, use far less water than others, such as concentrated animal feeding operations (CAFOs) which are common in countries where farmland is scarce. CAFOs confine the cows for more than 45 days in an area that doesn't produce grass. The cows are grainfed, a feed source that has a much higher water footprint than grass. Hoekstra and Chapagain acknowledge this complexity in a 2007 report: "There is a difference for instance between beef produced in extensively grazed grasslands of Botswana (use of [rainfall] water without alternative use) and beef produced in an industrial livestock farm in the Netherlands (partially fed with imported irrigated feed crops)."

Australian farming is markedly different to that overseas. Australia experiences a highly variable landscape and climate; there is far more land available in Australia compared to Europe, so cows and sheep are free to graze on grass. In 2008 the Victorian Department of Primary Industries published a report into virtual water that "examines the methodology for estimating virtual water and identifies several important flaws ." The report says, "Water that is available to rangeland agriculture would not generally be available to be used to support other production systems since there is no infrastructure to capture and transport this water."

The water content of the soil fares much better in organic systems. In *The End of Plenty* Bourne writes, "The fields are not irrigated, and during drought years, corn yields in the organic plots were 31% higher than yields of conventional corn. Not surprisingly, water volumes contained in the organic soils were 15% to 20% higher than those in conventional plots." Conventional agricultural systems often have a negative impact on water resources; agricultural runoff can pollute groundwater, streams, lakes and oceans. According to Tristram Stuart, author of *Waste: Uncovering the Global Food Scandal*, "The irrigation water used globally to grow food that is wasted would be enough for the domestic needs (at 200 litres per person per day) of 9 billion people—the number expected on the planet by 2050."

Taken with a grain of salt, the WFN's figures are a useful way to build awareness of embedded water, but they may be open to question. Peter Gleick, author of *The World's Water*, writes: "While the concept of the water footprint is an extremely valuable one, the process for computing footprints continues to evolve, and data sets continue to improve." A group called WULCA, founded in 2007, is an international working group modelling water footprints using life cycle assessments (LCA) to the ISO 14046 standard. Anne-Marie Boulay, a WULCA researcher, quotes Irish physicist Lord Kelvin, "If you cannot measure it, you cannot improve it." Here at *ReNew*, we look forward to improved methodologies. ✱

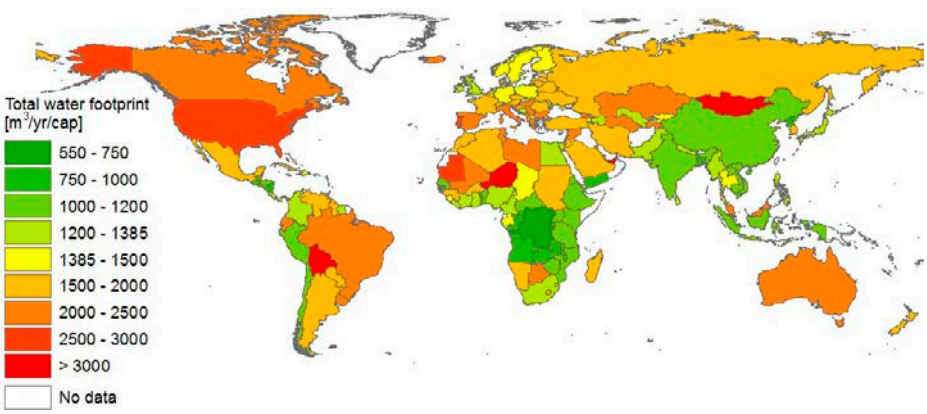


Image courtesy of waterfootprint.org

↑ The total water footprint consumption per country in the period 1996–2005 (cubic metre per year per capita). Countries shown in green have a water footprint smaller than the global average; countries in yellow and red (Australia included) have a water footprint larger than the global average.

Further info

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The End of Plenty: The Race to Feed a Crowded Planet (2015) by Joel K Bourne

The Green, Blue and Grey Water Footprint of Crops and Derived Crop Products (2010) by Mekonnen and Hoekstra, www.bit.ly/21LMdvZ

2014 ISO 14046, www.bit.ly/1oTPlaF

ABC report into water footprints in food manufacturing at www.ab.co/1Qv6dPE

Water Footprint Calculator www.bit.ly/1Tu5fG5

Introduction to Water Footprint video on WULCA website www.bit.ly/1RsABqe

An Update on Water Footprints (2016) by CSIRO researcher Brad Ridoutt, www.bit.ly/1L6Wi2z

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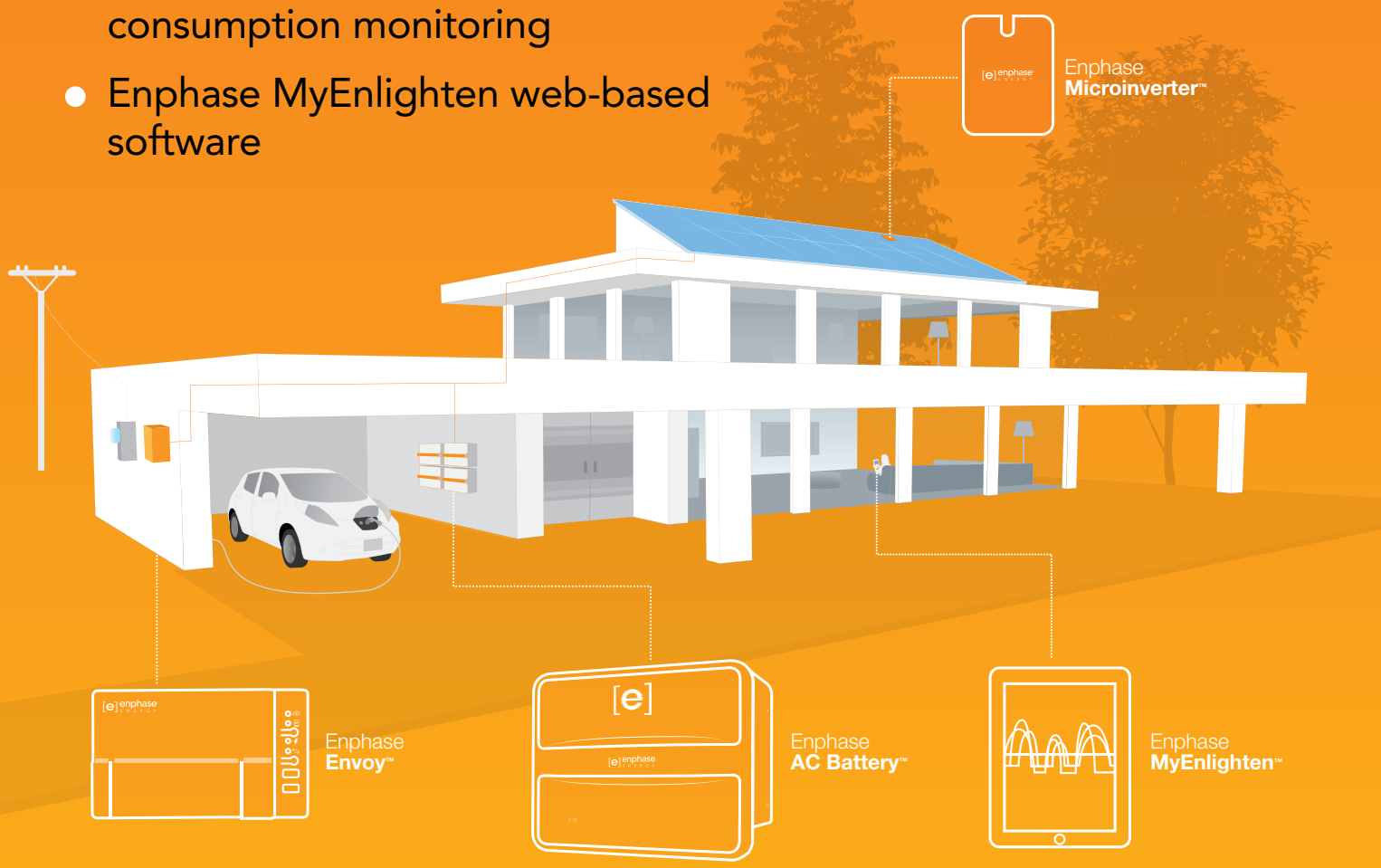

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Stay warm this winter
A heating buyers guide

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

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

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

Image: maramicado via iStock

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

Hydronic heating

THE BASICS

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

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

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

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

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

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

The next disadvantage is complexity. Hydronic systems can end up using a maze of pipes and valves, so you need a space for all this equipment. This is usually housed

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

in a cupboard or the laundry, out of view most of the time, so the thought of complex piping really shouldn't be a deterrent. Further, 'partage' boxes, such as those from Immergas, are designed to take most of the control pipework from a multi-zoned system and place it all inside a neat box, hiding it from view, giving a much cleaner installation.

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

RADIATORS

Aside from the afore-mentioned in-slab systems, there's a vast array of radiators available, from the traditional standing radiators through to towel rails, bench seats, skirting boards (such as ThermaSkirt), mirror surrounds, in-floor trench convectors (radiators embedded in steel boxes fitted into the floor, covered by a grille, used where above-floor radiators are not suitable), ceiling radiators, and even decorative wall art. Which you choose will depend on your needs, but there's certainly no shortage of variety.

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

WHICH FUEL?

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

But even if you have mains gas, is it the best option? The price of gas is more closely linked to the international pricing system now, so prices have been increasing. Further, as more gas comes from coal seam deposits and by fracking, gas is becoming a dirtier fuel. For more information on getting off gas, see 'Are We Still Cooking with Gas?' in *ReNew 130* and the associated report, available at www.bit.ly/1R6eLZx.

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

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

Heat pumps use a refrigerative system to extract heat from the outside air and concentrate it into the water tank. Even air that feels cold to us contains a lot of usable heat, although the colder the ambient air, the lower the overall heat pump efficiency. Systems that

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

take heat from the air are called air-source heat pumps; there are also ground-source heat pumps that extract heat from the ground, but these are generally more expensive. See the 'Heat pump basics' box and the 'Efficiency of heat pumps' section for more on how heat pumps work and the efficiencies available.

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

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

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

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

Although there are some disadvantages to such a system, such as increased standing losses from having multiple smaller tanks, the advantages include the ability to use CO_2 refrigerant systems (see box on refrigerants) as well as having a degree of redundancy built in—if one of several heat pump units fails, you still have the rest to keep you warm—you are not stuck without heating until a repair can be effected, as you are with a single large boiler. However, multiple smaller heat pumps will cost more for the same heating capacity as a single large system. Note that several DHW heat pump manufacturers specifically state that they don't recommend their systems for hydronic heating use—although none actually gives a reason that we could find!

RETROFITTING AND DIY HYDRONICS

If you already have a gas hydronic system in place but running costs are too high due to it being an older, inefficient system (or maybe the system is nearing the end of its lifespan), then you should be able to have your system's boiler replaced with a heat pump or other fuel system. Just select a boiler with a heat output similar to what you currently have in the desired fuel type. In most cases, the best option will be to move to a heat pump system.

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

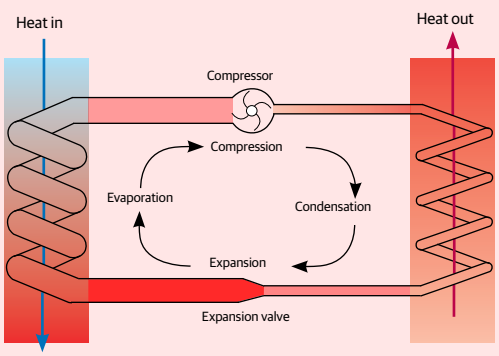
However, note that it is illegal to install any mains-pressure plumbing system yourself unless you have the appropriate qualifications. Should a DIY system leak and damage your home, your insurance company may also have grounds to reject a damages claim. Licensed installers should be employed to install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

Heat pump basics

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

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

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



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

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

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

"Some heat pumps can have their COPs reduced to low levels (less than 2 in some cases) as the ambient temperature approaches 0 °C. If you live in an area that sees close to zero winter temperatures, make sure you check the efficiency curve."

Reverse-cycle air conditioners

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

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

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

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

EFFICIENCY OF HEAT PUMPS: COP AND EER

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

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

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

SPLIT SYSTEMS AND INVERTERS

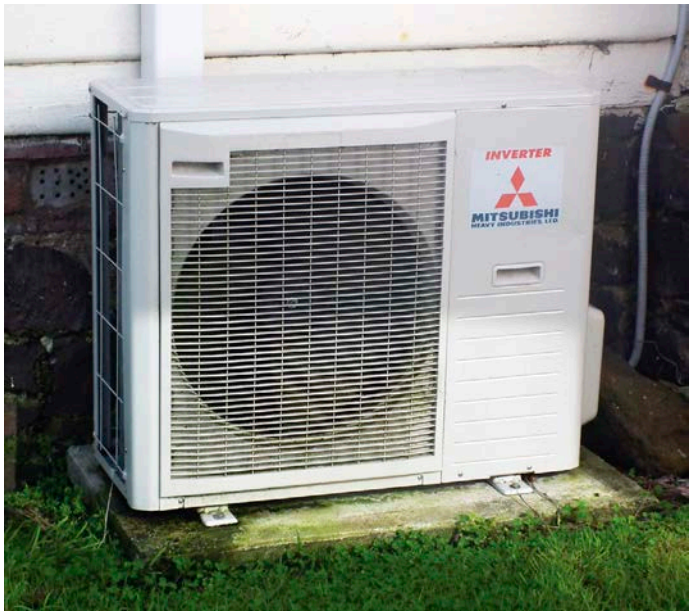
All of the reverse-cycle systems in our guide tables are split systems, where the indoor unit and outdoor unit are separated and linked by flexible or rigid high-pressure hoses or pipes.

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

Air handling units are usually 'wall hung' but there are other types, including floor-mounted and 'cassette' types, which are mounted in the ceiling.

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

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



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

Refrigerants

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

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

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

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

Domestic hot water heat pump systems, sometimes used in hydronic systems as mentioned earlier, have progressed towards more environmentally sound refrigerants such as CO_2 (R744).

REVERSE-CYCLE SYSTEM FEATURES

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

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

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

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

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

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

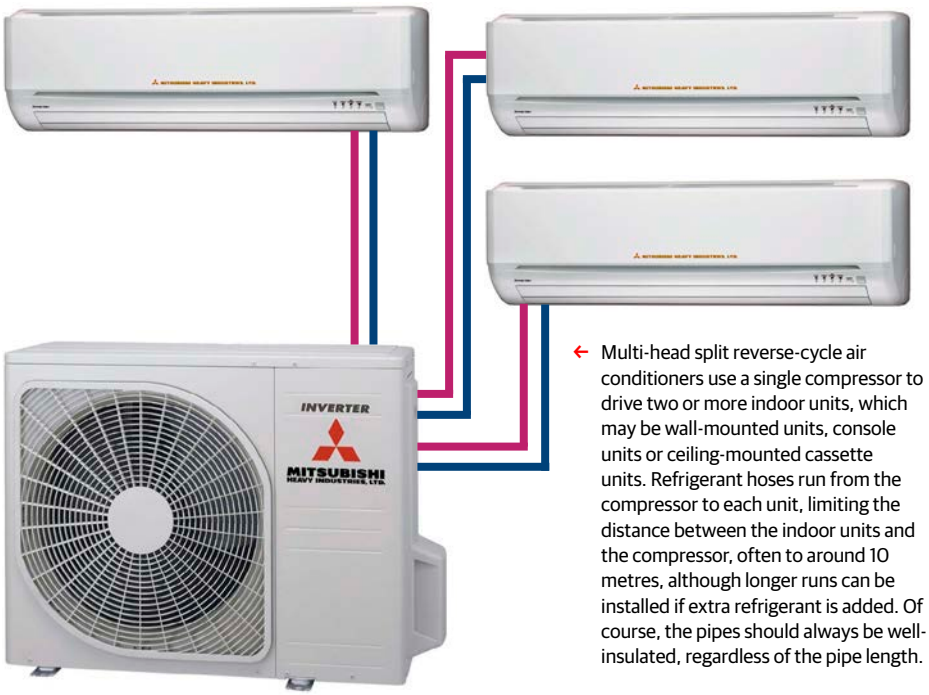
IMPROVING AIR CONDITIONER EFFICIENCY

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

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

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

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



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

MULTI-HEAD OR MULTIPLE UNITS?

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

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

The downside to multiple small air conditioners is that you increase the required wiring, as each unit needs to be wired in. Also, you will have one outdoor unit for each air conditioner, which takes up more space and may be harder to hide visually. Many units use power for their crankcase heaters (low power heating elements used to prevent refrigerant mixing with crankcase oil when the unit is off, and to prevent condensation of refrigerant in the crankcase of a compressor), at least in the cooler months, thus increasing standby load considerably. The standby load may or may not be listed in brochures and datasheets, so if it is not listed for your preferred model, contact the manufacturer or the installer/salesperson, but the latter may not know about this issue.

AIR CONDITIONER COMPROMISES

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

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

Are hydronic or reverse-cycle systems cheaper?

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

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

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

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

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

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

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

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

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

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

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

Sizing a system

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

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

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

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

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

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

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

What about ducted air conditioning?

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

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

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

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

to run over time as efficiency degrades.

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

Reduce leaks too!

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

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

About the tables

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

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

More info:
'Winter comfort: not just a heater choice' in *ReNew 127*.
'A tale of two heaters: gas vs electric' in *ReNew 133*.
Are we still cooking with gas?', ATA report at www.bit.ly/CAP_GAS and in *ReNew 130*.

Table 1. Hydronic suppliers summary. (NG = natural gas)

Supplier	Brand	Type	Fuel	Heating capacity	Maximum fuel consumption	Heat pump COP/ efficiency (%)
Australian Hydronic Supplies	Radiant	Gas instantaneous condensing and non-condensing	NG/LPG	9 to 100 kW	78 to 394 MJ/h	up to 98.3%
	Laing	Resistive electric	Electricity	6, 9, 12, 15 kW	6, 9, 12, 15 kW	COP 1
	Ambient	Variable speed air-source heat pump	Electricity	9 to 23 kW		COP 1 to 4.5
Automatic Heating	Meridian	Gas condensing hydronic boiler	NG/LPG	24 to 150 kW	92 to 592 MJ/h	97%
	Firex	Biomass hydronic boiler	Wood	28.2 to 45.2 kW		82%
Bosch Climate	Bosch	Instantaneous gas boiler	NG/LPG	18 to 37 kW	75 to 133 MJ/h	88.5 to 91%
Comfort Heat Australia	Intaflo	Reverse-cycle air-source heat pump boiler	Electricity	12 to 35 kW		COP 2.42 to 3.2
Daikin	Altherma	Air-source heat pump (reverse-cycle option)	Electricity	11 to 16 kW	2.55 to 3.92 kW	COP 4.08 to 4.39
Geoexchange Australia	WaterFurnace	Reverse-cycle ground-source heat pump	Electricity	6 to 150 kW		COP 3.1 to 4.3
	NIBE	Air-source heat pump	Electricity	7 to 20 kW		COP 3.66 to 4.05
Hunt Heating	Immergas	Gas instantaneous condensing and non-condensing	NG/LPG	12 to 36 kW	49 to 147 MJ/h	87 to 98.6%
	MCZ, Red	Solid fuel boilers	Wood, pellets etc	16.8 to 32 kW		90.2 to 93.7%
Hurlcon Heating	Beretta, Lamborghini	Gas pre-mix condensing external/internal	NG/LPG	30 kW upwards	140 MJ/h upwards	98 to 98.7%
Hydro Heat	Baxi	Gas adaptive condensing, DHW option	NG/LPG	12 to 40 kW	50 to 165 MJ/h	91.2 to 97.1%
Pivot Stove & Heating	Esse	Wood boiler	Wood	4 to 16.9 kW	1.8 to 4.5 kg/h	72 to 81%
Run On Sun	Hydronic-1000	1000-litre HW cylinder with evacuated tubes/stove	Solar/stove	4 to 25 kW	Varies	
Siddons Solarstream	Siddons Solarstream	Air-source heat pump	Electricity	6 to 17.3 kW	1.7 to 7.5 kW	COP 3.3
Skyline Energy	Skyline Energy	Air-source heat pump	Electricity	5 to 28 kW	1.4 to 9 kW	COP 3 average
Solar Lord	Solar Lord	Solar pre-heat with gas instantaneous	Gas	30 kW	135 MJ/h	
Superior Boilers	ÇETİK ISI SANAYI	Wood, wood pellet	Wood, wood pellet	23 to 104 kW		88 to 94%
Tubulous Australia	Tubulous	Wood boilers	Wood	4 to 88 kW		
Tivok Energy	Tivok Energy	Air-source heat pump	Electricity	7.25 to 17.5 kW	1.8 to 4.7 kW	COP 4.03 to 4.2
Wise Living Products	Thermalux	Wood boilers	Wood	15 to 50 kW		

Table 2. Reverse-cycle air conditioner suppliers summary.

Brand	Type	Inverter	Phase	Cooling input power	Cooling capacity	EER	Heating input power	Heating capacity	COP	Refrigerant
Bd-Bingdian	Single split system	Yes	Single	0.57 kW	2.5 kW	4.39	0.7 kW	2.8 kW	4.00	R410a
Daikin	Single split & multi split systems	Yes	Single & three phase	0.41 to 3.87 kW	2 to 16 kW	3.89 to 5.95	0.59 to 4.22 kW	2.7 to 18 kW	4.00 to 5.81	R32 and R410a
Fujitsu	Single split system	Yes	Single	0.51 to 0.6 kW	2.5 to 2.6 kW	4.31 to 4.9	0.65 to 0.81 kW	3.2 to 3.5 kW	4.32 to 4.92	R32 and R410a
Haier	Single split system	Yes	Single	0.62 kW	2.7 kW	4.35	0.8 kW	3.5 kW	4.38	R410a
Hitachi	Single split system	Yes	Single	0.55 kW	2.5 kW	4.55	0.68 kW	3.2 kW	4.71	R410a
Kelvinator	Single split system	Yes	Single	0.59 kW	2.5 kW	4.24	0.75 kW	3.2 kW	4.27	R410a
LG	Single split & multi split systems	Yes	Single	0.52 to 3.86 kW	2.5 to 15.5 kW	4.02 to 4.81	0.65 to 4.16 kW	3.2 to 17.4 kW	3.96 to 4.92	R410a
Mammoth	Self-contained	No	Single	0.66 kW	3 kW	4.58	0.71 kW	4 kW	5.61	R410a
Midea	Single split system	Yes	Single	0.52 to 0.6 kW	2.55 to 2.6 kW	4.25 to 5.00	0.57 to 0.62 kW	2.65 to 2.8 kW	4.27 to 4.91	R32 and R410a
Mitsubishi Electric	Single split & multi split systems	Yes	Single & three phase	0.49 to 5.19 kW	2.5 to 22.4 kW	3.85 to 5.10	0.58 to 5.73 kW	3.2 to 25 kW	4.13 to 5.52	R32 and R410a
Mitsubishi Heavy Industries	Single split & multi split systems	Yes	Single	0.35 to 1.08 kW	2 to 5 kW	4.31 to 5.71	0.45 to 1.31 kW	2.5 to 6 kW	4.35 to 5.56	R410a
Panasonic	Single split & multi split systems	Yes	Single & three phase	0.41 to 4.77 kW	2.05 to 22.4 kW	4.31 to 5.00	0.55 to 4.87 kW	2.7 to 25 kW	4.32 to 5.16	R32 and R410a
Samsung Electronics	Single split system	Yes	Single	0.48 to 0.6 kW	2.5 kW	4.46 to 5.21	0.62 to 0.7 kW	3.2 kW	4.57 to 5.2 kW	R410a
Stirling	Single split system	Yes	Single	0.8 kW	3.4 kW	4.25	0.87 kW	3.8 kW	4.37	R410a
Toshiba	Single split system	Yes	Single	0.49 to 2.21 kW	2.5 to 10 kW	4.52 to 5.12	0.58 to 2.34 kW	3.2 to 11.2 kW	4.79 to 5.52	R410a
York	Single & multi split systems, and self-contained systems	Yes, No	Single & three phase	0.62 to 5.53 kW	2.7 to 22.8 kW	4.07 to 4.35	0.78 to 6.03 kW	3.5 to 26 kW	3.87 to 4.49	R410a

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.

5W LED dimmable Edison screw

Price: ~~$12.70~~ now $10!

A replacement for a standard Edison screw bulb, these economical natural white LED units draw only 5 W yet produce 450 lumens of light—equivalent to the total light output of a 40 W incandescent.

LED strip light

Price: $24

A stylish aluminium LED strip light kit with diffuser. Suitable for caravan, marine, 4WD, auto and domestic applications, the strip light is 34 cm long and stackable, and runs from any 12 VDC power supply with over 0.5 A output.

Power-Mate Lite

Price: ~~$125~~ now just $100!

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).

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.

Sanctuary: modern green homes issue 34

Price: $11.95

Sanctuary 34 features green homes for less, tiny project homes, saving seed, Passivhaus in Australia and New Zealand, building with earth, green financing and much more!

Shipping: booklets and magazines - postage $3.50 anywhere in Australia, all other items (books and electronics) $10.

DIFFICULTY RATING: ★★★☆☆

Double glazing on a budget
Saving money one window at a time

Double glazing can be very expensive, but with a bit of care and patience you can add double glazing to existing windows without breaking the bank. Alan Cotterill shows us how.

BUILT in 2002, my four-bedroom brick veneer house has stock standard powder-coated aluminium windows and doors. With my previous efforts to retrofit for energy savings and thermal comfort (see 'Efficiency on a budget' in *ReNew 130*), I had already fitted effective shading for my windows in the warmer weather. As I understand it, this is a prerequisite if double glazing is not going to be counterproductive in summer. But for winter, double-glazed windows insulate and thus hold in the heat much better than a single-glazed pane. Thus, I embarked on a project to retrofit my windows with a second (acrylic) pane.

↑ Here you can see one of the acrylic sheets attached to a fixed window, before the protective paper is removed.

Materials

For the additional panes, I used 3 mm cast acrylic sheet accurately cut to size commercially by The Plastics Factory. They cut 34 panels within a tolerance of 1 mm to my requested dimensions. Accurate measuring by myself was of paramount importance for this! Buying direct from a wholesaler meant a good saving; in fact, the cost was around half that of uncut sheets from local retail outlets.

I adhered the acrylic sheet to the aluminium surrounds of each panel of glass using highly flexible silicone sealant. The reasons for this choice were two-fold.

Firstly, the linear expansion rate from a change in temperature is significantly different between the acrylic sheet and the aluminium frame, with the acrylic expanding at three times the rate of the aluminium. With a 1200 mm edge and a temperature change from 0 to 40 °C, the acrylic would expand nearly 4 mm more than the aluminium frame. Flexibility of the sealant would cater for this to some extent.

Secondly, if a glass panel needs replacing down the track or a return to single glazing is desired, the silicone sealant could be scraped off (although still a tedious, fiddly job!)

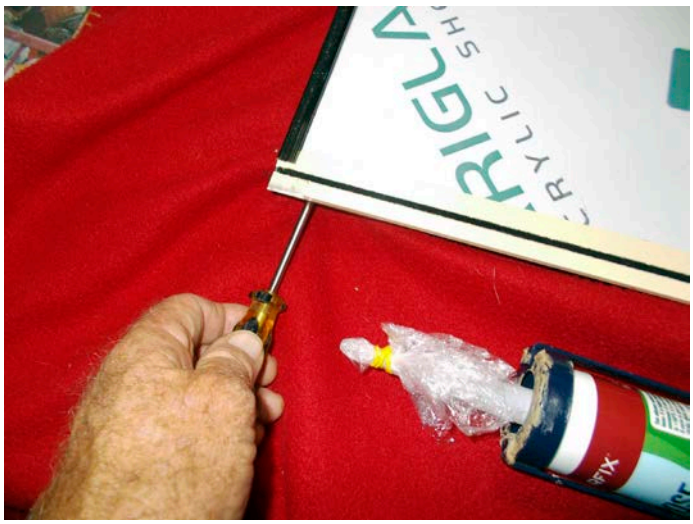
Selection of sealant/adhesive

I tested several sealant products in my workshop. I already had decided to use highly flexible silicone sealant to cope with differing expansion rates between aluminium and acrylic. All the silicone sealants at local outlets advised that bonding may be poor with many plastics. Initial testing with both flexible and highly flexible silicone sealants suggested that bonding to sheet acrylic was poor regardless of brand or label descriptions—silicone sealant is always silicone sealant. I found that most silicone sealants adhered firmly to the powder-coated aluminium. However, the bond to the acrylic sheet was poor using any of the available brands.

I trialled the highly flexible sealant on a number of windows with mixed and usually short-lived success. Some acrylic is still bonded after twelve months, but other panels separated along some edges and needed to be redone. Sizing without allowing any tolerance for the acrylic expanding more than the aluminium was often to blame.

Even though I shaded the double glazing

↑ The acrylic panels were glued over the rubber surrounds of the sliding windows, giving an air gap without spacers.



↑ Two screws on each corner were adjusted to give tolerance for fit and expansion.

in the hotter months, some acrylic sheets popped off on the western wall due to air expansion within the sealed cavity. Later, I decided to drill a 1.5 mm hole in a top corner of each of the acrylic panels to prevent any bulging of the panels.

A more successful solution

After the issues highlighted in these trials, I found a recently available and cheap co-polymer sealant which adhered very strongly to the acrylic sheet. Indeed, it adhered too strongly to risk anywhere near the aluminium window frames. The solution was to run a thin film of the co-polymer sealant around the edge of each acrylic sheet. This gave an etched effect to the edge of the sheeting and, when dry, bonded very strongly with the flexible silicone sealant, which now firmly adhered the etched acrylic edging to the aluminium frame.

Placement of acrylic sheets

I assessed each window and its aluminium frame to determine a suitable perimeter to adhere the acrylic sheet to and to ensure a functional spacing or gap between the glass and acrylic. This led me to fix the majority of my acrylic panels external to the existing glass. Just 10 (out of the total of 34 panes) needed to have the acrylic internal to the glass to be able to ensure a suitable air gap. These were the fixed panels below the sliding windows across the front of the house.

I decided not to double glaze the two large sliding doors in the open plan living area, but to have the glass in these managed with professionally applied low-e film.

When I lifted out my sliding window panels, I found that the rubber packing external to the glass acted as an already-present spacer. After allowing for the thickness of the sealant used, this gave me an air gap of 7 to 8 mm for these windows. I did not need to use any introduced spacers on any of the other windows either. The aluminium channel walls acted as spacers on all the fixed windows, giving air gaps of 12 mm to 16 mm—a better size.

The aluminium frames of each sliding panel have two securing screws on each corner. By removing one and loosening the other (nearest the corner), the frame could be squared or enlarged slightly to neatly fit each acrylic sheet (see photo above). With the edges of the acrylic sheet previously etched with the co-polymer sealant, a bead of highly flexible silicone sealant along the top of the rubber surround and a loose tightening of both the screws on each corner, the result was a firm fit and no problems sliding on the track.

Final appearance and cost

Visitors to our home have remarked: "I thought you said you double glazed your windows?" I have to open a slider and have them feel the thickness of the double glazing for them to believe me! The only giveaway is the odd dribble of silicone sealant,

A bead of sealant showed on the sliding panels before they were fitted, but the flyscreen surrounds totally hide this from view. The fixed panels of acrylic sheeting adhere to the aluminium surrounds with no sealant visible when looking out the window.

The total cost to double glaze my four bedroom home (excluding my two sliding doors) was $1441, including:

- 34 acrylic panels, precut and delivered ($1351)
- 6 tubes of Parfix highly flexible silicone sealant @ $8 each ($58)
- 4 tubes of Parfix Maxi-clear co-polymer sealant @ $8 each ($32).

Effectiveness and appearance

I installed the acrylic panes over a period from November 2014 through August 2015, starting with initial trials of eight panes. It took longer than expected due to the work required to re-attach the acrylic sheets using the co-polymer sealant etching technique. As a result, I don't have energy use data from a full winter of double glazing. Even after winter 2016 it will be difficult to determine specific savings on winter heating due to other recent energy efficiency improvements. In summer, our evaporative cooling system requires windows to be partly open, so there are less likely to be savings there.

One immediate and obvious benefit has been an improvement in soundproofing, particularly noticeable with a neighbour's dog barking for long periods at night.

In terms of appearance, I have not detected any detriment to visual quality in the panels installed 12 months ago. Some of my early efforts show excess sealant on the edges of some panels. The overall neatness of my work hasn't been helped by having to go

↑ The acrylic sheets applied to the fixed windows were supported while the sealant cured.

Warnings and comments on choice of cast acrylic sheeting

While acrylic sheet is less scratch-resistant than glass, it is much lighter, more impact resistant and much safer to work with than glass sheets. We recommend anyone doing DIY double-glazing to use cast acrylic or another polymer glazing material, such as polycarbonate sheeting, rather than glass.

Cast acrylic sheeting is reported to go cloudy if certain strong cleaning agents are used. A gentle clean using a soft cloth and warm water with a few squirts of washing up concentrate will safely do the job.

back and do the job twice! An important consideration for a homeowner, who may not be as pioneering as myself, is to weigh up whether a future buyer might think that this low-cost approach to double glazing reduces the value of the home. Ordering a few panels and trialling, say, in one room, would be a good way to start. ✷

Alan Cotterill is a retired GP who made a 'tree change' to Wagga Wagga 42 years ago.

Small-scale solar heating
A DIY mini hydronic system

Hydronic systems don't have to heat a whole house. Martin Chape describes his mini DIY system that just heats one room using solar heat.

↑ The solar thermal collector (at rear) that provides the heat for the mini hydronic system.

FOR quite a few years I have dreamed of using the sun to heat my bedroom via a solar thermal hydronic system. Eventually, in spring 2014, I decided to bite the bullet and stop procrastinating. I'd been put off by problems with installing hydronic pipes in the concrete floor; that would have meant either increasing the floor's height by an additional 50 mm, or buying slotted timber flooring to overlay the concrete and hydronic pipes. Both seemed difficult and impractical.

Bargain hunting

Instead, I watched Gumtree for those heavy cast-iron radiators that are popular in the UK. Lo and behold someone local advertised a houseful. I made an offer of $200 for the lot and they even threw in the gas boiler.

It wasn't long before another bargain turned up: a new 180-litre hot water tank that a builder had dropped, damaging the outside casing. I offered him $100 and he accepted. A little panel beating and body filler and the hot water tank looked like new.

Next I needed a heating element. I sourced a set of 30 evacuated tubes from a South Australian supplier and a stainless steel header tank with float from Queensland. Although two of the tubes were broken upon arrival the supplier had sent me an extra box of 10, so I actually have spares left over.

A tricky solar hot water system install

The tubes were supplied with a frame designed to sit on the ground. However, my mounting situation was complex, with the unit to be mounted across a roof hip and with two slopes.

So I first completely assembled the frame on my back deck to get an idea of how it was set up. Then, using the material supplied for the frame and some extra aluminium RHS (rectangular hollow section) from a metal supplier, I was able to fabricate a frame to hold the tubes at an angle from the horizontal, facing north to suit the winter solstice on my sloping roof.

I mounted the header tank containing a float valve on top of the frame, ready to be connected to the mains water supply by my plumber. An overflow point on the header tank was piped down to drain into the roof gutter.

Cast-iron vs fan coil radiators

It was around this time that I discovered I could obtain fan coil units from China and I decided to use these instead of the secondhand cast-iron radiators. It turned out that the cast-iron units were corroding on the inside; dirty water ran out of them when I transported them. This made me aware that they were likely to have a short remaining life.

The fan coil units contain a brass radiator, not unlike a car radiator, which could be made to last quite some years. They also come with built-in electronics, a thermostat, a timer, a control wire to run the flow pump and a remote control, meaning each one can be remotely and independently controlled. To use the cast-iron radiators, I would have had to build all these electronics myself.

In addition, I would have had to mount the

A bunch of secondhand radiators and a boiler for under $200.

The collector frame being tested before going on the roof.

cast-iron units near the floor, possibly behind furniture or at least taking up usable floor space. The fan coil units come in three types, one of which is a high-mounting wall unit that looks very much like the indoor part of a split system air conditioner. This is the type I chose. (The other two types are a narrow floor-mounted unit and a cassette setup that could be mounted in the ceiling.)

The fan coil units are an excellent way to deliver heat or cold to an existing home that doesn't have hydronic pipes installed in the slab at construction time. They can also deliver hot or chilled water.

I ordered a wall-mounted unit and after shipping paid around AU$250.

Installation and wiring

I mounted the 180-litre hot water tank on a small rainwater tank pedestal in my bedroom courtyard, close to where the fan coil unit would be mounted, thus keeping the feeder pipes short. I plumbed the tank to the evacuated tubes on the roof using 12 mm copper tube, over which I slid a UV-stabilised insulation sleeve before wrapping with foil tape from Reece Plumbing, guaranteed to temperatures of 150 °C. I did the same to connect the tank to the fan coil unit through the bedroom wall.

I did the low-pressure plumbing between tank, collector and fan coil unit myself, but employed a plumber to connect the high-pressure mains to the low-pressure header tank containing a float valve.

I bought a Chinese solar hot water system controller, model SR868C8, on eBay. It came with a control panel with a control wire attached. Also supplied were three thermistors of two different types, one for the roof and two for the top and bottom of the tank. Because I could not use the solar HWS control unit with the 240 volts AC it was designed to switch (it was not approved for Australia, although a 12 V DC version is also available), I replaced its transformer with a 24 to 12 volt DC converter to feed the circuit board, then mounted the board into an electrical utility box. The solar control unit now switches a 24 volt DC pump which circulates water from the tank through the tube array during the day. At night a second 24 volt DC pump, operated by the control wire from the fan coil unit, circulates hot water from the tank to heat the room. The 24 V DC for the system is supplied by my previously installed solar-powered air cooler, as seen in *ReNew 126*.

After my plumber hooked in the inlet tank on the roof to the water mains, I filled the whole system with water.

Evaluation

I used the hydronic system through the winter of 2015. Temperatures of 80 °C were achieved in the tank at the end of each day, and throughout winter it successfully supplied heating to keep my bedroom at a comfortable temperature until after midnight.

Future plans include buying or building an adsorption chiller to use the excess of hot water generated by the system during our hot summers. This would allow chilled water to be pumped through the fan coil unit to cool my bedroom. ✱

Martin is a retired engineer and freelance consultant who tinkers in solar projects and is happy to share his experience with others. His email is martyc@perthpcug.org.au

The indoor fan coil unit looks a lot like a reverse-cycle air conditioner.

Warning

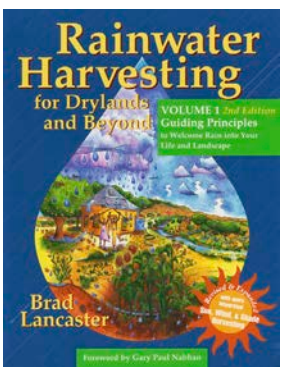
All plumbing work must be carried out by a licensed plumber. Should a self-installed hydronic system fail, causing damage to your home, your insurance company may not honour any insurance claim.

When working with any pressurised system that involves an uncontrolled heat source such as the sun, care must be taken to provide the required pressure/temperature relief valve and control system to prevent the tank boiling. We highly recommend that if you choose to install a system yourself, solar heating systems should use open-vented tanks (unpressurised) for safety, as this system does.

We also recommend that you use extra-low voltage (12 or 24 V) pumps and electrical systems for safety when doing DIY projects, as mains-powered wiring should only be done by an electrician. As with any electrical system, ensure adequate circuit protection in the form of appropriately rated fuses or circuit breakers are used for each circuit.

Water saving books
A thirst for knowledge

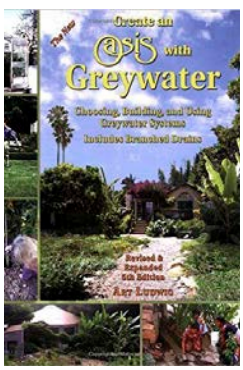
Sarah Coles reviews the field and finds an array of books to slake your thirst for water saving approaches in your home, garden and community.



Rainwater Harvesting for Drylands and Beyond, Volume 1: Guiding Principles to Welcome Rain into Your Life and Landscape

2013 by Brad Lancaster

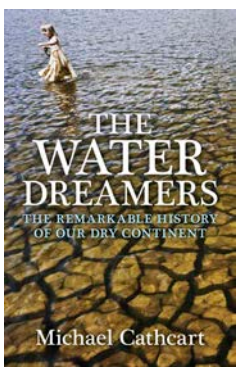
Rainwater harvesting is an integral part of water efficiency. Five million Australians own a rainwater tank but there is much more to be done. This is the first book in a three-volume guide that teaches you how to maximise water-harvesting systems in your home, garden and community. It contains a primer on water/energy/carbon connections and descriptions of water flow patterns. It's richly illustrated throughout. Ask any permaculturist for their top five books about water and chances are high this will be on the list.



Create An Oasis with Greywater: Choosing, Building and Using Greywater Systems

2015 by Art Ludwig

This book is an excellent resource. With chapters on greywater basics it is suitable for people who are new to greywater, but it also contains comprehensive sections on complex greywater systems for the more experienced reader. It includes practical sections on design, plumbing, greywater in the landscape and system selection charts, plus a range of guides: site assessment forms, guides to measuring elevation and slope and guides to pumps and regulations. It also includes sections on household water sustainability, a chapter on common greywater errors and inspiring real world examples. *Create An Oasis* will have you pumped about using water from your washing machine to grow apple trees.



The Water Dreamers: The Remarkable History of Our Dry Continent

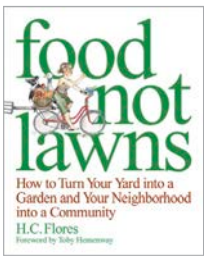
2010 by Michael Cathcart

A history book about how water scarcity has shaped Australia. Cathcart is quick to point out that when Europeans arrived, the first peoples had been here for at least 40,000 years and that they owned every waterhole. He looks at the subsequent battles that ensued over the resource and shows how quickly the First Fleeters polluted the Tank Stream that flowed through Sydney. He examines the once popular idea of an inland sea and the case of Griffith Taylor, who wrote *The Geography of Australia* (1914) which pointed out that Australia's centre was too dry for farming. Taylor's book was banned by the government. *The Water Dreamers* is a fascinating history of colonialists, farmers and explorers as they hunt for water and build irrigation systems and dams. A solid primer on the history of water in the driest continent in the world.

The Water-Wise Home: How to Conserve, Capture, and Reuse Water in Your Home and Landscape

2015 by Laura Allen

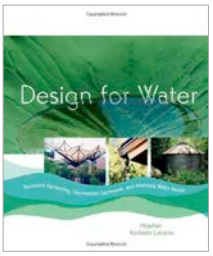
"There are a lot of things wrongs with our water systems. From where we get water to how much we use, and from what we put into it to where it goes." Part 1 of this book outlines the ways the water system is unsustainable and Part 2 explains how you can radically reduce water use in your own home. This book explains how to build low-tech systems that conserve and reuse water in your home and garden, with chapters on greywater, rainwater catchment, rain gardens and waterless composting toilets.



Food Not Lawns

2006 by Heather Jo Flores

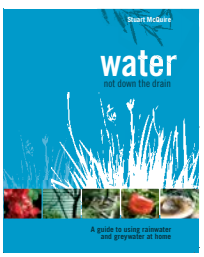
This book advocates tearing up your lawn and planting a productive food garden instead. The author points out that the lawns in the USA consume around 270 billion gallons of water a week and that lawns are unsustainable in terms of water efficiency. In the foreword Toby Hememway describes *Food Not Lawns* as, "a road map for a personal and cultural transformation that begins on our lawns and carries us into our neighbourhoods, communities and society." The book outlines a nine-step plan to build soil, grow food, save water and promote biodiversity where the lawn once grew.



Design for Water: Rainwater Harvesting, Stormwater Catchment, and Alternative Water Reuse

2007 by Heather Kinkade-Levario

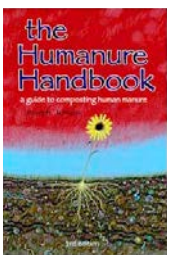
This book contains over 30 case studies of water systems in residences, businesses and public spaces. Each case study includes a photograph of the system, a diagram explaining how it works and specifications. A great book for seeing what others have done.



Water, Not Down the Drain

2008 by Stuart McQuire

Australia is experiencing extreme pressure on its finite water resources. This book, written by a past president of the ATA, is a comprehensive guide to saving this precious resource. It outlines the steps Stuart and his family took "to go from water wasters to sustainable water users." What started with the installation of a shower rose escalated into a brilliant understanding of greywater, composting toilets, mulching, swales and rainwater tanks. It has useful sections such as 'Where do you use water?', 'Check for leaks' and 'How much rainwater is available?', and a comprehensive section on rainwater tanks. If you want one book to get started on saving water, this is it. Stuart advises, "Take things at the pace that suits you. Learn from what others have done." This book is currently out of print, but may be available from your library.



The Humanure Handbook: A Guide to Composting Human Manure

2005 by Joseph C Jenkins

The Humanure Handbook looks at options for human excrement that don't involve flushing fresh water down the drain or polluting the water supply. It goes into detail about how when we flush our waste down the drain we are missing out on all of the possible nutrients we could gain by composting our 'waste' back into the soil. The book delves into the science of thermophilic bacteria and the hot environment in a healthy compost which breaks down pathogens to make fantastic compost. Jenkins describes a two-bin compost system, a sawdust toilet and greywater systems. This book isn't for everybody, but if you are serious about saving water, humanure makes sense.

Creating Rain Gardens: Capturing the Rain for Your Own Water-efficient Garden

2012 by Cleo Woelfle-Erskine and Apryl Uncapher

The interaction between geology, soil, landform, plants, climate, water and humans makes for interesting reading. This book explains how to design, build and plant a rain garden, with sections on swales, French drains and ponds. It includes case studies and instructions for rain barrels, green rooftops, permeable structures and planters. Rain gardens capture stormwater runoff so that it is absorbed back into the soil. As well as being a water-efficient method of gardening, rain gardens are great habitats for wildlife. *Creating Rain Gardens* shows you how to harvest rainwater that would otherwise go down the drain.

The Pears Report
Global energy markets

Following his participation in two international summits recently, Alan Pears reflects on approaches to a transitioning energy market, both internationally and in Australia.

MY opportunities to present at an Asia-Pacific Economic Cooperation (APEC) energy ministers' conference and also an Association of South-East Asian Nations (ASEAN) energy summit late in 2015 gave me some fascinating insights into the energy picture beyond Australia. There was no debate about climate change—the science is accepted, the evidence is clear, and the impacts are real and terrifying. The two forums, however, showcased quite different approaches to addressing the issue.

Among APEC ministers, there was intense discussion about how best to help the rural poor gain access to renewable energy off-grid or on microgrids. APEC energy leaders were, on the whole, quite progressive, and my presentation on the future role of clean energy generated a very positive response.

Energy efficiency was seen as a key priority, as was equitable access to energy and, of course, renewable energy. The Philippines has identified renewable energy resources 13 times larger than present capacity. Several speakers outlined goals to reduce energy intensity (energy use per unit of GDP); for example, China aims to achieve a 45% reduction by 2030 relative to 2005.

The need to attract private capital was also a major theme. Most focus was on large projects, although some emphasised the role of micro-enterprises. Of course, investment in energy efficiency and distributed renewables is a very effective way of using private capital!

Coal was mentioned, but without great enthusiasm. Coal is a problem for most APEC countries—coal imports add to their balance of payment problems, as well as pollution. APEC is supporting efforts to develop clean coal technologies as one of a number of themes, but my impression was that this is more because those supporting this approach are prepared to fund the work.

And APEC is not interested in upsetting powerful groups. Its focus is more about fostering dialogue and sharing experiences. Indeed, several people expressed their relief that newly appointed Australian energy minister Josh Frydenberg attended and participated constructively; Australia, one of the key drivers of the creation of APEC, had vanished from the scene since the election of the Abbott government, much to the bemusement of many.

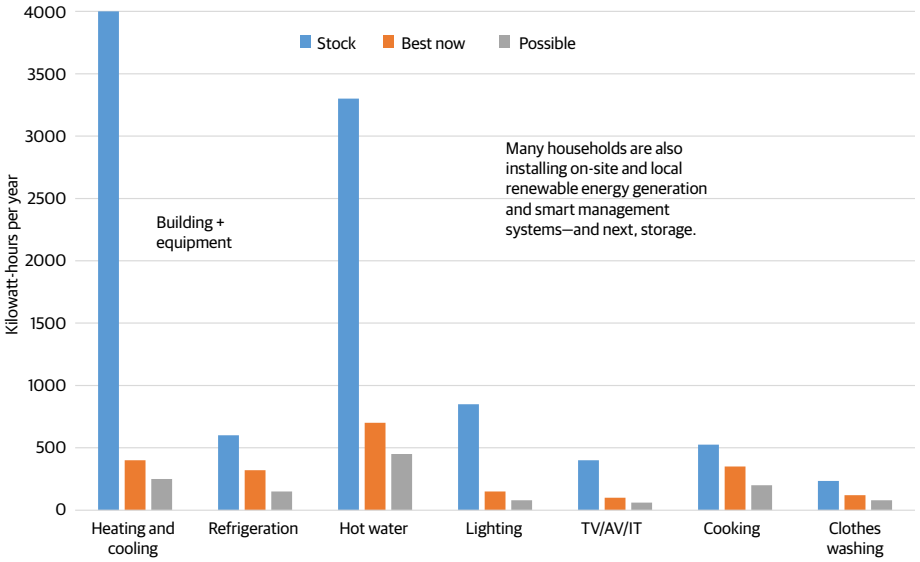
The first day of the ASEAN summit in China was a very different matter, and reflected much more the Australian situation. It was dominated by presentations on large-scale generation projects—mainly renewable and nuclear—and grand visions of huge inter-country power grids that would enable the diverse renewable energy resources of the region to be shared, while also building regional cooperation. All this was based on an assumption that regional electricity demand would triple or quadruple—trending towards the US level of per capita consumption.

I was the only one of about 20 (all-male) speakers from the energy sector who questioned the assumption of massive energy growth, the logic behind large projects and the belief that inter-country grids would improve relationships. I was relieved when, at the end of the first day, quite a few people thanked me for my 'intervention'. Clearly not everyone at the summit was excited by the scenarios presented. For me, this highlighted the enormous and powerful cultural forces within the energy establishment driving large-scale, capital-intensive solutions. I come from a very different perspective!

The second day was an incredible contrast. I presented at the Smart Cities forum—one of four streams; the others being nuclear, power grids and PV. Presentations discussed smart use of 'big data' to optimise building performance, applications of smart grids and case studies of low-carbon urban development. By the end of this day, my optimism had returned.

One of the interesting aspects of these experiences was the significance of the informal discussions and networking, which is difficult to achieve via the internet or correspondence. On the second day, I sat next to one of the key speakers from the previous day, and we discussed the concept of energy services and how people didn't actually want energy. His summation at the end of that day included some of the points I had raised with him! On the following day we had a site visit to Yingli Solar, the fourth-largest PV manufacturer in China. A Chinese energy policy maker sat next to me on the bus, and we discussed the issues I had raised on the

"There was no debate about climate change—the science is accepted, the evidence is clear, and the impacts are real and terrifying."



↑ Residential technology transformations; this graph shows the energy efficiencies on the horizon, with where we're generally at now ('stock' housing/appliances) compared to the best available now, and what's possible. (Based on Alan Pears' presentation to Sydney A2SE Workshop in April 2014, and part of his presentation to the APEC conference in October 2015)

previous days. Our bus driver got lost, so our conversation continued for nearly an hour!

Now I'm back in Australia, slogging away writing my submission to the Victorian Essential Services Commission Inquiry into the 'true value' of distributed generation and trying to generate some interest in Australia's National Energy Productivity Plan. Reality bites!

How to drive energy efficiency and productivity

Australia's National Energy Productivity Plan (NEPP) was launched last December. Its aim is to deliver more economic output per unit of energy consumed. It includes quite a few worthwhile actions, but its weakness is lack of focus on the institutional and funding arrangements needed to drive outcomes.

To date, the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC) have proven effective at driving renewable energy research, innovation and commercialisation. Energy efficiency investments already represent about 30% of CEFC's funding. But ARENA's agenda is focused more narrowly.

One practical step forward would be to rename ARENA as AEPA (Australian Energy Productivity Agency) and broaden its terms of reference to include energy efficiency—and provide it with more funding. This would not solve the broader institutional blockages to energy efficiency, but it would start building Australia's capacity to drive decarbonisation in an integrated way.

Low fossil fuel prices—what do they mean?

Over the past year we have seen global oil, coal and liquefied natural gas prices crash. Not many predicted this. It seems to be the result of over-production and lower-than-expected demand. For me, this is a very interesting phenomenon.

Usually, low prices would drive up demand until production was matched by demand. But not this time. Many economists argue that the problem is that low economic growth is limiting demand growth. But there seem to be some other factors at work.

First, global economic development, especially in China, is shifting from physical production to services, which are much less energy intensive (that is, they use much less energy per unit of economic activity). Second, services are displacing resource production and manufacturing, reducing average energy intensity of the existing economy. Third, distributed clean energy is swamping traditional energy supply, as it is now cheaper and much less risky. Fourth, modular, mass-produced energy solutions (both supply side and demand side) are accelerating, driven by remarkable innovation and cost reduction.

While traditional economists keep hoping that demand will recover to take advantage of the low prices, we are seeing some very different responses. For example, the Indonesian government has taken the opportunity provided by falling oil prices to remove subsidies on diesel and other petroleum fuels. This positions Indonesia to shift to a low-carbon future and improves government revenue significantly while also reducing oil import costs.

So the global economy seems to be moving on, beyond fossil fuels. As an OPEC sheik said in the 1970s, "the Stone Age didn't end because we ran out of stone".

Some organisations, such as banks and big fossil fuel producers, will try to fool investors by continuing to deny the need for change while they quietly shift their own investments, selling to those silly enough to believe that fossil fuel projects are good investments, then admit afterwards that change was necessary, and claim that they have managed the transition competently. I'm glad my investments are in other sectors!

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 slides and speaking notes from the APEC conference can be downloaded in PDF format at www.bit.ly/1RacCBW
His article about the NEPP can be viewed at www.bit.ly/1QQgCSF

Q&A

Do you need to know which electric vehicle to buy, how to upgrade your downlights, what rebates are available for lighting or how much energy your toaster uses? Ask *ReNew* your question via renew@ata.org.au.

Mixing solar panels

Q —

We have a remote-area power system in northern Queensland—we currently have fifteen 80 W polycrystalline solar panels, which are sufficient for our needs except during the wet season when we often end up in deficit.

We are wondering if adding some amorphous thin film panels might help boost our power supply (if compatible with our PL60 controller), to assist with maintaining a suitable level of power generation during the wet season when we have extended periods of very hot and/or heavily overcast weather.

Alternatively, would we be better off buying some more polycrystalline or monocrystalline panels to add to our existing array (but larger units than we currently have—e.g. 120 watts or larger).

I have two questions for you. Firstly, are we able to add polycrystalline panels of a larger size, e.g. 120 watt panels, to the array and still feed into the same controller. Secondly, can we mix polycrystalline panels with amorphous thin film panels and feed into the same controller?

—Arwen Rickert

A —

You could add some extra panels in parallel, but there are a few things to be careful of. Firstly, you mustn't exceed the 60A rating of the charge controller or the existing wiring. Also, to get the maximum output out of the new and existing panels, you would need to use panels with IV curve characteristics similar to what you currently have. At the very least, they should have peak power points at a similar voltage to the existing panels.

You don't say what voltage your system is, but the odd number of panels implies 12 or 24V (assuming the panels are 24V panels). Most likely it's a 24V system, this would be within the current rating of the charge controller.

Because you are needing to maximise output from the panels, you might want to consider a MPPT charge controller, at least for the new array. These make the most of the panel output and can increase current into the battery by 20% or more.

If it were my system, I would add the extra panels on their own separate MPPT charge controller. There are some quite nice lower cost units around now, such as the EP Solar units (www.futurlec.com) and the Victron Energy units (www.victronenergy.com/solar-charge-controllers).

—Lance Turner

Which EV?

Q —

Our family is pondering which electric car to get this year. Our new home will have solar panels to charge a car. Have you crunched the numbers on which of the limited options is close to reasonable?

—Ian Mack

A —

The answer to that would depend a lot on your budget and your driving patterns. The Nissan LEAF, the BMW i3 and the Tesla Model S are the main choices for pure electric vehicles. The i3 has a range-extender (petrol engine) option.

The Tesla is cheapest per kilometre of range, but most expensive overall, and the LEAF is cheapest in raw dollar terms (and is also available under $30,000 secondhand).

Depending on your driving, you'll need to allow enough panels for the car and house.

You'll probably be able to get a good look at them at the Melbourne EV Expo in October, or all of those dealers would happily take you out for a test drive. See *ReNew 130* for our most recent round-up of the Australian EV market.

—Doug Rolfe, ATA Branch Manager

Single slice toaster

Q —

I read your article on household appliances 'It's in the Stars', but what about the humble toaster? Every morning in households across Australia and worldwide, power is wasted because, if you only want to toast one slice of bread, both elements fire up if you are using a two-slice toaster. If you are using a four-slice toaster and want to cook one or three slices, again an unneeded side of the element will switch on.

It shouldn't be too hard for toaster manufacturers to design a more energy-efficient unit with independent elements. Small individual savings like this can add up to significant savings in energy use. There must be lots of ways savings can be achieved. It just needs someone to develop the ideas.

We can't rely on our governments to make all the right decisions on the important subject of climate change and carbon footprints. I believe that it is up to the individual as well to make an effort to keep their energy use down to a minimum if we are going to make a difference and survive this crisis.

—Jo Prendergast

A —

Very few toasters are designed for just one slice. There are single-slot toasters designed for two slices side by side, but, of course, when toasting one slice, the elements are effectively larger than needed and so there is still wasted energy.

There was a toaster designed in Japan that just does one slice, but it is only available for 100V supplies and it doesn't get good reviews. However, Dualit's two-slice classic toaster (www.dualit.com/products/2-slice-newgen) has the ability to turn off one slot for toasting just one piece, so that would be the best option. They are also designed to be repairable, another plus.

The downside is price; they are around $400, although they can be found cheaper if you look around. The energy saving would never pay for the difference between these and a cheap toaster, but given the Dualit is designed to last a lifetime (although there are reviews to the effect that they have early failures as well), then it might be worth the investment. There may be other, lower cost toasters with a single-piece capability but I

couldn't find them after about 10 minutes of searching and checking reviews.

Overall, the energy wasted by a toaster is pretty small as it only runs for a few minutes at a time. While it does add up to a lot across the whole country (or planet), other inefficient appliances can waste a great deal more. For example, if a toaster is running an unnecessary 500 watts of element for three minutes, that equates to 25 watt-hours, or the same amount of energy wasted by a small plugpack drawing just one watt or so continuously—not much in the scheme of things. Indeed, a 3 kW solar power system would produce this much energy in just 30 seconds.

So, while all energy savings are important, there needs to be enough to provide an incentive to actually manufacture a more energy-efficient device, and I suspect that in this case, there just isn't enough incentive to do so for most manufacturers.

—Lance Turner

Upgrading downlights

Q —

As an ATA member I was hoping to call on your expertise for some advice regarding halogen downlight replacements. Are there any reliable rebate schemes or providers that you would recommend? We seem to get a lot of calls from companies regarding this service, but I'm dubious. Are there any specific products I should be looking at?

Sadly, we currently have probably 30 halogen downlights in our house.

—John Dykes

A —

The Victorian Energy Efficiency Target scheme is called the Energy Saver Incentive. It's a market-based state government scheme that discounts the shelf price of eligible technologies. Some lighting can be reduced to virtually $0, and accredited providers (who are sometimes electricity retailers) offer this so that they can then talk to you about potentially buying other products or moving your electricity contract to them. In South Australia there is also Residential Energy Efficiency Scheme (REES). Usually rebates are state-specific, so it depends where you live. You can check the available rebates at www.yourenergysavings.gov.au/rebates. You can check whether a company is accredited on the Energy Saver Incentive and REES websites. The company must also provide details of their accreditation on any marketing material.

I would be wary of any mob cold-calling offering rebates as cold-calling is specifically disallowed by these schemes.

The products to use depend on a number of things, including budget, the beam angle you want (do you want to stick with the relatively narrow beam angles the halogens have, or are wide flood angles preferred). Brightgreen has a good range of very high quality lights, and they have started to introduce lower cost units like the D700+ which retails under $70 and has some excellent features including gimballing, airtight sealing and their TruColour system for good colour rendering.

If they are out of the budget, there are many lower cost units; indeed, you can get them almost anywhere. Bunnings has a good range now, with low-cost units like the Deta 12 W Dimmable LED Daylight Downlight Kit for just $16, which, while not as nice as the Brightgreens, are good value and will probably give you quite a few years of service.

We also ran an LED lighting buyers guide in *ReNew 133*.

—Lance Turner

Needing a skilled plumber

Q —

I'm seeking a recommendation regarding a Sydney-based plumber who might be able to assist us, as our repeated attempts have proven both fruitless and expensive.

We have Rainsaver storage guttering (water is stored in the gutter instead of a tank) connected to three household toilets. It has worked well for most of its 13 years but several years ago the inlet valve broke so we have to manually top up when the system runs dry. For six months now our ensuite toilet has not flushed. Numerous plumbers seem unable to resolve these problems due to the low pressure of the system and non-standard parts such as the inlet valve. Honestly, we are not sure why, and have had three or four plumbers look at the system in the last year.

We are on the verge of simply converting the house to mains pressure and allowing the gutters to fully empty into our rainwater tanks—it seems a sad defeat, and would not be cheap either, but we can't keep bucketing water down loos. We don't want to use a pump from rainwater tanks to flush toilets, and are keen gardeners so would use the water captured. But this is one last effort to find a plumber who could actually assist us. Can you recommend anyone?

—Susan Clark

A —

There could be a couple of issues with the toilet cistern. The first could be that the inlet filter (often a flat perforated strip of plastic inserted up the inlet tube) is clogged. I had that problem recently with mine, water simply wouldn't enter the cistern, even with water from the bore pump under pressure. A simple clean of the filter fixed that.

The inlet valve is probably the type made for low pressure systems such as gravity-feed systems. The Fluidmaster is the most common and they have a page on slow/non-filling issues with their valves at www.bit.ly/1Qv4EN6; there's also a thread on this in the ATA forums at www.ata.org.au/forums/topic/2174. The Fluidmaster helpline number is there and they might have a plumber recommendation. Fluidmaster valves are distributed here by Haron, see www.haron.com.au. There are some excellent tradies out there, but finding them can be difficult, particularly if you're doing something out of the ordinary—that's where forums can help.

—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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Branch out into sustainability with the ATA

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Sydney West survey
The Sydney West branch is currently running a survey of local ATA members to inform their approach and activities. Find it at www.community.ata.org.au/branches/sydney-west-branch.

Advertiser Directory

ATA member profile
We heart Tankulator

From studying environmental science, to working in the urban stormwater sector, to installing an intensive green roof on top of her home, ATA member Claire Hanley talks to Sarah Coles about community engagement with water.

CLAIRE Hanley is an environmental scientist working with Marrickville Council in the urban stormwater sector. She works with the Waterevolution team and manages small infrastructure projects and the urban water education program, which includes workshops on water-sensitive urban design and rainwater harvesting. The three-part water-sensitive design series has a hands-on component: "In part three we go to someone's house and build a stormwater treatment device. It's usually a rain garden, but we've done wetlands and greywater systems as well."

A few years ago Marrickville Council ran water workshops in five languages (Arabic, Vietnamese, Portuguese, Mandarin and Greek) at the library with the Ethnic Communities Council. Claire makes an interesting point: "Often people from non-English-speaking backgrounds come from countries where water hasn't been readily available and has been considered a real resource. They're really aware of water issues because they lived with not having water on tap."

Marrickville Council are soon to launch a program aimed at helping residents to stencil the slogan 'We are all Cooks River People—water in drain flows to the Cooks River' on top of the drains, to alert people to where their stormwater goes.

The council is known for its rain gardens, and one suspects Claire has a lot to do with this. The Scouller Street rain garden was completed with the Cooks River Alliance in 2015, and it has transformed the dangerous, hot and polluted intersection. The council worked with the community to design rain gardens on either side of the road with a sharper turning angle to slow down traffic.

↑ Claire's 45 m² intensive green roof provides a great habitat for birds, pollinating insects and small native animals, and fosters joy in the neighbourhood. Image: Studio Commercial

They had a community planting day last year: "We had over 50 locals turn up on a Saturday morning to plant out the gardens." A University of Western Sydney microbiologist has been doing research into pollution reduction at the site and the test results are encouraging.

Claire and her husband have also completed an eco renovation of their 1920s semi-detached house. "The rear of the house had a tin roof," says Claire, "and was boiling hot in summer and freezing cold in winter. So we demolished the back of the house and rebuilt with a green roof on top." The green roof keeps the house cooler in summer and warmer in winter. Additional benefits include reductions in both impervious surfaces and the urban heat island effect.

They needed extensive engineering assistance to design/install the green roof, as it weighs so much; council regulations required engineering diagrams. It has a deep soil profile of about 350 mm and includes a drainage system. The roof was lined with a waterproof liner and the soil pumped from a truck onto the roof.

"Our neighbours like it because their verandahs overlook our roof. We're making their day better!"

The result is a 45 m² intensive green roof, planted with natives which have proved effective in providing habitat. A student at Macquarie University conducted a biodiversity study using Claire's green roof, favourably comparing the amount of invertebrate activity on green versus conventional roofs. Claire adds, "Our neighbours like it because their verandahs overlook our roof. We're making their day better!"

Claire became an ATA member because of a love of Tankulator, the ATA's online rain harvesting calculator (tankulator.ata.org.au). She says, "We always recommend Tankulator to people in our council rainwater workshops.

"And it is great getting *ReNew* magazine," she adds. ✱

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