ReNew

Technology for a sustainable future

Issue 132

BUILDING MATERIALS SPECIAL

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Innovative sustainable materials

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Design that lasts

Farming renewably & more

Issue 132 July-September 2015
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www.renew.org.au

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Local, clean, green: the new generation
Building with SIPs: quick and easy
Go with the flow: micro-hydro guide

Go hybrid: solar + storage

SAMSUNG SDI

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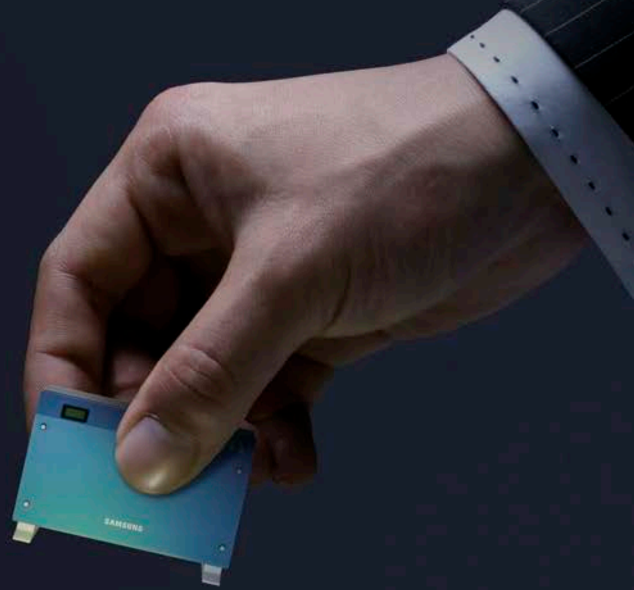
With the compact all-in-one energy solution, you can save space to optimize power consumption and significantly reduce maintenance cost with Samsung SDI's monitoring system that can detect errors in advance and be controlled remotely. Have a great experience of the world best ESS solution with Samsung SDI.



CLEAN ENERGY COUNCIL

VDE REG.-Nr. E517

* Certified under AS4777, AS3100, EN/IEC62109, & CEC Listed

SPECIAL FEATURES

COMPACT
- 3 Functions (PV & battery inverter + lithium-ion battery)
- Simple installation

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- Prior malfunction sensing
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RFI SOLAR

www.rfisolar.com.au

1300 000 734

Q What's the most efficient heat pump in Australia?

A Sanden Eco®

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

A Because it's so efficient and heats water so quickly it can run on off-peak only or be set to daylight hours only and be powered by your PV solar. The in-built digital timer gives you the control to maximise your savings.

Q Why purchase a Sanden Eco® Hot Water Heat Pump System?

A The superior design of a Sanden Eco® Hot Water Heat Pump ensures:

- Highest Coefficient of Performance (COP=4.5) results in significantly reduced energy use and CO_2 emissions
- Up to 50% faster heat recovery than typical heat pumps
- No back-up element required
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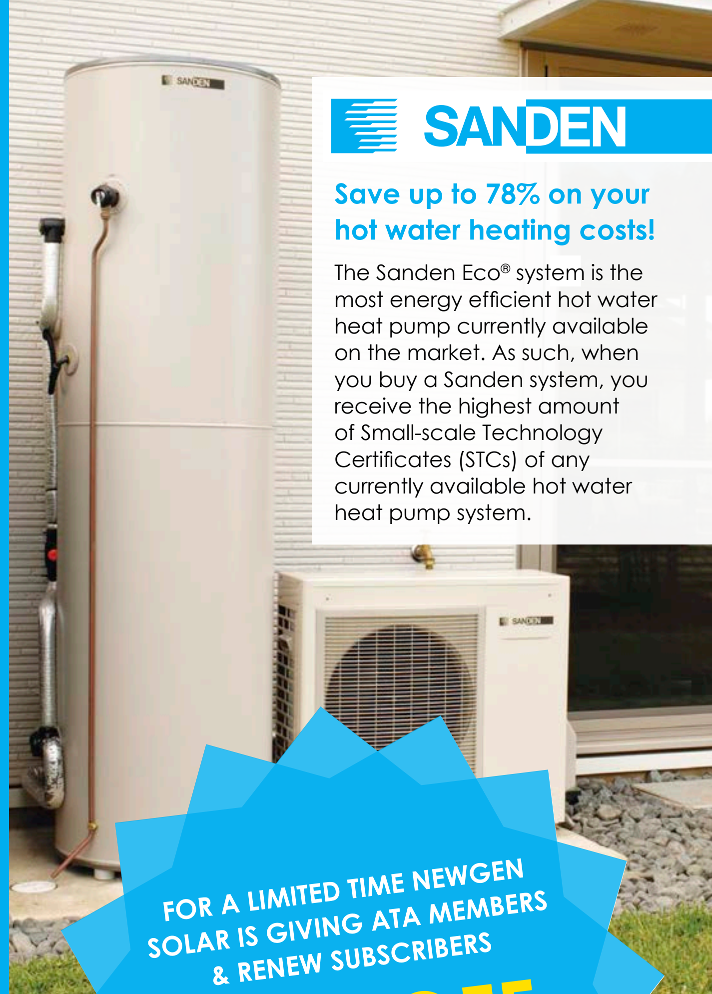
- Superior CO_2 based ozone friendly refrigerant allows performance down to -10°C
- 15 year warranty on Australian made stainless steel tank



SANDEN

Save up to 78% on your hot water heating costs!

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Alternative Technology Association
MEMBER

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NEW SOLAR DEALS

120W CAMPING SOLAR DEAL

TOTAL VALUED OVER $1120

Enjoy camping in the great outdoors with all the essentials. This affordable DIY solar package is ideal for powering your gadgets and equipment for longer camping or holidays off grid. The included portable solar panel folds up easily and is supplied with a bag for convenient storage when not in use.

DEAL INCLUDES:

1 x 12V 120W Fold-Up Solar Panel with Charge Controller	ZM-9134
1 x 12V 100Ah Deep Cycle SLA Gel Battery	SB-1695
1 x Battery Box with Power Accessories	HB-8500
1 x Flexible LED Light Strip with Hook & Loop Backing	ST-3950

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Jaycar carries a wide range of smart energy products. Head to our new website or your local store for all your power requirements.

· Smart power monitors
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· Solar panel mounting hardware
· Sealed lead acid batteries, and more!

SEE OUR NEW & IMPROVED WEBSITE: WWW.JAYCAR.COM.AU

BUNDLE DEAL
$1069
SAVE OVER $58

REDUCE YOUR WINTER POWER BILLS NOW!

DIGITAL DC POWER METERS

Suitable for DC operation from 5 to 60V, these meters display and store power usage allowing you to monitor the system over time. An ideal addition to low voltage DC circuits on boats, caravans, or solar systems.

0-20A Rated with Internal Shunt MS-6170 $79.95

0-200A Rated to suit 50mV External Shunt MS-6172 $89.95

FROM $79.95

USB Data Adaptor
Enhance data collection of the digital DC power meters by connecting to your PC with this USB data adaptor.
MS-6174 $99.95

DUAL BATTERY VOLT/ CURRENT MONITOR

Don't let your battery run flat ever again! Ideal for boats or caravans/RVs, especially when running refrigeration products or lighting. It is mounted with a single hole, suitable for bulkheads up to 27mm thick. 250A current shunt supplied.

- Audible warning below 11.5V or over 15.5V

$179
MS-6176

DELUXE POWER METER

Monitors the energy consumption of your appliance with the added convenience of being able to read the large LCD screen via an extension cord. Displays wattage, voltage and cost usage.

- 10A max
- Extension lead 1m long

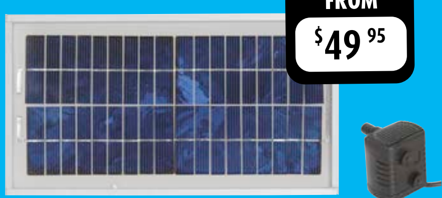
$34.95
MS-6119

SOLAR POWERED WATER PUMPS

Run a garden pond or water feature from the sun and eliminate the need for wiring or the safety aspects of electricity near water. Each unit comes with a solar panel, cable and pump assembled and ready to use.
Includes 2m cable.

7V 900mW	**140 Litres/hr**	**ZM-9200**	**$49.95**
12V 2.4W	**200 Litres/hr**	**ZM-9202**	**$99.95**

FROM $49.95



Solar Rechargeable LED Worklight

This handy 5W LED worklight produces an amazing 300 lumens of bright white light, ideal for camp site and emergency repairs. The included rechargeable battery pack doubles as a portable 4400mAh power bank via the 1.0A USB charging port.
Up to 3 hours continuous usage per full charge.

- Water resistant, IP54 rated
- Charge time (mains/solar): 5 hr/8 hr

$89.95
SL-2792

Portable Solar Rechargeable Power Pack

An all-in-one solar power solution for the caravan, boat, or even tent! Recharge the built-in 12V 4Ah AGM battery via the 5W solar panel or 16VDC mains power cable (both included).

- Output sockets: 12VDC cigarette socket, 5VDC USB socket
- Two 3W LED lights included

$139
MB-3697

LED Strip Lights

Provides evenly distributed light beams suitable for caravan, marine, 4WD and domestic applications. Available in 280 and 520 lumens, fixed or linkable models. Fast and easy installation.

12VDC ALUMINIUM WITH SWITCH:
280 Lumen ST-3930 $19.95
520 Lumen ST-3932 $34.95

12VDC ALUMINIUM LINKABLE:
280 Lumen ST-3934 $24.95
520 Lumen ST-3936 $39.95

12VDC LED DIMMER SWITCH TO SUIT:
2A In-line Dimmer ST-3938 $14.95

FROM $19.95

& SOLAR PACKAGES

MORE PACKAGES IN-STORE

GRID CONNECT SOLAR DEAL

TOTAL VALUED OVER $1740

Reduce your electricity bill by powering your home or business with clean energy. This grid connected solar power system will supply your household with energy and, if you consume less than you produce, feed the surplus to the electricity grid. The included SolarWorx grid-tie inverter differs from most grid-tie inverters currently on the market, as it allows you to feed power back into the grid either directly from your solar panel array, or feed power back into the grid from a battery bank that is charged externally by your solar array or other renewable source.

NOTE: Contact your local electricity provider for details on grid-tied solar power credits. Special metering is required to receive feed-in tariffs.

- Suitable for use with solar, wind, hydro or other renewable energy sources
- Maximum Power Point Tracking (MPPT) system

DEAL INCLUDES:

1 x 12V 2000W Grid Connect Inverter	MI-5192
2 x 24V 200W Monocrystalline Solar Panel	ZM-9088
1 x 4-Way IP66 Circuit Breaker Enclosure	SF-4158
2 x 550VDC 10A 2-Pole DC Circuit Breaker	SF-4154
1 x 240VAC 10A 1-Pole AC Circuit Breaker	SF-4150

**MI-5192 and SF-4154 are not stocked in stores but can be ordered. Call your local stores for details.*

BUNDLE DEAL $1599 SAVE OVER $143

FREE 6-Way Energy Saving Powerboard MS-4080* Worth $39.95

***Valid with purchase of Grid Connect Solar Deal**

High Current Circuit Breakers

DIN rail mounted circuit breakers suitable for solar applications. Commonly used in domestic and commercial switchboards, fuse boxes, distribution boards etc. Available in AC and DC models.

- Electrical safety authority approved

240VAC	10A	Single Pole	SF-4150	$4.95
240VAC	16A	Single Pole	SF-4151	$4.95
240VAC	20A	Single Pole	SF-4152	$4.95
240VAC	32A	Single Pole	SF-4153	$4.95
550VDC	10A	Dual Pole	SF-4154	$32.95

FROM $4.95

50A High Current Connectors

Easily adapt or extend your 50A high current connectors in your solar system with the following options. Adaptor includes 300mm cable length. Extension lead includes 5m cable length.

Eye Terminals	PT-4444	$14.95
15A Cigarette Plug	PT-4446	$16.95
15A Cigarette Socket	PT-4448	$16.95
Insulated Battery Clamps	PT-4449	$19.95
2-Way Splitter	PT-4442	$34.95
5m Extension	PT-4440	$74.95

FROM $14.95

Protect Your Valuable Solar System and Batteries

Our range of highly efficient solar charge controllers allow you to have total control over battery charging and power usage. Features in-built microprocessor, adjustable charging voltage, automatic dusk-till-dawn on/off, overload protection, etc.

See our website for full details.

- 3-stage charge modes
- LCD display shows system status

12V 20A MP-3129 $149.00
12V 30A MP-3722 $199.00
24V 20A MP-3724 $199.00

MPPT MODEL ALSO AVAILABLE:
12/24V 30A MP-3735 $259.00

FROM $149.00

GENERATE MORE POWER FROM THE SUN!

POWERTECH MONOCRYSTALLINE SOLAR PANELS

Each of these high quality solar panels features a 3.2mm thick tempered glass front panel, which is capable of withstanding up to 1 inch hailstone. The panels are fitted with a waterproof junction box, UV stabilized output cables and bypass diodes to withstand harsh environments. All are covered by a 25-year limited warranty. T&C applies.

** ZM-9088 has the required IEC certificates for the Australian Solar Rebate Scheme*

12V 80W	ZM-9097	$239.00
12V 90W	ZM-9086	$249.00
12V 120W	ZM-9085	$329.00
12V 145W	ZM-9087	$399.00
24V 200W	ZM-9088*	$469.00

FROM $239

FLEXIBLE SOLAR PANELS

The flexibility of the solar cells is limited by the plastic base but will easily bend on the long axis to accommodate a yacht deck or RV roof. Best of all, these units do not have a heavy rigid frame and are therefore light, and easy to stow away when you travel. The flexible non-glass area of the solar panel is tough enough to walk on.

FROM $94.95

12V 18W	ZM-9150	$94.95
12V 40W	ZM-9152	$199.00
12V 100W	ZM-9154	$399.00
12V 180W	ZM-9156	$649.00

SOLAR BATTERY CHARGERS

Weatherproof solar panels ideal for charging sealed lead acid batteries. Mount on a flat surface or on their brackets so it can be moved to follow the sun. Great for use on a yacht, boat or car.

12V	1.26W	ZM-9016	$49.95
12V	4.50W	ZM-9018	$119.00

FROM $49.95

SCAN THE QR CODE FOR NEAREST STORE

Jaycar Electronics
Better, More Technical

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Issue 132, July – September 2015

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Building blocks

Materials, mass and more

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↑ The Green Swing share their journey of collaboration in the building process. Page 34.

Features

Special feature: building materials

↑ Community energy projects are making a real difference. Learn more on page 38.

↑ Studio Nimbus: built to last in one of Australia's most beautiful, and challenging, regions. Page 54.

← **Cover image courtesy EPFL – SwissTech Convention Center**
The SwissTech Convention Center, Lausanne, Switzerland, features the first solar photovoltaic glass facade of its type on a public building. The Grätzel facade, built by Hevron in Courtételle, consists of 300 m² of Grätzel dye-sensitised solar cells from Solaronix in Aubonne. These cells imitate photosynthesis in plants to produce electricity while reducing solar heat entering the building. They are integrated into the west face of the centre with a beautiful stained glass appearance and are expected to generate up to 8000 kWh of energy per year. Artist Catherine Bolle, in conjunction with the Grätzel laboratory and Richter Dahl Rocha & Associés, designed the facade to make best use of this technology. Page 69.

↑ Beautiful, strong, sustainable bamboo. Not for everyone, but one of the many materials emerging in the building market. Page 69.

↑ Explore the design principles that give buildings a longer lease on life. Page 64.

Guides

Micro-hydro buyers guide

DIY

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 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 looks at tiny homes, modular and prefab housing, flexible shared living, and much more.
www.sanctuarymagazine.org.au

Advocacy and projects
The ATA conducts research and advisory projects with partners from government, industry and community sectors, as well as advocating on issues important to sustainable households. The ATA has just completed leading-edge modelling into the economics of gas versus electricity for Australian homes. The ATA is also further developing the Sunulator solar system feasibility calculator.
www.ata.org.au/projects-and-advocacy

ATA branches
ATA branches are involved in activities such as running monthly seminars, visits to sustainable homes and projects, and attending community events. Find one near you:
www.ata.org.au/branches

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 5500 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.
www.ata.org.au

Become a member of the ATA
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: technology for a sustainable future* and/or *Sanctuary: modern green homes* magazines, free access to back issues online, 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
The ATA is escalating our work in East Timor thanks to a $250,000 grant from Google Australia. Over the next two years the ATA will train and employ local technicians to install and maintain lighting systems in remote houses throughout East Timor.
www.ata.org.au/ipg

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Contributions are welcome; guidelines available at www.renew.org.au or on request. Next editorial copy deadline: 20 July 2015.

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Editorial

Sustainable building: Not just another brick in the wall

WE'VE gone a little bit *Sanctuary* (our sister magazine which showcases modern green homes) this issue! Or, at least, our theme of building blocks sees us concentrating a bit more on sustainable building materials and systems, and a bit less on technologies such as solar and batteries.

But we haven't completely forgotten solar, with an article by the ATA's energy guru Andrew Reddaway on ways to add batteries to an existing grid-interactive system, to create a hybrid system. He suggests that for many in our cities this will be a more cost-effective and sustainable approach than going off-grid, with the recently announced Tesla Powerwall setting a lower-cost and longer-warrantied battery system benchmark that we're hoping many other providers will follow.

We also look at solar panels as a building material in our article on emerging materials. Building integrated PV promises a way of reducing construction materials, replacing roofing or even windows with solar panels, and we're pleased to see some roofing companies taking up the challenge.

As part of our building theme, we decided to cast a *ReNew* eye over the many possible approaches to building walls. The array of choices can be confusing, so we've created a quick guide that looks at how each wall construction system works and considers sustainability across a range of criteria.

In terms of building guides, we also feature Mullum Creek, an innovative residential development in Melbourne's east, which is providing guidelines for purchasers on both sustainable design and building materials. For example, their clay products guide lists local products and suppliers that have lower impacts than typical brick products. Each listing comes with a comment as to why it's been included, a helpful pointer on the issues to consider in selecting materials.

We also consider longevity and sustainable design. As architect Ande Bunbury asks, shouldn't we be designing buildings to outlast us? Getting the basics right, flexibility and durability are all important for longevity.

There's much more besides, including a sustainable farm conversion that's going from strength to strength, a discussion of the advantages of collaboration in building design, an update on the ever-expanding world of community energy, the results of our cooking challenge, a DIY roof heat capture system and a micro-hydro buyers guide. Alan Pears features several times: with an in-depth look at where/when thermal mass is effective, a book review and his column on the bizarre world of Australian climate policy.

We'd also love to get your views on *ReNew* in our reader survey, running until 31 July. It really helps us to hear what you'd like to see more (and less) of in *ReNew*. It only takes 10 minutes and there's a prize of organic wine or olive oil on offer. Find it at renew.org.au/readersurvey.

Robyn Deed
ReNew Editor

In *ReNew 133*, out late September

Reuse and recycling, LED lighting buyers guide, phase change materials + more.

OUR mission at the Alternative Technology Association (ATA) is to enable, represent and inspire people to live sustainably in their homes and communities. We've been doing this for 35 years, providing independent advice and sharing stories of practical sustainability from across Australia.

We're very excited to announce a major step forward in our work, as co-organiser of Sustainable House Day in 2015 with the EnviroShop. The ATA has been a long-time supporter of Sustainable House Day, with many ATA members opening their homes on the day, allowing the general public to see good sustainable design, ask questions and receive unbiased advice.

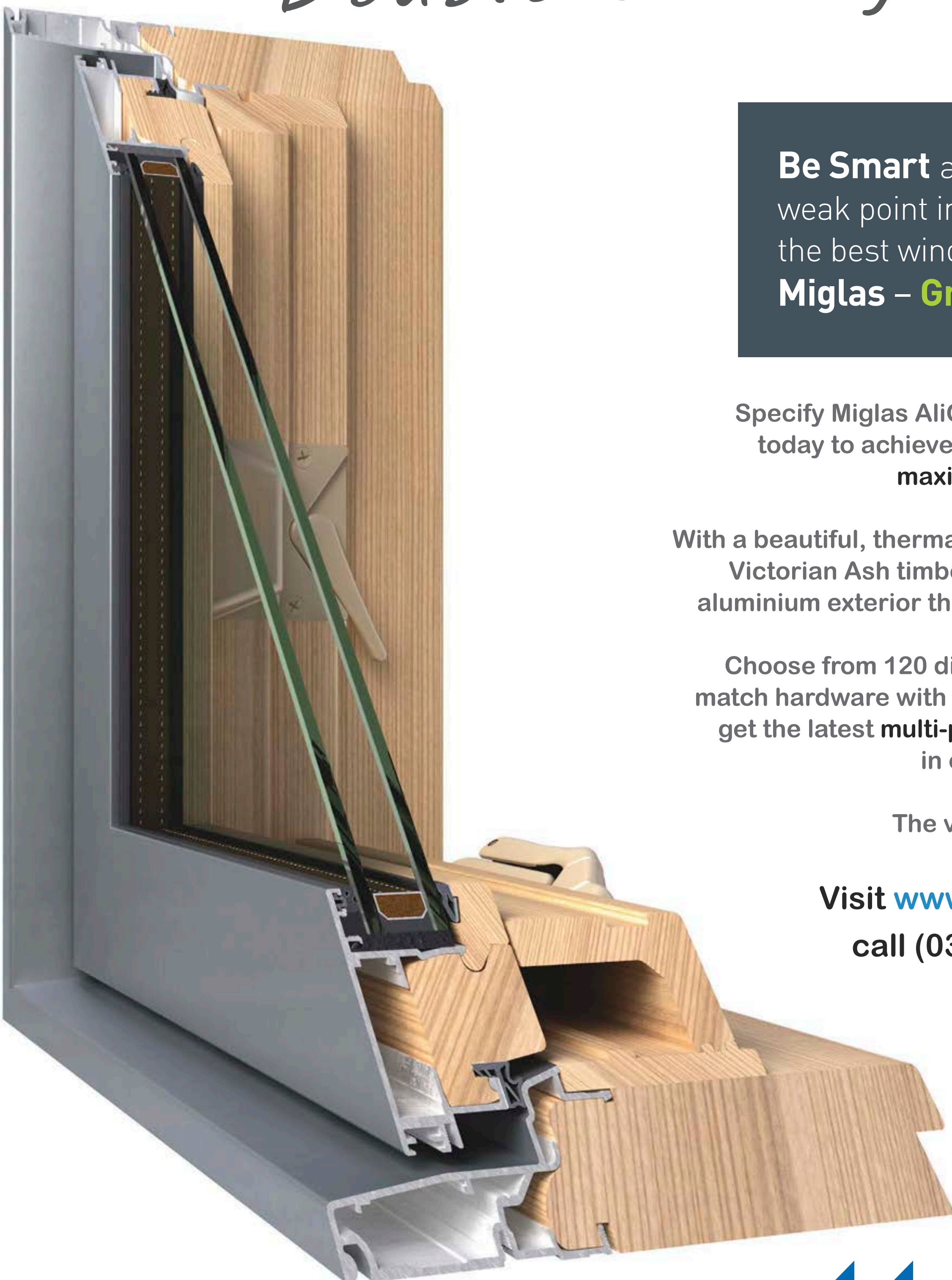
Sustainable House Day joins a range of events the ATA conducts each year to provide face-to-face advice on practical green living. This year we've already held Speed Date a Sustainability Expert events in Sydney, Melbourne and Perth and there are more coming up in Brisbane, Sydney and Melbourne's western suburbs.

Without the support of our members, with many actively involved in their communities sharing information on sustainable living, none of our work would be possible.

As we come to the end of the financial year you can support the ATA's work by making a tax-deductible donation. As well as supporting Sustainable House Day, your donation will enable us to continue development of the on-grid battery component of the Sunulator solar system feasibility tool and to advocate for consumer protection and carbon reductions in a changing energy landscape.

You can make a donation online (www.ata.org.au) or by calling 03 9639 1500. With your support we can continue to enable practical action on climate change free of commercial influence.

Donna Luckman
CEO, ATA



Up front

Electric shuttle buses for Sydney Airport

Following the publication in April of its first sustainability report, Sydney Airport has invited expressions of interest from Australian and overseas manufacturers in an open tender to supply six electric buses to replace the diesel buses currently being used to shuttle people between the T2/T3 precinct and the Blue Emu car park.

"Finding sustainable transport solutions is a priority for the airport, and advances in electric vehicle technology in recent years mean we can now look seriously at the feasibility of introducing electric buses," the airport's General Manager Parking & Ground Transport, Craig Norton, has said.

In 2014, more than 1.6 million passengers and airport workers were transported on the Blue Emu car park's buses. Being such a busy route, passenger comfort and operational efficiency will be key criteria in assessing tenders, Mr Norton notes.

Electric shuttle buses operate in Manchester and Nottingham in the UK and at Amsterdam's Schiphol Airport, while electric bus trials have taken place in Los Angeles, Bangalore and Kuala Lumpur.

www.sydneyairport.com.au

Hunter Valley EV race encouraging students in the sciences

The annual Hunter Valley Electric Vehicle Festival (HVEVF) will be hosting its fifth electric vehicle competition, culminating in the student prize race on 13 August at the Newcastle Kart Raceway in Cameron Park.

The Tom Farrell Institute for the Environment at the University of Newcastle initiated the festival with two goals in mind: to encourage and attract more school students into careers in science and engineering, and to stimulate clean energy manufacturing in the region.

The EV competition gives students a fun format to explore physics, chemistry, engineering and mathematics, as well as emerging sciences such as nanotechnology, which is the basis for recent improvements in battery technology.

Beginning in 2011 with just eight teams and 300 spectators, the competition last year boasted 61 teams from 18 schools and 5000 spectators.

Participating students have said that the process of designing, building and racing their EVs has been fun, and has developed their technical skills, problem solving and teamwork. Feedback from teachers suggests student engagement in the sciences has improved, and more students are electing to study science, technology and maths subjects in their senior years.

www.hunterevfestival.net

Setting a new tone for roads

The City of Sydney is trialling a new environmentally friendly asphalt blend that uses old printer toner to resurface city roads.

The TonerPave technology being used in the asphalt mix was first developed in 2012 by the City's road contractor, Downer EDI, in partnership with cartridge recycling company Close the Loop, which collects and recycles used printer toner cartridges, and provides the leftover toner to TonerPave. Using toner instead of bitumen, which is derived from crude oil, together with a process that heats at 20 to 50 degrees less than regular asphalt, is reducing emissions by around 40%.

With the City of Sydney resurfacing around 50,000 m² of roads every year using 6000 tonnes of asphalt mix, this new environmental blend is making significant inroads into their long-term target of reducing carbon emissions by 70%.

With cities using over two-thirds of the world's energy and emitting more than 70% of emissions, Mayor Clover Moore says, "If we're serious about tackling climate change, we need to take action in our cities."

www.cityofsydney.nsw.gov.au, tonerpave.com.au

Renewables looking good overseas

New Zealand's renewable energy sources contributed 79.9% of the total electricity generated in 2014, according to government figures. This brings NZ's share of renewable energy generation to fourth highest in the world.

Energy generation from geothermal, hydro, wind and biogas is at its highest point since 1996. And Energy and Resources Minister Simon Bridges said renewable energy production has seen "an increase of almost 5%" since 2013.

"We're making strong progress towards our ambitious goal of having 90% of New Zealand's electricity supply generated by renewables by 2025," Mr Bridges said.

Geothermal generation has almost doubled in the last decade and, for the first time in 40 years, has contributed more electricity overall than natural gas. Wind is now the fourth biggest supplier of electricity, overtaking coal, and contributing 5.2% to the renewables tally.

Hydro continued to be the primary energy source in 2014, accounting for 57.1% of total energy production. Wood and biogas showed a 7.7% drop in production from 2013 to 2014. www.cleantechnica.com

Although the US state of Alaska boasts 50 hydro power stations, Alaskans pay 50% more than the national average for their electricity, due to the reliance of most rural communities on diesel-powered generators. But this is starting to change, at least for one community; that of Kodiak Island in the state's south, population 15,000.

To combat high prices and climate change, the Kodiak Electric Association (KEA) set a target of 95% renewable energy by 2020—a 15% increase on current capacity. They have already surpassed this target, generating 99.7% of their energy from wind and hydro. Electricity prices are now 2.5% lower than they were four years ago, and there have also been considerable economic knock-on benefits for the community.

KEA achieved this transformation in a three-step process begun in 2009 with the purchase of three 1.5 MW wind turbines. Step two was the upgrade of the existing hydro power system, with the installation of a third 10 MW turbine, to better meet growing peak loads and provide grid stability. The final step was installation of three more wind turbines and a 3 MW battery storage system. www.businessspectator.com.au and www.bit.ly/1Fk9OCn

According to REN21's *Renewables 2014 Global Status Report*, global renewable power generation capacity exceeded 1560 GW in 2013, up more than 8% over 2012. Hydro power rose by 4% to approximately 1000 GW while other renewables collectively grew nearly 17% to more than 560 GW. For the first time, the world added more solar PV than wind power capacity. Solar PV has continued to expand at a rapid rate, with growth in global capacity averaging almost 55% annually over the past five years. www.ren21.net/gsr

Darwin solar suburb

Darwin is set to gain its first solar suburb, with 75 homes to be outfitted with 4.5 kW solar arrays and electric vehicle charging stations.

Spearheaded by Defence Housing Australia, the project in new development Breezes Muirhead is set to save residents $2000 a year on their energy bills, which are often large due to the need for air conditioning during Darwin's hot summers.

DHA Managing Director Peter Howman says the system's energy savings can be monitored via smartphones, and overall will "avoid the generation of more than 334,000 tonnes of CO_2 annually".

"We want our communities to leave a positive legacy both socially and environmentally. This new technology will produce a collective 600,000 kWh of energy per year and it is estimated that the systems could cut electricity bills by more than 70%," Mr Howman said.

The 337 kW solar suburb will use Enphase microinverter systems, which have a greater yield in partial shading compared to conventional systems with strings of panels reliant on full sun.
www.dha.gov.au

Floating solar first

Australia's first floating solar system was launched on 29 April. The 4000 kW system by Infratech Industries powers a wastewater treatment plant in the small town of Jamestown, 200 km north of Adelaide.

By having the panels sited on the wastewater ponds, Infratech director Felicia Whiting says the project has the potential to both reduce evaporation by up to 90 % and lift the quality of treated wastewater.

"Blue-green algae is a major concern for wastewater treatment plants, and the shade produced by the floating solar panels combats this problem by limiting the photosynthesis process," she notes.

Infratech estimates the plant will generate 57% more power than a similarly sized land-based system. The placement of the system on the water counteracts the gradual loss of output caused by overheating solar panels, creating a better-performing and more efficient system. The panels are able to track the placement of the sun, while the high concentration of panels allows light to be reflected back onto other panels and increase the amount of energy captured.

Fifteen Australian engineers and research scientists from Flinders University's Nano Science and Technology Department were involved in the project's development. The team will continue to gather data and research the possibility of integrated water and phosphorous treatment systems, and energy storage. Whiting says they are currently working on "on-site battery storage to be able to present a completely integrated solution."

The privately funded installation is the first in a large-scale $12 million project that will cover five basins of water around Jamestown and Gladstone.
www.infratechindustriesinc.com

Photo: printed with permission from www.infratechindustriesinc.com

Up front

A world of divestment

Go Fossil Free is a worldwide movement that is growing fast. It is a call to action for people to divest from, not invest in, companies that are contributing to the warming of our planet. This means getting rid of stocks, bonds or investment funds that fuel the activities of the fossil fuel industry.

Since starting two years ago, the movement has notched up a global tally of 33 universities, including our own ANU and University of Sydney's partial divestments, 42 local government areas (including six here in Australia) as well as two counties. Of the 75 religious institutions putting their money where their values are, 10 are home-grown; 56 foundations and other organisations, including the Rockefeller Brothers Fund and the Sierra Club, have voted with their money.

This is a grassroots campaign run primarily by volunteers and it has many in the fossil fuel industry worried.

www.gofossilfree.org.au

Free heating with cloud servers

Dutch company Nerdalize is partnering with Eneco, one of the largest electricity suppliers in the Netherlands, to provide residents with free heating as a byproduct of computing.

The Nerdalize Cloud is a decentralised data centre which sees servers installed across numerous homes, currently within a unit called the Eneco eRadiator. Rather than waste heat being dumped, as it is in conventional data centres, the heat generated by these server units—which look like 'normal' slimline wall-mounted heaters—helps warm the homes of Eneco customers.

Nerdalize covers the cost of the electricity used to run the server/radiator (monitored by the unit itself), so the heat generated is free.

In summer, when heating is undesirable, the generated heat can be expelled outside.

And not only do those who give these servers a home benefit, but the distributed cloud model provides "up to 55% lower" computing costs for companies using the Nerdalize servers, because they bypass the conventional costs of a centralised data centre.

www.nerdalize.com

First Solar milestone at Nyngan

The final PV modules at the Nyngan Solar Plant in NSW were installed on 17 April, completing module installation for Australia's largest solar project.

The 1.36 million modules that make up the 102 MW (AC) plant will produce enough electricity to power over 33,300 average homes in NSW.

Approximately 25% of generation from block one began in March this year. When fully operational in July, the plant will be the largest PV plant in the southern hemisphere, and also a major milestone for the utility-scale solar industry in this country.

Jack Curtis, First Solar's Regional Manager for Asia Pacific, says the advanced cadmium telleride thin-film solar modules "have a higher energy yield than traditional crystalline silicon modules, particularly in hot climates".

Working with AGL and First Solar during the project's planning and construction stages, ARENA—the Australian Renewable Energy Agency—has published 19 reports covering a range of topics from planning, approvals and logistics to procurement, construction and grid connection, to ensure the energy industry benefits from their experiences.

The construction of the Nyngan Solar Plant has created more than 250 on-site jobs. It also created off-site jobs to supply materials as well as roles responsible for the design, management and support of the project.

www.firstsolar.com

Photo: First Solar

↑ Aerial view of the largest solar PV array in the southern hemisphere, Nyngan Solar Plant.

True cost of fossil fuels revealed

The International Monetary Fund (IMF), one of the world's most respected financial institutions, has revealed that fossil fuel companies are benefitting from subsidies to the tune of $10 million a minute.

The estimated subsidies for 2015 are said to be more than the health spending of all the world's governments combined. When you consider the health effects of air pollution caused by fossil fuel energy production, and the concomitant medical and social costs of those, these estimates truly are "shocking".

The IMF suggests that cutting global subsidies would reduce carbon emissions by around 20%, and reduce the number of deaths from air pollution by 50% (1.6 million people per year).

It further suggests that freeing up the resources currently going to fossil fuel subsidies, and investing them instead in infrastructure, health and education, and cutting taxes that inhibit economic growth—particularly in developing countries—would be a "game-changer".

And if fossil fuel prices reflected the full cost of their impacts, investment in renewable energy production would immediately become more attractive.

US President Barack Obama and the G20 nations called for an end to fossil fuel subsidies in 2009. So far, relatively little progress on this has been made. The benefits of doing so, however, would be both global and local—tackling climate change and reducing air pollution, respectively.

www.theguardian.com

And the winner is ...

Tom Roper is the lucky winner of our last subscriber prize, a Siddons hot water heat pump worth just under $5000. He said, "It's nice to win; I hardly ever win anything!" Our new subscriber prize is a $5000 managed fund from Australian Ethical—see p. 68 for details. The prize is open to Australian and New Zealand *ReNew* subscribers and ATA members current at 30 October 2015. Subscribe or join ATA for your chance to win!

Letters

Standby power for air conditioners

I purchased a Panasonic reverse-cycle air conditioner in December 2014 after reading 'Are we still cooking with gas?' in *ReNew 130*. The master bedroom was still getting pretty warm so we finally decided to try a new, efficient unit.

After the installation, I connected my WorkZone clamp-on meter in the meter box and found that the standby power for the air conditioner was around 40 watts. I was surprised that it was so high, given the energy rating on the label.

At a talk in March 2015 at ANU by the ATA's Craig Memery about whether residential gas use is financially and environmentally sound, there were many questions and discussion about the ratings for typical energy use estimates. I mentioned that my standby power on the brand new Panasonic was 40 to 50 watts and the response was that there must be something wrong with the unit.

Subsequently I tested the standby power with an Efergy Classic E2 wattmeter and an LEM PR20 clamp-on current meter, both of which confirmed the earlier readings, so I decided to ask the retailer about the unit. As it turns out, this standby power is to be expected due to the need for a crankcase heater that keeps the refrigerant warm. Depending on the climate zone the standby power can be as high as 50 watts—or 1.2 kWh of energy use per day. [The energy the crankcase heater uses depends on the ambient temperature, but even in warm climates it may be running—*Ed*.]

In really cold climates this standby power is not to be ignored compared to the normal usage. In my house we rarely use more than 1 kWh per day for heating or cooling in the single room.

For a slightly more technical explanation, I did a patent search and found WO2013162349 which pertains to Panasonic air conditioners (I work in the Patent Office). It's also worth reading 'Cooling the planet: opportunities for deployment of superefficient room air conditioners', Shah, N. (2013), available at www.bit.ly/1cVF8VR.

Where multiple small air conditioners are installed, this issue might change the recommendations. In a cold climate it could be that standby power can be reduced by having a multi-split system, rather than multiple smaller air conditioners.

I hope you can find some way to inform other *ReNew* readers or ATA members about the potential standby power usage of currently available models.

Dale Siver

Heat exchange water tanks

Regarding Professor Peter Seligman's suggestion in a letter in *ReNew 130* to pass fresh water through a heat transfer coil in the hot water tank to remove the risk of Legionella, I visited Everlast Water Heaters (www.everlastwaterheaters.com) in Dandenong, Victoria, recently and saw a tank they make with two indirect coils, one towards the base and one towards the top. The top coil is intended to feed a hydronic heating system, but could presumably supply hot water instead. I found them an extremely pleasant and helpful company to deal with.

Adam Thomson

Heat exchange gone missing

I read with interest Peter Seligman's letter in *ReNew 130* and was going to correct his misinformation on heat transfer hot water systems in Australia. Sadly, I find I can no longer do so. I have a hot water system manufactured by a Western Australian company, SolaKleen (Smalls), that has a copper heat transfer coil in a copper tank. The hot water provided to the house is heated by heat transfer so no threat of Legionella. Unfortunately, I've just discovered that the company closed recently because they couldn't compete with cheap imports. My system had run without fault for 12 years and suffers from none of the corrosion problems of other designs.

Angus King

Everlast makes heat exchanger tanks, as mentioned earlier.

Lance Turner

Legal Segways

Your recent issue on electric vehicles (*ReNew 131*) failed to mention the Segway. I purchased a Segway many years ago and rode it frequently around Melbourne CBD and when working in England.

I loved the Segway experience. Unfortunately I allowed my battery to die some years ago and have not been able to afford the price of a replacement, so my Segway is languishing in my shed.

I have become aware that Segways do not qualify as on-road vehicles or as 'gophers' and I would like the experts at the ATA to look into this. Specifically, what would it take to modify a Segway to make it on-road legal? Could you examine this and run a story in *ReNew*, because Segways deserve further consideration as an alternative EV.

David Bell

The issue with the Segway is the high motor power. It is well above the 200/250 watt limit for electric bikes and so is considered a motor vehicle. However, it doesn't meet the ADR (Australian Design Rules) requirements for vehicles such as motor scooters, so they are not road-legal here.

Segways are not banned everywhere. Queensland lifted its ban on personal transporters (the category the Segway falls under) in August 2013, allowing them to be used on footpaths. And Segways can also be legally used on bike paths in Canberra. There have also been numerous short-term permits issued to Segway tour companies around Australia. And, of course, you can use them on private property as much as you like.

Regarding your faulty battery, you should be able to replace the cells in the battery pack with equivalents without paying for a full original equipment

Boosting charge voltage

I am writing regarding the problem some people seem to have with charging the auxiliary battery in a camper trailer or van while in transit, partly due to lower voltages in newer cars and 4WDs. This is even more an issue if the battery is a lithium unit, as full charge requires 14.4 volts for the battery management board to equalise the cells.

I have a 90 Ah lithium battery and found the best (cheapest) way was to use a boost converter available on eBay for less than $10. It can provide about 12 amps output, which is better than nothing. I set the output voltage to 17.5 volts and plug it into the solar input while in transit. The solar regulator does all the work of keeping the battery correctly charged.

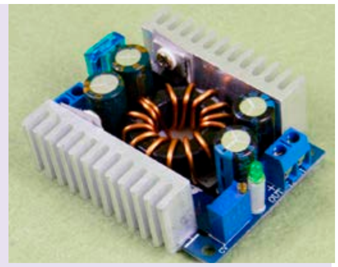
I installed it in a old modem box with an 80 mm fan to make sure it is as cool as possible, as it's fully loaded when the battery is run down a bit.

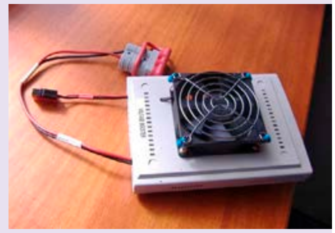
It works for me and should be okay on any small system. I hope this is of help to somebody.

Frank Smith

That's a great idea, the only thing to be aware of is that this and similar designs of DC–DC converters can have problems with the electrolytic capacitors (the large cylindrical devices) as they are mounted so close to the heatsinks. The heat can cause them to 'dry out' and eventually fail, so a fan is a good idea, or find a converter with the heatsinks away from the capacitors.

Lance Turner





↑ The boost charger module, top, and the housing with fan.

battery pack. Electric vehicle enthusiasts should be able to help you out with sources of these cells. It would be worth talking to the ATA Melbourne EV branch (community.ata.org.au/branches/melbourne-ev-branch) or the Australian Electric Vehicle Association (www.aeva.asn.au).

Lance Turner

EV uptake inhibitors

As a motoring enthusiast with an interest in the environment and sustainability, I am aware of most of the current electric vehicle (EV) offerings, but I think that at the moment the biggest inhibitors of EV uptake are:

1. Price. On a straight out purchase or lease over, say, three years, even if you put a price on carbon, which our current Federal Government refuses to do, conventional vehicles seem to win the economic battle.

2. Range. This can be managed through hybrid technologies—the use of an internal combustion engine to supplement the batteries when they run low, with the IC engine tuned for maximum efficiency [it runs at a fixed speed rather than the variable speed of a normal car engine—*Ed*]. The Tesla Model S and the Nissan Leaf don't have IC motors, but the Tesla really is a niche vehicle and the Leaf is still limited by range and price.

As battery technology improves I think there will certainly be a place for EVs as high-volume mainstream passenger vehicles, I just don't think we are there yet. If I can be proved wrong, great!

George Tillett

Australian small cars

If all two-car households had as one of their two cars a small city car, mainly for single drivers going on short trips, we would save on petrol, emissions, traffic jams and parking. We could even make them instead of big cars, and keep an Australian automotive industry.

Valerie Yule

Sustainable transport goes beyond EVs

After the electric vehicle edition of *ReNew*, are other ATA members like me hoping for a sustainable transport edition?

The editorial devotes a paragraph to the importance of "better public transport, better planning and bike-friendly roads", and Lance Turner discusses electric buses.

But the seven articles on EVs beg the vital question: are EVs the answer to the massive challenge of sustainable transport, particularly in our cities? For example, would the East-West Link, recently dumped due to widespread community opposition, be acceptable if its 100,000+ vehicles a day in 2031 were electric?

I think the answer is no. The social and environment impacts of motor vehicles go well beyond their emissions. Thinking about sustainable transport calls us to think about what sort of city we want, not just what sort of fuel we'll use.

Building our cities around the car means urban sprawl continues to eat up vital agricultural and bushland. More than a third of the land in our cities is sacrificed to roads and car parks, and access to education, recreation, shops and other essentials can be difficult without a car. Car-dependent cities force low-income households in the outer suburbs to run multiple cars, at high cost, reinforcing disadvantage. And that's not to mention the 1100 people killed and many more injured on Australian roads in the past year. Do we want a city that continues the current path of car-dependence and all its consequences?

I am not against cars. I drive a car. But I dream of a future for Melbourne that is not locked to the motor vehicle, whether petrol or electric.

I'd like to see a sustainable transport edition of *ReNew* that looks beyond EVs and "what's available and how they work", and instead asks: what is the place of EVs in our transport mix. Why have our cities become so car-dependent? What can ATA and its members do about it?

Linda Parlane

Write to us

We welcome letters 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 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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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

Dual-output PV SHW diverter

We have looked at a few direct PV solar hot water diverter systems, but the SunnyMate from Australian Wind and Solar is the first with dual outputs.

PV diverters are used to heat water in an electric hot water system using excess energy from a solar array, rather than sending it to the grid for a pittance. The SunnyMate can divert between 100 and 3500 watts to a hot water system, and when that has reached its set temperature and turned off, any excess energy can be diverted to a second load, which could be a pre-heater tank or even a spa pool heater.

The SunnyMate adjusts output power every two seconds, so it is always sending the right amount of energy (only surplus to the other needs of the house) to the hot water system. It includes multiple programmable timers so that you can change when the water is heated to take advantage of off-peak rates, and can even display the tank water temperature when used with the optional temperature sensor.

The SunnyMate features a four line LCD for ease of use and comes with a five-year warranty. It measures 198mm high x 132mm wide x 68mm deep, and is designed to be wall mounted, with either bottom or rear cable entry. Installation can be done by any electrician—a solar installer is not needed.

RRP: $800. For more information and to buy, contact Australian Wind and Solar, ph: 1300 736 458, www.australianwindandsolar.com.

02

Low-cost stainless steel heat pump

Heat pumps are the most efficient form of mains-powered electric water heating, but even after STCs they can be out of reach for many people.

Hydrotherm has a range of lower cost heat pump water heaters using Panasonic rotary compressors to provide a CoP (coefficient of performance) of over 4, so you can reduce your electricity use by over 75% compared to a resistive element hot water system.

There are models available with either 150 or 275 litre tanks. To work out which model you need you can simply use the online system selector by choosing the number of bedrooms and bathrooms your home has and your hot water usage needs.

The systems come with a 2mm thick 304 grade stainless steel tank with a huge 15-year warranty, with a five-year warranty on the rest of the system. Operating ambient temperature range is -5°C to 45°C.

One drawback we can see with these units is that, being a Queensland company, the systems are not available everywhere in Australia. The refrigerant R417a also has a relatively high global warming potential.

The units start at around $995 after STCs are deducted. For more information and to buy, contact Aquatech Solar Technologies Pty Ltd, 94-96 Kortum Drive, Burleigh Heads QLD 4220, ph: 1300 769 904, info@hydrothermhotwatersystems.com.au, www.hydrothermhotwatersystems.com.au

03

Top-end tiny PC

We have looked at many small, low-power PCs in the past and most have had limited processing power to go with their low energy consumption. But as processors improve, so do computer capabilities without blowing the energy budget.

For those looking for a tiny PC with a bit more power, the Intense PC2 (IPC2) from Compulab is available in several models including the IPC2 i7 Win7, which features a dual-core 3.3GHz i7-4600U processor with Intel 4400 graphics, 8GB of DDR3L DRAM and a 1TB 2.5" hard drive.

This all combines to provide quite a bit of power for such a small PC, especially considering that power consumption ranges from just 6 watts to a maximum of 24 watts and that the IPC2 is completely fanless and uses passive cooling only.

Other features of the IPC2 i7 Win7 include six USB ports (four of those are USB 3.0), two gigabit network ports, 2.4/5GHz dual band wifi, Bluetooth 4.0, 7.1+2 channel audio including optic port, no less than three display outputs (two HDMI ports capable of 4096 x 2304 dpi and 3200 x 2000 dpi DisplayPort), three serial ports, mini-PCIe and mSATA ports.

The IPC2 comes complete with Windows 7 Pro, so it's ready to run. It measures 190 x 160 x 40mm and weighs 1150g.

RRP: US$1254. For more information, go to www.fit-pc.com.

04

LED bulbs that don't look like LED bulbs

LEDs are taking over the lighting world, but many people don't like the look of the bulbs, which often look very little like the incandescents they replace.

To address this, manufacturers have more recently been producing 'filament' LED bulbs. These are very similar to incandescents but instead of a tungsten filament that glows white hot they have LED filaments made of multiple small LED chips attached to a glass substrate, all covered in phosphor to enable the filament to produce white light.

The biggest drawback with most LED filament bulbs is that they have a relatively low colour rendering ability, so colours such as reds and greens don't appear as vivid as they would under incandescents or daylight.

Loomi has addressed this with their range of filament LED bulbs with CRIs of 90 or more, which also feature Loomi's Tru-Colour system which enhances reds to make skin-tones appear more lifelike.

Bulbs range from a two watt candle bulb through to a four watt large round bulb. Light output is 200 lumens for the two watt units and 400 lumens for the four watters, making them suitable for use in areas that need lower lighting levels, or in multi-bulb fittings.

RRP: From $19 for the 2 W candle bulb through to $34.50 for the 4 W large round bulb. For more information and to find your local stockist, contact Loomi on ph: 1300 672 499, www.loomi.co.

05

Advanced battery monitoring

If you have a battery-based renewable energy system then adequate battery monitoring is important. Just reading battery voltage isn't enough to tell you what is happening to the battery through each charge/discharge cycle.

The Trimetric TM-2030-A battery system monitor from Bogart Engineering provides important information on your battery bank condition, including battery capacity remaining, displayed as a percentage (based on amp-hour monitoring, not battery voltage).

Other information displayed includes battery charging or discharging (displayed in amps or watts), battery voltage (the meter can handle voltages from 9 to 75 V and capacities from 10 to 10,000 Ah), the days since the batteries were last fully charged and the days since the batteries were last fully equalised.

Another interesting function is the replaced percentage of charge display, which shows how much energy the battery has received compared to the most recent discharge, so you can ensure the battery bank is receiving appropriate levels of input.

There is also an audible low battery alarm, based on volts and the capacity monitoring, which can be silenced. The unit also logs data for the last five charge/discharge cycles to allow easier diagnosis of system problems.

Available from Australian Solar Industries, PO Box 21, Laidley QLD 4341, ph: (07) 5465 2218, www.australiansolar.com.au. Also see www.bogartengineering.com/content/trimetrics.

06

A quadbike without the noise and smell

Electric options for off-road vehicles seem to be few and far between in Australia and the one or two that are available are quite expensive.

Not so this neat little quadbike from Electric Vehicles Oceania. The Goanna 1000 features a 1000 watt motor powered by a 36 volt, 40 amp-hour battery pack. The battery can be fully charged in six to eight hours with the included charger.

The maximum load is 100 kg, making it suitable for most people, and it has a maximum speed of 25 km/h. Maximum grade is 30 degrees so it should suit most properties.

Other features include front hub and rear hydraulic brakes, front and rear cargo racks, lights, two forward speeds and reverse gear.

The Goanna 1000 measures 1330 x 760 x 860 mm and weighs 115 kg.

RRP: $1595 including GST. For more information contact Electric Vehicles Oceania, 220/354 Eastern Valley Way, Chatswood East NSW 2067, ph: (02) 9417 1547, info@lordco.net.au, electricvehiclesoceania.com.au.

Products

07

Convert your pump to solar

If you have a mains-powered pump, be it a bore pump, pool pump or other, converting it to run directly from solar power can make a lot of sense, especially if you need the pump to run independently and not be a drain on the home's main solar energy system, or if you are happy with its performance and don't want to completely replace the pump.

The range of AC pump inverters from Commodore Australia let you convert almost any mains-powered AC pump to a solar pump without the need for batteries.

Models are available that let you convert pumps with motors ranging from 550 watts single-phase right up to a huge 75 kW three-phase. The inverter simply connects to the pump in place of mains power and a suitable solar array is connected to the inverter.

You can even set up the system to maintain grid backup, so you can solarise a bore pump and still have it pump water at night or on cloudy days.

The inverters feature passive cooling (fanless) design for reliability and are IP65 sealed, so can be mounted outside.

RRP: start at $1995 for the single-phase 1500 W unit. For more information, contact Commodore Australia, ph: 1300 669 256, sales@commodoreaustralia.com.au, www.commodoreaustralia.com.au.

08

Water-efficient power-free washer

Even most front loaders are not that water efficient when washing a partial load, so wouldn't it be great to have a washing machine that can wash a few small items without hassle and with minimal water use? Or maybe you live alone or even off-grid and a full-sized washing machine just doesn't suit.

The Yirego Drumi is a new take on human-powered washing machines. It can wash up to 2.3 kg of clothes in just a few minutes using just 10 litres of water. You simply put in the clothes and five litres of water (the lid holds exactly that much water so can be used as a measure) and a tiny amount of detergent. Pump the foot pedal for two minutes and you are ready to rinse. Water is drained from the unit by pressing a button, so it needs to be positioned over a drain or used outside. Another five litres and two minutes for rinsing and then a minute for the spin dry (yes, it is a spin dryer too!) and your clothes are done.

The Drumi is not yet in production as Yirego plans to crowdfund it later in the year, but US and Canadian customers can reserve one for just US$129 (customers outside of the USA and Canada will be able to buy it soon, according to Yirego, and can sign up to be notified when it is available). Estimated delivery is July 2016.

For more information, contact Yirego Corp., Room 7211, 205 Richmond St W, Toronto Ontario M5V 1V3, Canada, info@yirego.com, www.yirego.com.

09

Divert your solar array

With feed-in tariffs being all but gone, solar energy system owners are looking at new ways to make use of their solar-generated electricity rather than feeding to the grid for only a small return.

One way is to divert the energy to another use, such as charging a battery bank. However, diverting a grid-interactive solar array directly, without it feeding through the inverter first, has not been realistic up until now.

The Solar Array Transfer Switch (SATS) from Latronics solves this problem. It simply fits between the solar array and the grid-interactive inverter and allows you to divert the output of the solar array to whichever alternative load you require, be it a heating element, MPPT charge controller for charging batteries or a controller for a solar pump. There are two models, SATS-10 and SATS-20, which have ratings of 100-500 VDC, 10 A, or 100-600 VDC at 20 A respectively.

The SATS units feature double pole switching for safety, MC4 connectors for quick installation, a 24 volt DC input for controlling the switching, an isolated relay output for driving an indicator or display, LED status indicators, and an IP65 enclosure so the unit can be mounted anywhere in the system. It measures 170 x 135 x 90 mm and comes with a two-year warranty.

RRP $1028.50 inc GST for the SATS-10 and $1228.70 for the SATS-20. For more information, contact Latronics, ph: (07) 5491 6988, info@latronics.com.au, www.latronics.com.au

10
Coatings made from waste

Most renders and wall coatings are pretty basic, involving the use of cement, sand and similar materials. They can be heavy (which adds to the embodied energy due to transport emissions) and have relatively poor environmental credentials.

Casafico makes a range of coatings which incorporate locally sourced recycled materials including glass, paper, polystyrene and even carpet fibres. They use no sand, so are much lighter than many other coatings, and require no sand mining, which can be a destructive process. They also have no iron content, so can't stain through rusting.

The range includes the all-purpose acrylic highbuild (which can also be used as a lightweight moulding medium), liquid plasterboard (an alternative to plaster), concrete repair and finish materials, a number of different textured renders and finishes, primer, exterior paints, wall tiles and tile adhesive.

All finishes are developed and manufactured in Australia.

For more information or to check out the range, contact Casafico, 18 Tarnard Drive, Braeside VIC 3195, ph: 1300 832 625, www.casafico.com.au.

11
Affordable, simple storage

Tesla Motors has turned their lithium battery expertise to domestic and commercial energy storage systems.

The domestic-scale system is called the Powerwall, and it comes in two variants—a 7 kWh daily cycling unit designed for load shifting on a daily basis and a 10 kWh weekly cycling unit for grid power backup.

Both units look the same and include battery bank, liquid thermal control system (like the cooling system in a car engine—it keeps the battery within the operating temperature range of -20 °C to 43 °C) and charge-control system all housed in a stylish wall-mounted outdoor-rated cabinet measuring 1300 x 860 x 180 mm and weighing around 100 kg.

Battery output voltage ranges between 350 and 450 volts, so they will be compatible with the majority of grid-interactive inverters already on the market. Rated output power is 5 kW continuous and 7 kW peak, with a 92% round-trip DC efficiency.

The Powerwall units are stackable, so if you need more storage capacity or maximum power capacity you just link two or more together. They come with a 10-year warranty, with an optional 10-year extension.

RRP: Australian pricing is TBA. The Powerwall is not expected to become available here until early 2016. Current US pricing is $3500 for the 10 kWh unit and $3000 for the 7 kWh model. For more information, see www.teslaenergy.com

12
Integrated energy system

Giant Power Integrated Grid System (IGS) is a hybrid unit designed for integrating grid power with solar and a backup battery. The IGS combines the functionality of an inverter, battery charger and solar controller, so it can manage all aspects of the power system. It is highly configurable to suit individual requirements and the system automatically prioritises and combines power sources in real time, based on availability and power usage.

There are a number of models, from the 800 W, 12 V unit to the 4000 W, 48 V model. The solar controller can be either a PWM (pulse width modulation) or MPPT (maximum power point tracking) unit. This lets you choose a model best suited to an existing solar array without needing to reconfigure the array.

The IGS will automatically channel power through its internal grid relay and combine grid power with its own output, for times when power draws exceed the inverter's capacity.

Other features include the configurable multi-stage battery charger compatible with AGM and gel SLA batteries, LCD control panel, included monitoring software, timers for engaging different power sources, full overload protection, lightweight high-frequency design, low standby power draw and wall mountability.

For more information, contact Giant Power, ph: 1300 877 554, www.giantpower.com.au.

Going hybrid
Adding batteries to grid-connected solar

Going off-grid may not be for everyone; a better route may be to 'go hybrid', by adding batteries to grid-connected solar. Andrew Reddaway explores the options.

THE solar battery industry is on the verge of disruptive change. Traditionally, large batteries were only seen in houses at off-grid locations such as Moora Moora (see box on the solar hybrid training course held there, which I attended earlier this year and which provided input to this article).

For off-grid systems, reliability is crucial; failure prompts an emergency call to the solar installer, so such systems have been designed conservatively using proven lead-acid batteries.

Meanwhile, in towns and cities, grid-connected solar systems have gone mainstream. As feed-in tariffs for solar export have dropped far below the rates paid for grid electricity, householders are looking for ways to cut bills by making better use of their excess solar generation. One answer is to add batteries to create a hybrid system: a grid-connected solar system with batteries either for backup or load-shifting.

This article gives an overview of current hybrid technology and the options available for adding batteries to an existing grid-connected solar system.

Different batteries for hybrid

A hybrid solar system is tough on batteries. Unlike an off-grid system that may store enough energy to last multiple days, a hybrid system's entire usable capacity will be charged and discharged daily. This requires a battery that can handle fast discharge rates at high levels of efficiency. Lithium batteries fit the bill, and have already become dominant in consumer electronics, power tools and electric cars. Compared to lead-acid, they are also smaller, lighter, don't require monthly maintenance and don't emit hydrogen gas. The only things holding them back in the solar market are unfamiliarity and price.

Image: Bosch Power Tec

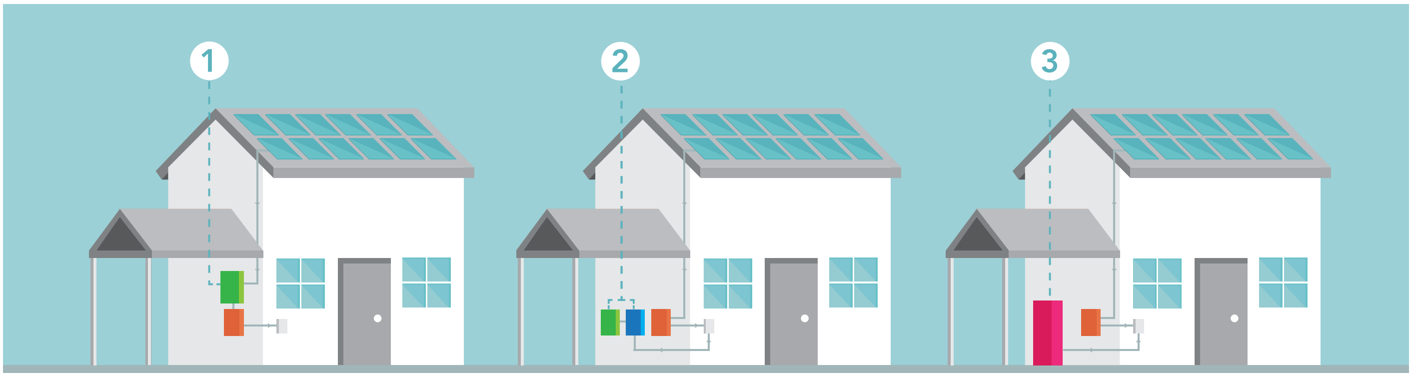
↑ Storage systems, such as the Bosch Power Tec BPT-S5 Hybrid, look more like appliances than battery systems.

The recently announced lithium Powerwall battery from Tesla is priced well below previous products and has a 10-year warranty. Traditional lead-acid batteries cannot compete with this new benchmark, so it's expected that systems will start to move away from them. Hybrid systems are now expected to become viable on pure economics in a few years or less. Early adopters are already installing lithium hybrid systems, as are some who value maintaining power during a blackout.

Option 1: Solar buffer battery

So how can a battery be added to an existing grid-connected system? The simplest concept is to connect it between the panels and the grid-interactive solar inverter, most likely wall-mounted next to the inverter. From a string of panels, current flows at, say, 400 VDC into the battery during the day. The voltage is regulated to the internal battery voltage, say 500 V. At night, DC current flows from the battery to the inverter and then to the house switchboard at 230 VAC. The inverter doesn't even know that a battery is present—as far as it's concerned the solar panels are still generating!

To work as a proper solar buffer, a sensor at the switchboard is also required. When the house is starting to import electricity



↑ Options 1, 2 and 3 for adding storage to an existing grid-connected solar system. The orange box is the existing grid-interactive inverter. In option 1, the batteries (green) are added between the solar panels and the inverter. In options 2 and 3, no changes are required to the wiring of the grid-interactive inverter; instead, a new circuit is added to the switchboard: In option 2, this connects the batteries (green) and a new inverter/charger (blue); in option 3, an all-in-one system (including batteries and inverter/charger in a fridge-sized box) is connected. Depending on the component housing, all these additions may require protection from the weather and ventilation.

from the grid the battery should discharge, and when the house is starting to export the battery should charge.

The advantage of this approach is that no new conversions from AC to DC are introduced. Costs are minimised as additional inverters aren't required, and efficiency is high. However, blackout backup may not be available, as a typical grid-interactive inverter shuts down when the grid is not present. An issue to check is whether the battery will interfere with the inverter's maximum power point tracker (MPPT). Also, how does panel generation bypass the battery when it's full? If the battery has a lower power rating than the total solar array, will the panel output be clipped?

It appears at least one of the Tesla Powerwall systems is designed to be installed this way (as far as the currently available specs imply, as of early May 2015). Another yet-to-be-deployed product is the Australian Sunsink. SMA sells a grid-interactive inverter with 2 kWh of lithium batteries included, although it is not yet available in Australia.

Option 2: AC-coupled inverter-charger

An alternative approach is to keep the battery separate from the existing grid-interactive inverter and wire it to the house switchboard. As the switchboard runs at 230 VAC, this is called an AC-coupled system. Batteries are DC, so an inverter-charger is required near the battery. The battery's nominal voltage is likely to be 24 V or 48 VDC.

One advantage of this method is that blackout protection can be provided by the inverter-charger. When the grid goes down, a high-quality hybrid system will step in so fast that house appliances are not disturbed by the changeover. As far as the grid-interactive inverter is concerned a blackout never occurred, so your panels can keep generating. Appliances can be powered by the total output of both the inverter-charger and the grid-interactive inverter (if the sun is shining).

To conserve the battery during a blackout, it is possible to have some high-usage household circuits switch off, such as the oven, air conditioner and pool pump. A petrol or diesel generator is relatively easy to add, with startup controlled by the inverter-charger. In fact, a good AC-coupled hybrid system has all the features to disconnect from the mains and go off-grid! However it may be under-sized to run the whole house full-time.

You can also exploit additional strategies to use the battery with such a system. For example, if you have cheap grid electricity in the middle of the night you could use it to charge the battery to cover a morning consumption peak. Another benefit of this method is that the existing solar system is not disturbed, avoiding potential remediation work where standards have changed since the original solar installation.

The main drawback of this approach is the cost of the smart inverter-charger. Also, electricity that goes through the battery requires an additional conversion from AC to DC and back again, reducing efficiency.

An issue to check is how the hybrid system regulates power from the solar panels during a blackout. Some inverter-chargers can communicate with the grid-interactive inverter, throttling its output when the battery approaches capacity. However, this feature may only be available with compatible models of grid-interactive inverter. If this is not possible, the system may not handle a large solar array.

If you're installing a grid-connect solar system now and considering adding batteries later, it's worth checking whether the inverter can communicate with any hybrid inverter-chargers.

There are many examples of AC-coupled inverter-charger hybrid systems, using, for example, Schneider Conext, SMA Sunny Island and the Australian Selectronic SP-Pro inverter-chargers.

Option 3: Self-contained appliance

This option uses an appliance with an inverter-charger in the top and lithium batteries in racks at the bottom, often called an 'all-in-one system'. Installation is simple—wheel it in, set it on the floor and wire it into the switchboard. The solar array may connect directly via a DC cable (DC coupled) or via a grid-interactive inverter (AC coupled). Ideally, battery capacity is expandable so you can start with a small capacity to minimise costs, see the effect on your bill and add

What about microinverters?

Currently it is difficult to add batteries to a microinverter solar system. Option 1 is not possible as electricity from the panels is AC. Options 2 or 3 are problematic as no microinverters can yet communicate with an inverter-charger. This will change when Enphase (the leading microinverter manufacturer) releases their own battery later this year.

additional cells as desired. If you move house, you can take it with you! Downsides to this option are cost, and finding a suitable place for the system. Examples include the Solari Energy SolaGRID, the Bosch BPT-S and the ZEN Freedom PowerBank. These all-in-one systems were covered in a buyers guide in *ReNew 128*.

Predicting the future

It's still early days for hybrid solar systems. Different concepts are competing for a small pool of early adopters and it's not yet clear which will become mainstream.

When adding batteries to an existing solar system, I expect Option 1 will be most popular due to relatively low equipment costs. For new hybrid installations perhaps Option 3 will dominate as it requires only a single device beyond the panels, reducing installation costs. Hopefully battery systems will settle on standard sizes as other home appliances have. A fridge shape seems optimal where space can be found in the garage or house; perhaps such spaces will be included as standard in future building plans. Longer, slimmer appliances may find a market along the inside wall of garages.

If your goal is to reduce electricity bills, it's a good idea to hold off on adding batteries until price drops flow through to mainstream products. If you have other motivations, there are solid hybrid systems available right now, at a price. Talk to an installer experienced in hybrid and off-grid.

If you're getting a standard grid-connected solar system, aim to keep your options open to add batteries later. When installers are quoting, ask them how batteries can be integrated. ✱

Further info:
ReNew 128: Energy storage system buyers guide (covers all-in-one systems)
ReNew 131: Battery buyers guide (covers separate batteries)
ReNew 128: Off-grid basics
ReNew 130: AC vs DC coupling
ReNew 122: Inverter buyers guide
ReNew 129: Inverter basics

Solar PV hybrid training course

Earlier this year I attended the Australian Solar Council's Solar PV Hybrid Training course. Below is a student's perspective as a guide to others considering this course.

Four days from 9 am to 5 pm were split between classroom lessons, hands-on exercises and special activities. No prior experience was required—attending with me were a mix of solar installers broadening their service offering, utility employees, university students and specialists in renewables and energy efficiency.

Classes were comprehensive, detailing the entire workings of a solar electricity system from the photovoltaic cells to calculating how much battery capacity is required for an off-grid house, to rule-of-thumb cost estimates. Concepts were illustrated with real-life examples, including common pitfalls such as poor planning, unrealistic expectations and commercial pressures.

I found Glen Morris's teaching style engaging and relaxed. Participant questions frequently sparked lively discussion among the whole group, giving useful insights into broader issues such as the electricity 'death spiral'. As a long-term off-grid solar installer, trainer and vice-president of the Australian Solar Council, Glen's depth of knowledge is outstanding. Outside class, we had many opportunities to pick his brains about specific issues. A solar installer who lives at Moora Moora assisted Glen, and an equipment manufacturer also gave a presentation.

Most hands-on exercises were held in a shed kitted out with solar panels, a wind turbine and a range of off-grid equipment. DC voltages were kept low, enabling all participants to join in safely. Working in a few groups, Glen assigned us tasks culminating in a small, off-grid solar system. Just like chefs in a kitchen, competition for tools was sometimes evident! Participants with electrical qualifications were given tasks in an operational equipment room that supplies electricity at 230 V to a group of buildings. The gear in this room was impressive—manufacturers often supply Glen with new models for testing.

Other exercises included using devices to calculate the shade cast by a tree at different times of the year. We also toured the facilities at nearby inverter manufacturer Selectronic.

The course is held at Moora Moora Cooperative, an off-grid community located on Mount Toolebewong near Healesville, 70 km from Melbourne. The community's heart is an old farmhouse, with members living in clusters of houses scattered in the surrounding bush.

One afternoon we toured some of the houses (including Glen's) to check out their off-grid systems. We saw a broad variety of approaches including micro-hydro, defunct wind turbines, passive solar, solar hot water and mini-grids servicing multiple houses.

Most course participants took advantage of the included accommodation: backpacker-style bunkrooms upstairs in the well-heated farmhouse. However one Melbournite stayed at a B&B in Healesville where his family was holidaying. A highlight of the week was the food; three meals plus morning and afternoon tea expertly cooked by a chef who lives in the community!

Andrew attended the course in exchange for advertising in *ReNew* and this course review. See www.cleanenergy.org.au/training/solar-pv-hybrid-training for course details.

Farming renewably
Reaping the benefits

One person/farm can make a difference: David Hamilton describes how his farm's sustainable conversion cut carbon, benefited the landscape and turned a profit.

↑ Much-improved pasture and happy Wiltipoll sheep.

I'VE READ many inspiring articles in *ReNew* from individuals trying to live more sustainably and lessen their impact on the planet. This article takes a slightly different approach—a rural perspective—to demonstrate that it can be commercially viable to run a farming enterprise using systems that are truly renewable, whether that's for water, electricity, housing, food, livestock, pasture or wildlife.

Our journey to sustainable farming began in 1993, when my wife Roberta and I purchased a 60-acre property in the south-west of WA with the twin objectives of restoring the degraded land and becoming as self-reliant as possible. The land included pasture that was totally lifeless and neglected, along with a dam, two winter streams, old gravel pits and two areas of magnificent remnant native forest. We wanted to be independent for water, electricity and as much of our food as was practical. With fewer bills to pay, we could work fewer hours off the farm—which was very appealing.

As a registered nurse with no farming experience, I was on a vertical learning curve. Luckily, Roberta has a dairy farming background and, with her accounting experience, is a wizard at making a dollar go a long way.

When we began, we were both working full-time. We spent the first two years establishing a gravity-fed water supply, preparing house and shed sites, and fencing the property, including to protect remnant bush from planned livestock. We also planted over a thousand native trees and shrubs, plus a few 'feral' trees for their air conditioning and fire-retardant properties.

Next we built our workshop and shed, complete with bathroom, with fittings sourced from the salvage yard. We set up our bacterial biofilter sewerage system, with the resulting treated water directed as a deep root supply for our planned fruit trees. With these in place, we were then able to move onsite as caravan dwellers. Cooking and refrigeration were from bottled gas, a wood-fired heater provided hot water, and a 500 watt generator provided all our electrical needs.

A healthy soil

Our attention then turned to researching suitable livestock and pasture improvement methods. We already believed that the traditional superphosphate and chemical farming methods were not sustainable, as they are energy hungry, non renewable and destructive of soil microbiology. The idea of working with nature, rather than against it, sat most comfortably with us. This included nurturing the soil back to a healthy state without using chemicals.

In a healthy forest or grassland, the soil is rarely disturbed. Leaves, branches and trees fall and this organic litter accumulates,

→ House with verandahs all around, and the workshop with the 1.5 kW solar system, which, combined with 1330 Ah batteries, provides all their electricity needs.

holding in moisture and feeding soil microorganisms and fungi. These tiny workers produce the nutrients required to feed the forest, while birds and other animals provide feathers, manure and eventually their own bodies, adding more nutrients—a totally sustainable, renewable system.

All we had to do was copy nature's principles as best we could. It sounds simple, but we had to start by repairing the decades of neglect. Soil analysis gave us a baseline to work from, confirming we were drastically low in soil organics and moderately deficient in other elements. That meant importing organic material—ruined or previous seasons' hay proved the most cost-effective and, available locally, required the least amount of transport energy. Over the years we brought in hundreds of hay rolls which we rolled out over the paddock surface to about 50 to 100 mm thick. We left the weeds in place to add more nutrients. Most weeds are nature's soil repairers; those that are deep rooted bring up valuable nutrients from deep in the soil, while some are nitrogen fixers, an essential element in healthy soils.

Now we had the organics, but needed the microorganisms to break them down and start the nutrient cycle. For this, we purchased 20-litre drums of live soil bacteria and fungi. Fish emulsion and liquid seaweed provided other nutrients. Sugars, humic acid and fulvic acid are needed to help the organisms feed and multiply. Molasses, a waste product, proved an energy-efficient and renewable sugar source.

I looked at boom sprayers as a way to disperse the liquid-borne bacteria, fungi and microorganisms. However, they cost from $20,000 and the pressures and filters would destroy the organisms—obviously not acceptable. Instead, I found an American device called a boom jet, which can spray 20 metres width, operates at low pressures and doesn't damage the live organisms I wanted to apply—and it cost less than $500. I modified our portable fire fighter to operate it and it has proven a complete success.

The improvements have been amazing. The soil and pastures get better every year.

A role for animals

Animals play a vital role in nature's systems. They control the herbage by eating it, provide dung and urine, and their feet incorporate surface organic matter into the soil.

We decided sheep were a suitably sized, manageable animal to complement our soil repair program. But which breed of sheep? All animals are renewable through their reproduction cycles but we wanted an energy-efficient breed. The woolly breeds require huge energy inputs, such as shearing to take off the wool, drenching with poisons to kill internal parasites, dipping with poisons to kill external parasites, crutching to remove wool under the tail contaminated by dung, and mulesing, the surgical removal of skin and wool under the tail to reduce flystrike. It's worth remembering that the dung the treated animal passes contains such poisons which can continue to kill soil organisms and earthworms.

The Wiltshire sheep ticked all the boxes for us. An old English breed, it fully sheds its wool for summer and grows it again for winter. It's proven itself as a strong performer in Australian conditions from the harsh outback to high rainfall zones, and is an excellent meat breed. It can be managed as a totally organic, chemical-free enterprise. We went with the polled version (without horns) called the Wiltipoll. We are now a nationally registered stud breeder supplying Wiltipoll stud sheep to commercial sheep farmers, allowing them to reduce most of the aforementioned high energy input costs. We also supply flocks to olive farms, orchards, certified organic farms and small lifestyle farms.

Before we introduced the sheep, we needed stockyards to handle them. We started with simple pens and a loading ramp. Over time we upgraded to a fully weather-protected working area. We felt that working out of the elements would be less stressful for both the animals and us. Research shows when animals are stressed they burn stored energy to keep cool or warm, energy that could be used for growing. We apply this same principle to the pasture areas by planting trees and shrubs to provide shade, shelter, wind breaks and another food source from leaves and seeds.

To best use the improving pasture as sheep food, it was necessary to control the animal's access, so that they would eat the pasture grasses and clovers more evenly, and not pick

↑ Three options of hot water plumbing: gas-boosted solar, full gas and solar only.


↑ Levers are used to control ventilation ducts.

the best and trample the rest. We achieved this using simple tread-in electric fencing, moving it slowly across a paddock, allowing the sheep to access a narrow strip at a time.

The fencing is powered by a single 64 watt Unisolar photovoltaic panel on the roof of the stockyards, wired through a regulator to a 12 volt deep-cycle battery. A Pel 12 volt energiser (the device that sends high voltage pulses to the fence to electrify it) is connected to the battery and distribution wires run from this unit out to the fences. The system can supply full power to 50 kilometres of fencing 24 hours a day; the original $150 battery lasted eight years.

Chickens were included early in the system, as egg layers, meat birds, pest control agents, fertiliser suppliers and mini tractors to turn the soil. Australorp birds free range in the orchard as well as in the pasture with the sheep. Pekin birds do all the same jobs but they are much smaller and more gentle so they have the run of the vegetable gardens, and do most of the weeding and all of the pest control there.

Water is essential

A reliable supply of clean water is essential for humans and livestock. After cleaning out the dam and removing 100 years of silt and debris we sent water samples for a detailed analysis. Luckily, the results exceeded the health department standards: we had excellent quality water. We had already installed three 90,000-litre concrete water tanks, one to catch the rain from the workshop and two on the hill to operate on gravity-feed back to the house and out to covered water troughs in every stock paddock. One hill tank holds rainwater only and the other can hold rain or dam water. Only the house and workshop bathrooms use rainwater. We irrigate the orchard and gardens using dam water via measured trickle systems to minimise waste. A future fire-protection sprinkler system on and around the house will run on dam water.

To use a fuel-driven pump to move water is neither renewable nor energy efficient, so the logical choice is solar-powered pumping. We installed a Lorentz helical rotor DC pump on a float ring on the dam powered by two pole-mounted 75 watt Lorentz PV panels in a full sun position on the bank. The system moves 1200 litres a day, with a run of 200 metres (horizontally) and a head of 50 metres (vertically). This is more water than we need a day, so the control unit is switched off several times a year when the hill tank is full.

Building our home

We knew from day one that our house had to be as energy efficient as possible. After 10 years in the caravan we had learned many valuable lessons on energy efficiency and how easy it was to need and use less. Today we still ask ourselves if something is a need or a want. Building the house ourselves turned into a five-year project and required determination to maintain enthusiasm and see it through to completion. During this period I worked off-farm part-time to enable us to make the house construction a high priority.

Termites are important recyclers of nutrients and organic material, but we did not want our house recycled just yet so capped steel column foundations were required. The sloping site gave us a floor level three metres above ground at the front and half a metre at the back. From floor level up, the construction uses timber. We planted over 200 hardwood trees on the farm, to offset the hard and softwood timber we purchased. The roof is steel sheeting. By elevating the house we gain many benefits that improve our energy efficiency, plus plumbing is much easier.

For our location and personal needs, we determined that a low thermal mass house, with well-insulated roof, ceiling, walls and subfloor, excellent horizontal and vertical ventilation and three-metre verandahs all round would be the most energy efficient. Once the hot summer sun sets we usually receive a cooling night breeze and the low thermal mass building loses its stored heat within a few hours.

We incorporated a vertical main duct in the centre of the house to carry electrical switchboards and cabling, water pipes and a roof space warm air recovery system. Another section of the duct allows vertical air movement both passively and actively from under the house to the inside at floor level, then from ceiling level into the roof space, and finally out of the roof via a ridge-mounted cupola. All three air ducts can be closed down using simple levers in the main duct. This has been a great success for internal climate control. The fans use less than 40 watts and move 700 cubic metres of air an hour.

Energy systems

When we first purchased our property we enquired about having the power connected. Although the main line was less than one

"Termites are important recyclers of nutrients and organic material, but we did not want our house recycled just yet so capped steel column foundations were required."

→ The solar-powered pump is used to fill a water tank from the dam when required. The water is used in the house and to fill water troughs in paddocks.

kilometre away, the grid supplier estimated that the cost to connect to our boundary would be $28,000, plus an additional $10,000 to bring the line to the house.

It was this insane price that started my investigation and self-education on solar PV and sustainable energy systems. Reading *ReNew*, I immediately learnt I could install an appropriate system for less than $20,000, so right from day one, we were planning to use solar.

It took a couple of years to get the stand-alone system set up. For the first two years in the house, we ran on a Honda 2 kVA inverter generator for lighting, television and clothes washing, with refrigeration from our small 90-litre caravan gas fridge.

Today we have a 1.5 kW system that provides all the power we need and more. We installed eight 190 W Schott panels, an SMA Sunny Boy 1700 inverter, an SMA Sunny Island 2440 inverter/charger, with a separate control panel, and six 4 volt (2 V + 2 V) Exide 1330 Ah (C100) lead-acid batteries wired for 24 V. Our average daily power consumption is less than 2.5 kWh and the solar PV system produces between 6 kWh per day in winter and 10 kWh per day in summer.

We have since installed a small Panasonic inverter air conditioner in the bedroom, for those occasional very hot summer days and nights. We use all the basic mod cons: a twin-tub washing machine, breadmaker, TV, stereo and computer, but they have been carefully selected to be the most energy-efficient available and on our genuine need of the appliance. We do not have or need, a dishwasher. Refrigerator and freezer are energy-efficient 240 V AC units. An 1100 watt vacuum cleaner is used on sunny days only or we run it from a Honda EU20i generator in winter. This genset will easily run our complete house and workshop as a backup power supply and provide battery charging if needed.

We have three-phase woodworking machinery which is run from a three-phase diesel generator. Since this equipment is only used intermittently, the most efficient choice was to leave the diesel genset as a separate power system. I also use it for welding. I added extra change-over switches to allow me to send surplus electricity on one phase from the diesel genset into the system, so when it has to be run, it can power everything.

Hot water is supplied from a Beasley stainless steel solar hot water system with a Rinnai Infinity 20 instantaneous gas system as backup. By routing all the plumbing to a box near the gas unit on the verandah, we can simply change valves between full solar hot water, full gas or gas-boosted solar, depending on the weather. Over the last six winters we only needed to use the gas, full or boost, an average of 15 days a year—very efficient, we feel. For cooking we use bottled gas to a simple upright stove. Roberta makes our biscuits, pickles, jams, cakes, preserves, cuppas and meals on gas, and a nine kilogram bottle lasts about six months.

A satisfying conclusion

The transition from once degraded land to its present state of efficiency and health has been amazing and immensely satisfying. We now see a huge diversity in birdlife, insects, small mammals and reptiles, from top order predators, supported by a healthy food chain, right down to soil microorganisms. We have an environmentally and commercially sustainable farm and we're striving to keep it that way. I now work off the farm just two days a week. We enjoy sharing our knowledge and ideas with others and we are encountering more and more people who want to follow a similar path. The future sounds bright. The sounds we hear are nature's sounds. ✱

David and Roberta Hamilton are happy to assist with any queries on 08 9732 1334.

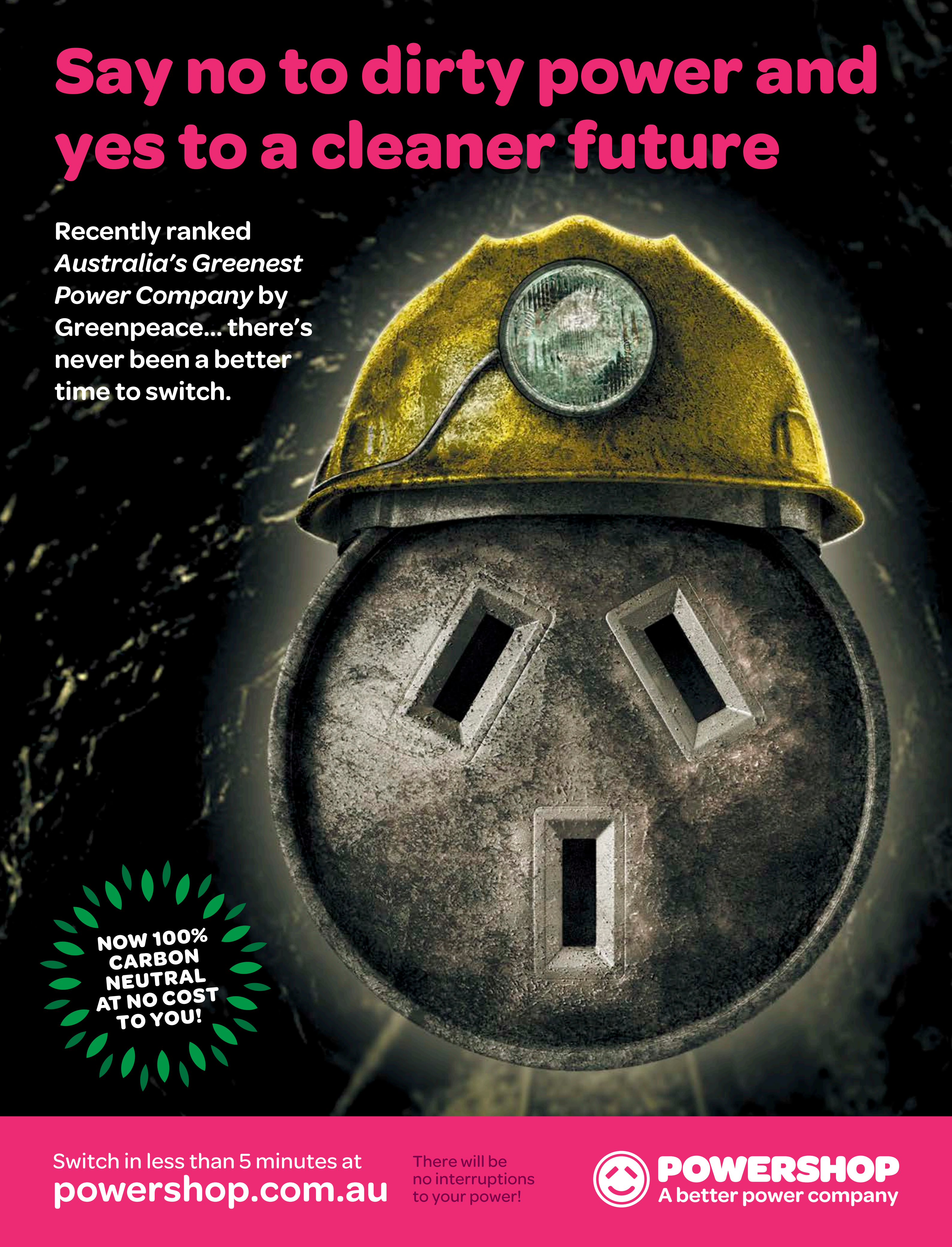
Other farms using a similar approach include:
www.taranakifarm.com.au
regenag.com
www.polyfacefarms.com

Sheep, emissions and ethics

While small farms with few sheep are able to look after the needs of their flocks with minimal environmental impact, the majority of sheep require considerable upkeep by way of chemicals for dipping. drenching and cleaning, all of which add to the contaminants and carbon footprint of wool production.

Sheep also produce methane from their digestive tracts, with a grass-fed ewe typically producing 17,000 litres (11 kg) of methane per year. That's close to 900,000 tonnes of methane (the equivalent of over 20 million tonnes of CO_2) produced from Australia's 80 million sheep (or about 3% of Australia's emissions). Emissions can vary based on type of sheep and diet.

There have been ethical issues regarding the sheep industry in Australia, particularly in the areas of mulesing and live export. The industry has been working to address the first issue with the development of the SRS Merino (www.srsmerino.com), which doesn't require mulesing. However, many farmers still run the older breeds which require mulesing to avoid flystrike, so more needs to be done to push the newer breeds of sheep. Overall, the industry is starting to think about what more needs to be done, both environmentally and ethically, and this has resulted in projects such as Target 100 (www.target100.com.au) with the aim of reducing the environmental footprint of animal farming while improving conditions for the animals.


Say no to dirty power and yes to a cleaner future
Recently ranked *Australia's Greenest Power Company* by Greenpeace... there's never been a better time to switch.
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Many hands make light work
Collaboration in building

Can a collaborative approach to building design lead to even better sustainability outcomes? Eugenie Stockmann describes a different type of development via The Green Swing.

WHEN setting up The Green Swing in 2010 to develop a plot of land in inner-urban Perth, we wanted to create a distinctly different type of housing development—one that would be sustainable, affordable and with a great community feel. After all, we were planning to live in it ourselves!

The Green Swing is what we called our development company, a partnership of myself, my partner Helmuth and another couple, Alana and Mark Dowley. That first project, Genesis, was completed in 2012 and is now home to the four of us, alongside two other apartment homes. Pleasingly, it went on to win several industry awards.

We learnt a lot along the way; perhaps most importantly, we realised we didn't want to let all that knowledge and experience just fade away. So it wasn't long before we commenced our second project, The Siding, due for completion in early 2016.

Image: Ethan Dowley

↑ The Green Swing crew looking at plans and materials on-site at The Siding with their architect and builder. From left to right: Alana Dowley, Mark Dowley, Sid Thoo (architect), Eugenie Stockmann, Gary Wright (Right Homes, builder), Helmuth Stockmann.

Oversights and inconveniences

We also learnt that there's always room for improvement. One area we were particularly keen to improve was the process of collaboration.

You might think that all buildings are designed and constructed via collaboration. After all, it's very hard for one person to design and build a house completely by themselves. Even the early stages of a project involve a number of people—the client, architect or building designer, draftsperson, engineer, planner and building surveyor, just to name a few.

Yet, the experience of our first project highlighted that effective and meaningful collaboration doesn't always come easy. With so many people involved, it perhaps comes as no surprise that problems, inconveniences and oversights often occur, resulting in head-scratching exclamations such as, "Why did they do that?" or "If only they'd asked before they did..." and "This could have been easily avoided if..."—you get the picture.

To add to the issues, people's idea of and commitment to sustainable building design and construction can vary. The Australian Public Service (2007) described sustainability as a complex, 'wicked' issue, in that no-one knows what it looks like, nor how to get there. Somewhat ironically, their conclusion was that a collaborative approach is best for dealing with wicked problems!

For us, it was experience that taught us the most about what real collaboration means: the importance of open and honest communication to make sure you're all 'on the same page'; that it is not necessarily what you know, but who you know, along with being able to admit what you don't know; that to reach your shared goal, you will need to be able to make compromises. We'd like to share a bit of our journey with you.

Shared values

The Green Swing is a partnership of two couples, so collaboration is integral to the way we work. Of course, this sort of business partnership can be challenging. For some architects we approached, this posed a 'red flag'; one even commented that it was hard enough to provide "marriage counselling" to one couple, let alone two. Unfortunately, it is not uncommon to hear of group projects or business partnerships that commence with great promise, but conclude acrimoniously.

Having a clear, concise vision was what kept us on track. It might seem like a small thing, but it was something to come back to when things got tricky. Coming up with our 'vision statement' also helped consolidate our own thoughts about what was important to us. Developed around the kitchen table over a number of weeks, our vision was (and still is) to create inner-city living environments which are highly sustainable and affordable, encourage creativity and inspire real change.

This vision guided us during the design phase. It led us to include apartments in the mix as an affordable option, to include a bridge between the buildings to inspire creativity, and to provide shared garages and common walkways to encourage community.

Was there much arguing involved to come to a consensus? No, just lots of good constructive discussions; everyone's input improved the result!

Ways to collaborate

In our first project, the builder was responsible for the overall project, but we took responsibility for various aspects, such as building the strawbale walls and the supply of many recycled materials.

For our second project, we were keen to further refine the collaboration to avoid some of the issues (such as late fire design requirements) that arose during the first.

To do this, we wanted to strengthen the working relationship between the architect, builder and other suppliers and consultants. Our first project took a year to get design approval and another year for the building licence. We felt this was too long and really wanted to reduce this if possible.

We also got other investors on board, which added to the collaborative effort. The Green Swing retained responsibility for the project, but the new investors provided some 'more hands', and played an active role in design meetings, major decisions and took on some administrative responsibilities.

Integrating design and construction

The design and construction of most building projects tends to be highly linear, as illustrated in Figure 1.

In some respects, this makes a lot of sense as there is a logical sequence in which a building needs to be assembled.

However, this ignores the close relationship between design and construction. Design is a creative process in which an idea for a new building is described via plans and specifications; construction then identifies the activities and resources required to make that idea a physical reality. Neither exists in a meaningful way without the other; for sustainable building, the flow between the two is doubly important to ensure that the designed-for Star rating is achieved in the build.

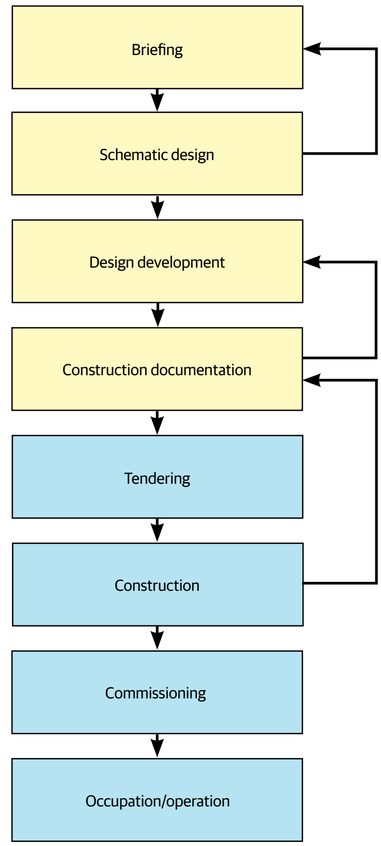
We were very keen for the architect and builder to work closely together from the inception of the project. We were also keen to get other consultants involved early in the design process, such as house energy rating and lifecycle assessors, landscape designers, and structural and fire engineers.

We hoped that this would mean that any issues with the design could be ironed out as early as possible, to minimise unexpected changes that might otherwise be required to obtain a building permit or that might increase construction costs. The other aim was to get regular feedback on costs from the builder to keep the project within budget without compromising on our sustainability goals—we've seen that it's not uncommon for a project's sustainability credentials to be watered down considerably after design approval due to cost blowouts.

Testing out a range of concepts

While schematic design is often thought of as a loose or conceptual part of the design process, many critical design decisions are made during this stage.

One of the things we loved about this stage was being able to explore a multitude of different ideas. Getting input from the builder meant that we could get a sense of how



Source: Danielle McCartney/www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1571.

↑ Figure 1. Generally accepted flow of tasks in building design and construction.

↑ One of the houses in the Green Swing's first development: affordable, sustainable and with a community feel (and a great vegie garden!).

↑ The Siding detailed sketch of one of the design concepts, left, and impression of the final design, right. The design includes three buildings with seven dwellings: two townhouses in one building, three apartments in the second and two apartments in the third. A sole occupancy unit is included in one of the apartments to enable shared but independent living, possibly for an older child or an elderly parent. Walls were constructed from insulated cavity brick downstairs and reverse brick veneer upstairs.

realistic or costly those ideas might be.

For example, our initial design concepts included one, two or three individual buildings of different shapes and sizes. We preferred a design consisting of three separate buildings: we believed this would provide the best outcome from a community perspective, creating interesting spaces around and between the buildings for private courtyards and common outdoor spaces.

However, we were mindful of the impact that three individual buildings might have on construction costs. Given our collaborative process, we were able to consult the builder, and they pointed out that there were actually advantages in having multiple buildings, such as the ability to stagger the build and have trades move from one building to the next. Hence, we felt confident to proceed with this approach.

Another example of collaboration was with the planning staff from our local council. The schematic design was developed with their input. While our previous project went on to win a number of awards and has been positively received by the local community, when it was originally submitted for planning approval, planning staff had ironically recommended the project be refused because it did not comply with local council streetscape policies such as setbacks and the location of front doors and garages.

Although these policies have since been reviewed and updated to encourage sustainable developments like ours, we were keen to get feedback from planning staff early in the design process to avoid that sort of surprise after submitting. It turns out that many local government authorities welcome the opportunity to discuss proposed developments at this pre-lodgement stage and we highly recommend taking advantage of this opportunity, if available. While it does not—and should not—guarantee a positive outcome or approval, it is a valuable opportunity to get feedback.

Developing the design

The next phase was design development, to get the detailed design ready to submit for development approval.

During this phase we continued the collaboration between us as clients, the architect and builder via regular meetings to discuss and fine-tune the design. At various times we also contracted experts such as building surveyors and fire design engineers to attend meetings and provide advice on aspects of the design, such as the location of windows, doors and fire exits.

We also used energy and lifecycle assessors to regularly benchmark the design, to ensure it would deliver the hoped-for sustainability outcomes. We were aiming for high-performing homes with a minimum NatHERS rating of 8 Stars. Lifecycle analysis helped us quantify the carbon effects of any changes to the design and the result was a design with a net carbon-positive outcome.

Having input from the builder proved pivotal. The builder was able to confirm that a suggested approach to thermal mass in the second storey was feasible. They also helped with costing different types of attic windows, and their input led us to update our design with a cost-effective approach to the rooftop balconies. The latter required updates to the drawings, but at this early stage that wasn't a problem.

Our builder also helped in assessing the cost-effectiveness of using SIPs for our roofing material. We got outside quotes for the SIPs and compared this to estimated costs from the builder for traditional roof construction. In the end, we decided we couldn't justify the extra cost for the SIPs (though we would like to explore this option again in a future project).

In our first project, fire design requirements proved problematic when we applied for the building licence, so we were keen to avoid that this time. By engaging a fire engineer during design development, we received invaluable advice regarding fire compliance for aspects such as wall openings near boundaries and escape distances.

A faster development approval

The plans for The Siding were accepted by council within seven months after purchasing the land (including the 60-day settlement period), a vast improvement compared to our first project (12 months) and a great result considering the bespoke nature of the project. Our experience from the first project definitely helped, but having early input from both council and other experts (as described above) were crucial too.

Getting the building licence

Preparation of the construction drawings and specifications required for a building licence can take a long time. Our first project had presented some unpleasant surprises and hurdles during this time and dealing with the red tape was a frustrating experience.

Contracting the builder and other consultants during design

The Green Swing's approach meant that we contracted our builder very early, so that they could provide input in the design stages.

Many people may be reluctant to lock in a builder upfront, out of concern that pricing may not be as competitive compared to a traditional tender. This is definitely a concern, and should be weighed up against the relative merits and drawbacks.

One of the advantages of The Green Swing's approach is that the builder is very familiar with the project before construction begins. There can be so much for a builder to take in if the plans are just handed to them for quoting, and there's a real possibility that they will overlook or not properly consider some things. It's also not uncommon for tenders to come in with considerable price differences or exclusions, which can make it difficult to objectively compare quotes.

The final contract price for The Siding ended up being slightly more than the original budget, with a cost overrun of around 5%. While no alternative quotes have been obtained, we still feel this is a competitive price.

Some suppliers provided pre-assessment consultancy services at no charge, on the understanding that they would be engaged for the actual work down the track and not spend much more time in total than they normally would. However, this can sometimes mean that the initial consultation may not be as comprehensive, or may require further investigation or review. It may be in your interest to pay properly for these pre-assessment services so you have clear, documented information that you can rely upon. However, this may lead to higher costs; it is a balance between best outcome and economic viability, for all parties.

Along the same lines, instead of committing yourself to a particular builder, you may consider engaging the services of a builder to provide an advisory-only role during the design phase of a project.

Is price the only consideration?

Is price the only selection criterion, or are there other things you should take into consideration when selecting your builder? Our view is that while price is important, it should be weighed against other considerations, particularly when sustainability is a key goal of the project.

One such consideration is waste management. The environmental impact of construction waste can be significant. The conventional way of dealing with this issue is to make waste management requirements a part of the tender documents and specifications. However, this can mean you end up with some requirements that are irrelevant or impractical, and, in reality, as a client, you have little control over what happens to waste on site.

We believe that it's therefore critical to have input from and cooperation of the builder to develop a pragmatic yet effective strategy for dealing with waste. For our first project, we went on a tour with our builder of a construction waste processing facility, and then jointly drafted our waste management plan. Together, we investigated new suppliers, materials and technologies before committing to them. For us, this collaboration around managing waste was equally as important as price.

Obviously, we were hoping to avoid this the second time around!

Despite rapid development approval, building permit preparations took longer than expected. The collaborative effort hadn't picked up on all the issues we'd hoped. More redrawing work was required than originally expected as the builder preferred to start technical drawings from scratch rather than using the architect's files. A crucial detail had also been overlooked during the preliminary assessment which had an impact on the design and engineering of one of the buildings—the building surveyor ended up classing one of the buildings as Class 2 which meant we had to change, for example, several openings to have fixed fire-rated windows.

Dealing with the red tape also still took a considerable amount of time. Approvals from the building surveyor, structural engineer, fire engineer, acoustic engineer and FESA (the government authority) often couldn't be completed concurrently, which would result in delays for a couple of days, if not weeks. We estimated that the timeline was drawn out by two to three months overall, because of redrawing and red tape; in total it took 10 months to go from development approval to building licence. Still, this was an improvement of around two months compared to our first project, and for a more complex project at that.

Stepping back from construction

For this project we made a conscious decision to take a step back and include most aspects of the construction in the contract with the builder. The collaborative build in the Genesis project was a fantastic learning experience, but it was also labour-intensive and time-consuming. We were ready for a break, to sit back and enjoy our new living environment.

But there are a few aspects that we've taken on—or rather that we'll take on in collaboration with the purchasers—such as the landscaping. We see developing the garden as a great opportunity for the new residents to get to know each other and so start to build a strong community.

Lessons learnt

Collaboration isn't always easy. As noted earlier, having a shared vision and being clear about what was important to us helped keep us on track. We sometimes had to compromise, of course, and consider alternative priorities or strategies, but we found that the benefits outweighed the negatives. Our collaboration meant we could draw on a range of different skills and, with more people, there's more time available to get things done.

We simply couldn't have done this on our own. We look forward to many more sustainable collaborations in the future.

This article was prepared in collaboration with The Green Swing's architect, consultant and friend Sid Thoo. For more on The Green Swing, see www.thegreenswing.net.

Local, clean, green
The new generation

ATA intern Ashleigh McMillan fills us in on the latest community energy projects driving change in Australia's renewable energy mix.

SEVERAL communities around Australia have taken up the challenge of going 100% renewable, and many more are crowdfunding solar on schools, community centres, pubs and more. Community energy is infectious it seems!

One of the driving forces behind that growth is the Coalition for Community Energy (C4CE). Formed in June last year, with the Alternative Technology Association (ATA, *ReNew*'s publisher) as one of its founding members, C4CE is a coalition of organisations all aiming to assist or develop local community renewable energy projects.

A key stepping stone towards that has just been released by C4CE: the National Community Energy Strategy. This document provides a snapshot of what's happening now in Australia's vibrant community energy sector, alongside an examination of future potential. It includes recommendations on community energy models, funding and regulatory reform. An important aim of the national strategy is to create an environment that encourages innovation and new funding models for community energy—something the ATA is deeply supportive of!

For those looking into launching their own community energy project, the strategy includes a detailed appendix (Appendix E) on behind-the-meter solar models—those where the solar energy generation is used on-site rather than being exported to the grid. The appendix provides case studies of successful projects and, more broadly, an analysis of the challenges and costs faced by community energy projects, and how they can be addressed. It also includes an interactive decision guide to assist with working out the model most appropriate for your project (see sample at right).

↑ Installed in March 2015 at the Beechworth Montessori School in Victoria, this 15 kW solar system was financed as a Corena 'Quick Win' project via crowdfunded donations providing an interest-free loan. Repayments on the 'Quick Win' loans go towards paying for new projects. This system includes an SMA 15 kW inverter and 60 Suntech polycrystalline panels at a total cost of $24,000, with $16,000 provided by Corena and the rest by the school. SA-based company Suntrix donated an educational monitoring system.

The Coalition for Community Energy's Nicky Ison says she hopes the national strategy "will help create a framework for and culture of collaboration between all organisations interested in growing a community energy sector in Australia."

The report highlights just how much has been achieved over the past year. Through 19 community energy projects, C4CE member organisations have:

- contributed over $23 million in community funding for energy infrastructure
- installed over 9 MW of renewable energy systems, with 50,000 MWh of clean energy already generated by end 2014
- avoided over 43,000 tonnes in carbon emissions
- developed a membership and supporter base of over 21,000 people.

The strategy was produced with welcome support from ARENA (Australian Renewable Energy Agency) and is available in full online. www.c4ce.net.au/nces

New partnership for ATA

The ATA has entered into a new national partnership with community energy crowdfunding platform The People's Solar to support projects across Australia. The collaboration aims to accelerate the delivery of energy projects that are community-owned, local and regenerative.

Director of The People's Solar, Tosh Szatow, says it's an important time for the sector to be focused on getting projects up and running to "prove it can make an impact on how quickly Australia transitions to 100% renewable energy."

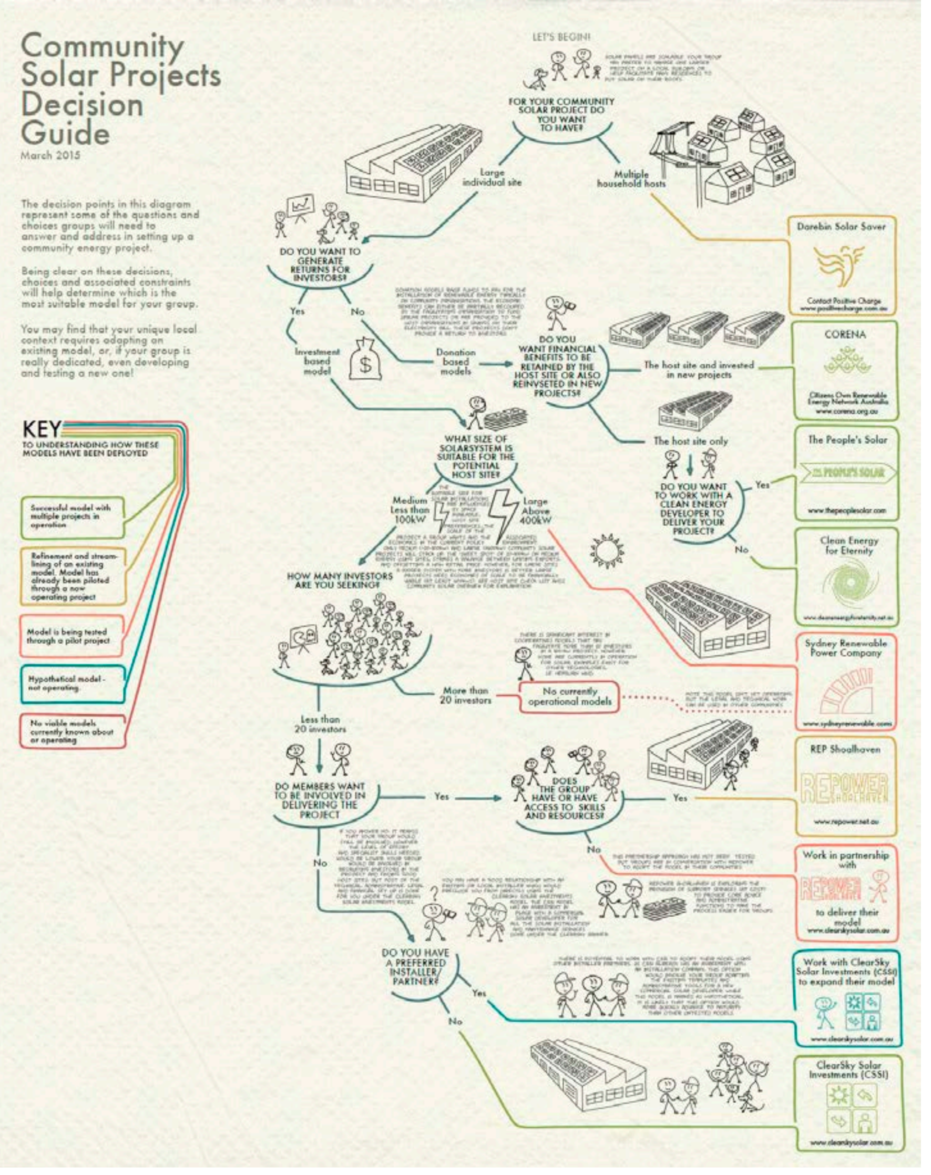
From St Kilda to South Geelong

The People's Solar has just succesfully completed crowdfunding of a 15 kW solar array and LED lighting for St Kilda Community Housing, a service that provides affordable housing for the disadvantaged.

With the solar array and LED lighting installed, St Kilda Community Housing will be able to use the savings of about $5000 per annum to train five tenants in semi-skilled work each year. The array will consist of Jinko Smart Panels with Tigo optimisers.

The People's Solar is also in the early stages of fundraising for a 13 kW solar array and LED lighting at South Geelong Primary School. The resulting $6000 savings per year will go towards new bike sheds and the creation of a food-producing green wall.

There are other benefits beyond the group or organisation receiving the solar array. Tosh says the Geelong project "has proved a great way of engaging the Geelong community on solar power, and the benefits it can have to the local community".
www.thepeoplessolar.com



↑ As part of the National Community Energy Strategy, C4CE has developed an interactive decision guide, with a sample above, to assist groups to understand the possible models and identify similar successful projects that may be useful as guidance. See www.bit.ly/1SOKLAM.

Energy for the people in Tyalgum

With support from the NSW Office of Environment and Heritage and local business Australian Radio Towers, the ATA is also working with Energy For The People (a 'benefit corporation' (see box) that manages clean energy projects from feasibility through to implementation) to help the community of Tyalgum in NSW transition to 100% locally sourced sustainable energy.

Energy For The People kicked off a community consultation process with two community workshops in May, along with other meetings with locals to explore their options. ATA's energy specialist and consumer advocate Craig Memery is helping the community to wade through the deep and murky waters of energy regulation and policy for community energy projects, joining the team for an inspection of the local infrastructure and a community energy forum at nearby Murwillumbah.

ATA and Energy for the People will be presenting a report to the community, setting out some of the costs, benefits, risks and opportunities associated with various ways of achieving their goal of 100% independent, sustainable energy.

The project draws on the work Energy for the People and the ATA conducted in 2014, that explored the economics of going off-grid across a range of scenarios including individual residential and community-scale off-grid systems.
www.energyforthepeople.com.au/content/little-town-big-vision

What is a benefit corporation?

B Corp is to business what Fair Trade certification is to coffee. B Corps are certified by the nonprofit B Lab to meet rigorous standards of social and environmental performance, accountability and transparency. Today, there are more than 1000 certified B Corps from 33 countries working together to "redefine success in business". www.bcorporation.net

↑ One of Australia's first community-owned solar farms is now a reality at Tathra on the NSW south coast, helping to power the Tathra sewage treatment plant. The 30 kW solar farm is an initiative of community climate action group Clean Energy for Eternity, in partnership with Bega Valley Shire Council, and consists of 120 panels of 250 W capacity arranged to form the word IMAGINE, visible from the air on the approach path to Merimbula airport. ATA's Sunulator tool helped in the feasibility analysis. See cleanenergyforeternity.net.au for more info.

Image: Andrew Brown, courtesy Bega Valley Shire Council

Corena's winning formula

Another grassroots group, Citizens Own Renewable Energy Network Australia (Corena), has recently installed a solar PV installation at Nannup Community Resource Centre in WA, bringing the total amount installed via their 'Quick Win' community solar model to 45 kW.

After just five projects, the group is excited about the potential for their 'revolving' funding model. Spokesperson for Corena, Margaret Hender, says, "The five projects completed so far have cost a total of $78,900. Climate-concerned citizens donated most of that, but $14,351 of it came from loan repayments from completed projects."

Tulgeen Disability Group's 7 kW system on their centre in Bega, NSW, was the first project funded via Corena in late 2013. Since then Tulgeen has even been able to self-fund the addition of 3 kW to the system. Tulgeen CEO Peter Gorton is a fan of the model. He says they're able to do more of their core work supporting 50 people with a disability as they are "wasting less on purchasing energy."

Corena provides crowdfunded interest-free loans to pay for solar installations, which are repaid over an average of five years from the resultant savings on power bills. Corena's next projects are a community centre in Queensland's Ravenshoe and a community childcare centre in SA.
www.corenafund.org.au/quick-win-projects

Investing in solar in Sydney

The Sydney Renewable Power Company, an ethical investment company for Sydneysiders, is preparing to open their first project to shareholders in spring 2015, financing a solar PV system atop the International Convention Centre (ICC Sydney).

The 520 kW system is expected to generate enough energy to power 100 homes, and is aimed at providing apartment dwellers and renters who can't install their own solar systems with a way to invest in solar, both for potential financial returns and to make a difference to the electricity supply. As Associate Professor Mark Diesendorf from UNSW says on their website, "Medium-scale distributed solar energy systems—located on the roofs of factories, warehouses, shopping malls and convention centres—could provide a significant proportion of urban electricity demand."

With this first project, all generated power will be consumed on-site by ICC Sydney over the life of the 25-year contract, with the Sydney Renewable Power Company eligible to sell and receive large-scale generation certificates.

The project is scheduled to start generating in December 2016. The company has been supported by funding from Embark, an Australian not-for-profit which supports community participation in renewable energy projects.

Sydney Renewable Power Company aims to show that energy projects can happen in a 'bottom up', community-driven way, rather than a 'top down' way.
www.sydneyrenewable.com

Sunulator

The ATA has continued to lead the development of tools to assist communities assess the financial viability of their projects. Sunulator assesses the economic feasibility of all sizes of grid-connected solar systems, of particular use to communities needing to understand the financial viability of a community solar project.

In news sure to be of interest to many ATA members, Sunulator is currently being updated to include battery storage. The feature is expected to be available for download in July—well before the first Tesla batteries reach our shores!

In a recent survey, Sunulator users asked for battery usage analysis to be added, and also pinpointed a need to be able to analyse solar data Australia-wide. Keep your eyes peeled for this being added later in the year.

Sunulator has been used to estimate solar generation for a number of prospective community solar projects in Victoria and NSW, including the Tathra Community Solar Farm and the Black Forest Timber Mill.
www.ata.org.au/ata-research/sunulator ✱

Resources:

See *ReNew 129* for articles on community energy projects around Australia and resources including a list of organisations involved in community energy and an article on models for community solar.

Coalition for Community Energy c4ce.net.au with the National Community Energy Strategy at c4ce.net.au/nces

Embark Wiki—resources for community energy projects embark.com.au.

Bricks, blocks and panels
What's in a wall?

There are many different approaches used for building the walls of a home, but which one is ideal for your build? Lance Turner takes us on a quick tour of the different systems, materials and their sustainability credentials.

FOR those embarking on a sustainable building project, there can be almost too much information available, making it hard to quickly compare the possible building approaches. One important decision is the wall-building system to use in your build.

To help in that evaluation process, this article provides a quick guide to the different wall-building systems and materials available. For each system, we consider how the walls are constructed, their thermal performance and sustainability. A table at the end of the article summarises each approach in terms of a range of sustainability criteria. It's intended as a quick guide; you'll need more information before you start your build, but we hope to give you a head start on the different systems available.

So, what is in a wall? There are many different methods of wall building, but they all fall into four broad categories—stud frame with cladding, bricks/blocks, cast/poured materials and pre-fabricated panels.

Photo: Copyright Brett and Sue Coulstock of Red Moon Sanctuary.

↑ Strawbale walls can have a wooden frame, or can be load bearing. The bales are fitted and rendered to seal them from moisture and vermin.

Stud frame with cladding

Probably the most common wall system used in Australia is a structural timber frame with cladding, in either a single or double timber stud system.

Single stud walls have one layer of framing—the internal cladding (such as plasterboard) is attached to the inside of the frame and the external cladding (such as weatherboard, fibre-cement or brick, as used in brick veneer, see later) is attached to the outside. Bulk insulation is fitted into the spaces between the studs of the frame, and foil insulation can be added as an additional layer around the outside of the frame, allowing for R-values up to almost R4 with the right material combination.

For example, according to the TasTimber document *R-values for timber framed building elements —walls* (www.bit.ly/1B4KOT2), a 90mm stud wall with R1.5 batts, reflective foil layer and AAC external cladding can achieve an R-value of 3.9.

To enable even more insulation, a double stud wall can be used. Double stud walls are just like two single stud frames, built one beside the other with a small gap in between. The resulting walls can be 200mm or more in depth, so a great deal of bulk insulation can be installed. Of course, a double stud wall costs more than a single stud wall, but its advantages may well offset the extra cost if you live in an alpine area or area with low average temperatures, such as north-west Tasmania.

For a truly thermally efficient home, thermal breaks (thin layers of insulation material) between the studs and external wall cladding should be considered, although the extra expense may not be justifiable in moderate climates where low levels of heating and cooling are required.

Pest damage must also be considered, and the requirements will vary from location to location. In most areas except Tasmania, some form of termite barrier will be required. In cold, damp climates cavity wall ventilation may also be necessary to prevent moisture buildup.

BRICK VENEER

We are all familiar with brick veneer, it being the mainstay of the Australian building industry for many decades, but, as traditionally built, these houses were not very energy-efficient.

↑ Autoclaved aerated concrete, such as Hebel Powerwall, is not only a fraction of the weight of regular concrete, it can be strengthened by the inclusion of reinforcing mesh.

Image: Jim Riggins

↑ Double stud walls allow for thicker wall insulation, ideal for colder climates.

In a brick veneer build, a single-layer brick wall is built around the outside of the house framework, the brick walls being tied to the wooden frames. Apart from bricks having a high embodied energy, the main problem with brick veneer is that the thermal mass is on the outside of the home instead of on the inside, where it is needed.

REVERSE BRICK VENEER

This is similar to brick veneer but addresses the issue of the thermal mass being on the wrong side of the walls. With reverse brick veneer, the brickwork is on the inside of the external walls, while the outside is insulated and clad. This results in a home that performs better thermally than regular brick veneer, despite the same or similar materials being used.

One advantage is that the materials used are familiar to most builders, so a specialist builder may not be required.

WEATHERBOARD AND OTHER CLADDING

A very common wall style in many parts of Australia is weatherboard. This uses a timber-frame with weatherboard cladding and plasterboard or fibre-cement sheet interior lining.

There's a large range of weatherboard materials available, from plantation softwoods through to hardwoods and modified woods such as Weathertex boards (which are 3% wax for water resistance), fibre-cement materials such as BGC Duraplank and Ezylite board, composite boards such as PermaTimber Eco Cladding, and even steel, such as Lysaght Weatherboard.

Wooden weatherboards usually need regular maintenance, such as painting or oiling, and must be protected from pests. Modified woods such as Weathertex are supplied pre-primed and require minimal maintenance if a good outdoor paint is used initially. Fibre-cement boards are resistant to rot and pests, and require minimal maintenance once painted. Of course, Colorbond steel weatherboards require virtually no maintenance.

Not all weatherboards are suitable for all fire zones. Wood-based boards tend to be rated to BAL19 or so and other materials, such as fibre-cement or steel should be used in higher bushfire zone areas.

Thermal performance of all weatherboard systems is generally low due to the low thickness of the materials, so weatherboard walls should include bulk fill and reflective foil insulation.

While all of the above-mentioned materials are supplied as individual boards which are installed like regular weatherboards, there are many sheet products that have a weatherboard finish while being faster to install. These are usually made from wood composites or fibre-cement sheets. Urbanline Euro Clad is an example of a composite weatherboard-style cladding panel.

Of course, there are other cladding options if you don't want the weatherboard look. These include regular fibre-cement sheet, available smooth or with woodgrain finish, engineered timber such as SHADOWclad exterior structural ply from Carter Holt Harvey, lightweight cement sheets such as INEX Renderboard, which contains 60% post industrial recycled content, and many others.

The other common cladding option, although not to everyone's taste, is steel sheet. Whether it be Colorbond or zinc finish, corrugated steel sheeting is becoming more popular as a robust, maintenance-free material that is quick to install.

The sustainability credentials of exterior cladding materials vary widely. Wood may be plantation-grown or from managed forests; composite materials often contain considerable recycled or waste material content and so reduce materials going to landfill. Fibre-cement materials are quite high in embodied energy, although some use recycled content or cementitious materials with lower manufacturing energy requirements such as magnesium oxide instead of Portland cement.

Steel-based products are light for the area they cover, reducing transport emissions, although they take considerable energy to manufacture. But when you factor in longevity and the elimination of the need for repainting, their environmental credentials are considerably improved.

There are so many external cladding options made from so many different materials that they can really only be evaluated individually—something potential home builders and renovators must do when researching materials. We've included a list of resources at the end of the article to assist with that process.

Of course, there are two sides to every wall, and so internal lining materials are also important. The most common options include plasterboard, magnesium oxide board, fibre-cement sheet and wood panelling. The same issues apply to interior materials as to exterior materials regarding sustainability and embodied energy.

Image: Stephen Dobson, Ramtec.

← Aside from having good environmental credentials, rammed earth walls provide good thermal mass and the layering effect can make a great feature wall. However, in most climate zones they need to be insulated externally for good thermal performance.

Block-style wall systems

Now let's look at systems that are similar to conventional 'bricks and mortar', starting with the most conventional.

DOUBLE-BRICK

As the name suggests, double-brick homes have external walls made of brick or other masonry blocks on both interior and exterior layers (called leaves), with an air gap (often 50 mm) in between. No timber or metal frame is normally used.

The exterior layer is usually conventional brick, while internal layers may be brick or concrete blocks or possibly other masonry blocks, depending on preference. The two layers of wall are connected together with brick ties for strength and stability.

The air gap between the two layers provides some level of insulation and further insulation can be added using rigid foam sheets or spray-in foams. The high thermal mass of the internal masonry helps stabilise indoor temperatures.

The internal masonry can be lined in plasterboard or another lining of choice, rendered or even left bare for interest. Of course, the choice of lining will determine how effective the thermal mass is, with high density materials such as cement render providing the best thermal coupling. Lighter materials such as plasterboard will introduce a thermal lag effect caused by the separate sheet and the small air gap inevitably created between lining and masonry.

While fired clay bricks are generally considered to have a high embodied energy, some manufacturers are making an effort to reduce the carbon footprint via reduced energy inputs for the firing kilns.

AUTOCLAVED AERATED CONCRETE (AAC)

As its name suggests, AAC is concrete that has been aerated—in effect, concrete foam. AAC is around 80% air (although this varies depending on the specific material and its intended use) and as such is much lighter than regular concrete. This gives it reasonable insulating ability while still retaining some thermal mass.

Autoclaved aerated concrete is available in numerous forms, from various sized bricks and blocks through to wall panels and even floor panels. It is easy to work with—blocks are simply cemented together with purpose-made cement. As the blocks are much larger than regular bricks, construction time can be quite rapid. The most popular AAC brand is Hebel; indeed, AAC is generally known by this name.

Because AAC comes in both blocks and panels, walls can be built in several ways. If built from blocks like other large-block materials, the blocks are the load-bearing components—no frame is needed. Alternatively, AAC panels can be used as cladding over a load-bearing frame, providing extra load-bearing support to the structure.

Because of the relatively high insulative value of AAC, especially the block form, no additional insulation is normally needed. For AAC-clad walls, additional insulation can be fitted into the frame like any other clad building.

INSULATING CONCRETE FORMS (ICF)

Moving into the more novel materials, we come across insulating concrete forms. These are large blocks, often made from polystyrene foam, which are built up like giant Lego bricks. Once the wall is complete, the forms are filled with concrete, which sets, forming a strong, insulated wall.

The outsides of the forms are then rendered or clad (more accurately, faced) to protect them from impact damage, as well as to provide fire protection.

Insulated concrete form walls can be good thermal performers and also provide high levels of acoustic attenuation, so are ideal in noisy environments, such as for homes near major roads, industrial areas or railway lines.

However, as they are filled with concrete, they can have a high embodied energy unless an eco cement is used. Also, polystyrene is not a very environmentally sound material (although production processes are slowly improving, such as with the elimination of CFCs as expanders) and it generally doesn't biodegrade. It is also a large component of waste plastic found in the oceans. Also, because installed ICFs are a composite of foam and concrete they are not readily recyclable at the end of the building's useful life.

TIMBERCRETE

Timbercrete is a mixture of wood wastes (sawdust), cement and sand which is formed into bricks, wall panels and pavers. Timbercrete products also contain non-toxic additives to improve block strength and stop excessive water penetration.

Timbercrete comes in a range of block and panel sizes and finishes, such as cobblestone, smooth and textured finishes, to suit almost any building style. Because its main ingredient is recycled timber waste, no trees are cut down to make Timbercrete. The waste timber content reduces the carbon footprint by locking up carbon, and the material is termite resistant.

Timbercrete has better thermal performance than concrete, and there is a high thermal performance block called the Super Insulating Block which combines a polystyrene foam core with Timbercrete inner and outer facings to provide both good thermal mass and a wall insulation level of R4.

STRAWBALE

Highly compressed strawbales are laid like large bricks and tied together with wire ties. Strawbales may either form infill between structural posts or may be load-bearing with the right construction technique. Strawbale walls are rendered on both sides to exclude pests and seal against weather.

Strawbale walls have low thermal mass (although this depends on the thickness of the interior render), but have very high insulative levels and can produce very stable internal temperatures with minimal heating and cooling. Embodied energy is low if locally produced bales are used, higher if they have to be transported long distances. They also lock up carbon, at least until the end of the building's life, which can be more than 100 years.

Despite being made from straw, strawbale buildings usually achieve high levels of fire resistance due to the sealed nature of the walls—there is very little air in the bales to allow combustion.

MUD BRICK

A mixture of soil, clay and water, and sometimes a reinforcing material such as straw, is poured or pressed into forms and allowed to dry. Mudbricks are used like conventional bricks, although they are usually larger and heavier. Mortar is usually a mixture similar to the brick composition. A small percentage of cement may be added to the brick and/or mortar mix for improved strength and weather resistance. Finished walls are usually sealed with a clear mudbrick sealer, or may be rendered or coated in another suitable material.

Mudbrick walls have high thermal mass and so provide stable internal temperatures, but insulation levels are not high and vary depending on the composition of the bricks. Fire-resistance levels are generally very high. Embodied energy is low if locally produced bricks are used, higher if they have to be transported.

STONE

Because stone is a naturally formed material, the embodied energy comes from quarrying/cutting/finishing of the stone, transport and the mortar used when walls are built.

There's also the environmental damage caused by quarrying activities to consider, although some companies remediate their quarries once exhausted.

Some properties have abundant natural stone just below the surface which can be harvested, washed and used as-is without any cutting. This is usually more suited to owner-builders, given the labour-intensive process of collecting and cleaning the stone.

The main advantages of stone, apart from potential low embodied energy, are high thermal mass and extreme fire resistance. However, like concrete, stone is not a good insulator and so rendering externally with a thick insulating render is usually required. Alternatively, stone may be used just for thermal banks inside the home, such as feature walls and fireplaces.

GREEN ENERGY BRICKS

This is a specific brand of unique building block made of high density polyisocyanurate (PIR) foam clad on the interior and exterior surfaces with 9 mm magnesium oxide (MgO) board. The bricks include locating lugs which provide alignment of walls, a mastic groove for sealing between bricks, and central voids for running services such as pipes and cables.

The bricks measure 600 mm long x 300 mm high and 320 mm thick (including cladding), and are simply stacked up together, with no mortar or concrete fill required, making for a very fast build. There are eight different shapes of Green Energy Brick to cater for corners, T-sections and the like.

The MgO cladding is fireproof and the PIR foam is self extinguishing, giving Green Energy Brick (GEB) walls a high fire-resistance rating. Insulation rating of a standard GEB wall is a huge R8, making for very good thermal performance.

Formed-on-site systems

That takes care of the commonly available block-style building methods, but there are many other ways to build a home. Some materials are not built up using discrete blocks, but rather are poured on-site, making walls that are essentially one solid block. These are usually formed by pouring or packing materials into forms—temporary wood or plastic moulds which are removed once the wall material has sufficiently set to be self-supporting.

HEMPCRETE

This material is composed of hemp hurd (the core of the stalks of the hemp plant), lime-based binder and water, although it can also include some sand for added strength and/or thermal mass. A wooden load-bearing frame is built and formwork installed on both sides. The hempcrete material is mixed on-site and packed into the forms in layers to produce solid walls that cover the frame. Finished walls can be sealed or rendered with breathable finishes; the material is interesting enough to leave as-is, although external

→ Structural insulated panels (SIPs) consist of a foam core clad both sides with wood, metal or cement sheet. They are very strong, rigid and lightweight.

Image: www.structuralpanels.com.au

sealing is generally required.

Hempcrete provides a good level of insulation and so thermal stability, and hempcrete walls are breathable and regulate indoor humidity, reducing the likelihood of damp and mould. The material is both fire- and termite-resistant. It also has a very low embodied energy, especially if the hemp and binder are produced locally.

RAMMED EARTH (PISÉ)

A mixture of clay, silt, sand and gravel is placed into wall forms and compressed using mechanical methods, such as a pneumatic hammer. Sometimes a small amount of cement is added to increase strength (known as stabilised rammed earth), and/or internal reinforcements are used. Walls may be left natural or sealed with a clear sealer, rendered or clad.

Thermal mass is high but insulation is relatively low. To improve performance, we recommend walls be built with insulation inserted in the centre of the wall, or existing walls be clad externally with insulated boards. Rammed earth walls have high fire resistance, good acoustic properties and low embodied energy (the more locally the earth is sourced, the lower the embodied energy). They are fully load bearing (up to 12 storeys high). An interesting possibility with rammed earth is embedding layers of different coloured soils in the walls to make impressive feature walls.

The main drawback with rammed earth is that it can be labour-intensive to build, depending on the method of compaction used (manual or mechanical). However, if there is a suitable source of soil on or near to the site, material costs can be relatively low.

One interesting variation on rammed earth wall building is used in an earthship. Old car tyres are stacked in layers and filled with earth that is then compacted. The external irregularities formed by the round shape of the tyres are then filled and rendered, resulting in walls with huge thermal mass and strength.

Earthships are usually made using locally sourced soil, so the embodied energy is low, and they often incorporate other waste materials such as glass bottles into walls for natural lighting. However, they are labour-intensive, so labour costs can be high unless you owner-build, and building regulations can be tricky. There are some examples of earthships in Australia; for example, see www.earthshipironbank.com.au.

↑ Timbercrete uses wood waste to reduce weight and increase thermal performance compared to concrete, as well as to lock up carbon.

CONCRETE

A mixture of cement, aggregates (gravel and sand) and water, concrete is the mainstay of the building industry. It can be poured on-site or bought in block form or even as pre-cast wall panels which are simply assembled on-site.

Its main advantages are speed of installation, high thermal mass and strength (concrete slabs and panels contain steel reinforcing which increases strength enormously), but it has a high embodied energy.

There are more eco-friendly versions of concrete (such as TecEco's reactive magnesia cements, see www.tececo.com.au, and Wagner's EFC, see www.wagnerscft.com.au/products/efc) that replace the cement with waste materials such as blast furnace slag and fly-ash from sources such as coal-fired power stations, while the aggregates can be replaced with crushed recycled concrete. This can reduce the embodied energy of concrete, while having no effect on the quality.

Prefabricated systems

SIPS

Structural insulated panels consist of an expanded foam core (usually polystyrene, polyisocyanurate or polyurethane foam) clad with various materials, often oriented strand board (a type of wood-based board), but also other materials including metal (steel or aluminium), magnesium oxide board and fibre-reinforced cement composites. They are provided in large panels that simply lock together to form walls. This results in a very fast build.

The main advantages are rapid construction, high strength and high insulative values, but there is little thermal mass in most SIPs, so if that is required then it needs to be provided through a concrete slab, internal masonry features or the like.

SIPs are generally termite- and fire-resistant and are often cyclone-rated, making them ideal for use in the northern part of the country, on coastlines or wherever weather extremes are experienced. It should be noted that the foam used in some SIPs may off-gas, at least when they are new, but most claim to use low VOC/non-toxic foams.

PREFAB WALL PANELS

While SIPs are a form of prefabricated wall panel, the more traditional types are usually made of reinforced concrete. They are trucked on-site and assembled using a crane to lift them into place (they are much heavier than SIPs). Prefab wall panels can be painted, rendered or clad with sheet materials or facings.

The high thermal mass makes them suited to homes located where there are large diurnal temperature ranges, but insulation may need to be added externally—insulated cladding, such as RMAX ThermaWallPlus, is a simple method of achieving this.

One advantage is fast building times, but the large quantity of concrete means that they have a high embodied energy, unless eco concretes are used.

Not all prefab wall panels are concrete. Rapidwall (www.rapidwall.com.au) is made from gypsum plaster with fibreglass reinforcement. There is no sand, gravel or cement used and the gypsum can be sourced from industrial processes where it is a waste product. Rapidwall panels are hollow and can be filled with concrete (for a high fire rating)

← These sample wall sections are printed on a giant 3D printer using a concrete made primarily from waste products. The developer of the technology, Winsun in China (www.yhbm.com) has already printed a three-storey villa and five-storey apartment building (both in a display village) using this system. Labour costs and building time are massively reduced compared to many other building systems, although it is early days for the technology, which is yet to become available outside China. The printer can manufacture wall sections in any shape desired, with reinforcing built directly into the design. The wall cavity can be filled with concrete for extreme strength, or with insulation for improved thermal performance, although the internal bracing design of the walls does introduce thermal paths that would reduce the insulation's efficacy.

or other materials such as insulation for improved thermal performance.

There are other variations on prefab panels which use various materials, but they are all based on some form of concrete, plaster or similar material.

Steel framing

While we have talked about timber-framed homes, you can eliminate timber from the framing system completely and use steel framing. The advantages of steel framing include higher strength to weight ratio and complete resistance to termites. However, steel framing is highly thermally conductive and so you must include thermal breaks (insulation) between the framing and the exterior wall material. See 'Emerging materials', p. 69 for a longer discussion of the advantages and disadvantages of steel and timber.

Other building methods

Like any industry, the building industry evolves over time, even if it is at a snail's pace. While things change slowly here in Australia, around the world there are many interesting building methods being explored, with some making it off the drawing board and into the real world.

An example of this is 3D printing. Winsun of China has been manufacturing wall sections using a huge 3D printer which extrudes a fibre-reinforced eco concrete. There are numerous other interesting wall construction methods, such as papercrete (a material made from a mixture of recycled paper, sandy dirt and a small amount of cement), log walls, load-bearing engineered wood panels and many others, but few examples of these exist in Australia. 'Emerging Materials', p. 69, includes a discussion of cross-laminated timber and its use in Australia.

Sustainability

While this article looks at individual wall-building methods, the entire house envelope should be considered holistically in order to attain the most sustainable outcome. This includes total life cycle of materials (natural materials such as earth usually win out here), as well as the health of the home (such as the number of air changes per hour, humidity regulation, off-gassing and the like)—which includes both the completed living space as well as the manufacture of the materials (some foams, for instance, require toxic chemicals to manufacture).

For a building to be sustainable, it's not just about minimising ongoing energy use: the total environmental impact of the building envelope should also be considered. ✱

See next page for a table showing wall options rated (approximately) against a range of sustainability criteria.

See pages 49–50 for case studies, plus page 54 for a SIPs and concrete blocks build.

Resources to assist material selection:

Your Home: www.yourhome.gov.au/materials/cladding-systems

Ecospecifier: www.ecospecifier.com.au

Good Environmental Choice Australia: www.geca.org.au

p. 53: Mullum Creek development includes links to guides to assist with selection of more sustainable timber, clay, steel and concrete.

Table 1. Common wall construction systems, rated against a range of criteria. Ratings are approximate and will vary depending on the production process and material specifications. Ratings are based on data from www.yourhome.gov.au; Hempcrete Australia; James Hardie Australia; Hebel Australia; *How to Reth¿nk Building Materials, Creating ecological housing for the designer, builder and homeowner*, CL Creations Pty Ltd; *Thermal Conductivity, Common Clay Masonry Material*, Howard Harris, Structatherm Projects; *The Use Of Cement Stabilized Rammed Earth For Building A Vernacular Modern House*, Gabriela-Teodora Ciurileanu (Cioca) and Ildiko Bucur Horvath, Technical University Of Cluj-Napoca.

Construction system	Embodied energy	Insulation ability	Functional thermal mass	Fire resistance	Sustainability in production	Maintenance	Acoustic performance	Cost	Construction time	VOCs
AAC (Hebel)	Medium	Medium-high	Medium-low	High	Medium	Low	High	Medium	Medium-low	Low
Brick veneer	Medium-high (depends on bricks used)	Medium (depends on cavity insulation used)	Low	High	Low-medium (depends on bricks and cladding)	Low	Low-medium	Medium	High	Low
Concrete	High (unless uses recycled or waste materials)	Low	High	High	Low (unless uses recycled or waste materials)	Low	Medium-high	Medium	Low-medium	Low
Double brick	Medium-high (depends on bricks used)	Medium (depends on cavity insulation)	High	High	Low-medium (depends on bricks and cladding/render)	Low	Medium-high	Medium-high	High	Low
Double stud frame	Medium (depends on cladding)	High	Low (depends on internal lining)	Medium-high (depends on external cladding)	Medium-high (depends on cladding and timber source)	Low	Medium	Medium	Medium-high	Low
Green energy bricks	Low	High	Low	High	Medium-high	Low	High	Medium	Low	Low (may produce toxic fumes during an extreme fire)
Hempcrete	Low	Medium	Low	High	High	Medium (depends on external render/finish)	Medium-high	Medium-high	Medium-low	Low
Insulated concrete forms (ICF)	Medium (depends on concrete and render)	High	Low-medium	Medium-high (depends on cladding/render)	Low-medium (depends on concrete fill and render)	Low	High	Medium	Low-medium	Low (may produce toxic fumes during a fire)
Mud brick	Low	Low	High	High	High	Medium	High	Low-medium	Medium	Low
Rammed earth	Low	Low-high (can have embedded insulation)	High	High	High	Low	High	Low	Medium-high (depending on compaction method)	Low
Reverse brick veneer	Medium-high (depends on bricks used)	Medium (depends on cavity insulation used)	High	High (depends on external cladding)	Low-medium (depends on bricks and cladding)	Low (depends on external cladding)	Medium-high	Medium	High	Low
SIPs	Low-medium	High	Low	High	Medium	Low	High	Medium	Low	Low-medium
Stone	Low	Low	High	High	High	Low	Medium-high	Medium (depends on stone type and source)	Medium	Low
Strawbale	Low	High	Low-medium (depends on internal render)	Medium-high (depends on bale density and render)	High	Medium	High	Low-medium	Low-medium	Low
Stud frame	Medium (depends on cladding)	Medium-high	Low (depends on internal lining)	Medium-high (depends on external cladding)	Medium-high (depends on cladding and timber source)	Low	Low-medium	Medium	Medium-high	Low
Timbercrete	Low	Medium-high (depends on product used)	Medium-high	High	Medium-high	Low	High	Medium	Medium	Low

Bringing the options to life: case studies

Hemp-lime walls

↑ The Wadsworth's completed 'hemp house' in Mullumbimby.

↑ Hemp-lime wall prior to rendering.

Photos: Andrew Wadsworth

Since moving into their new home in Mullumbimby, NSW, at the end of March this year, Meg and Andrew Wadsworth have enjoyed the stable, comfortable indoor temperatures provided by their sub-tropical 'hemp home'.

The insulation provided by the hemp-lime walls works with the home's orientation and thermal mass in the slab to retain the sun's heat, mitigating autumn's cooler outdoor temperatures. Andrew says the hemp walls also look amazing. The exterior was left for six weeks to dry thoroughly before a lime-based render was applied. They decided to leave the interior walls exposed, except for rendering around the windows.

The material used in Meg and Andrew's build was from the NSW-based Australian Hemp Masonry Company, who source hemp and binder from Australian farmers and processors. Their certified hemp-lime construction materials were originally developed at UNSW for use in Australian conditions.

Andrew and Meg visited the site regularly throughout the build, and particularly during the hemp-lime installation, which took only a week all-up (with two people working on the forms and packing the hemp-lime, plus one mixing). In the hot, humid summer during the build, they noticed that the material made for very pleasant conditions inside. Ongoing, they believe it will also inhibit mould—a major contributor to respiratory problems and skin allergies—in a location where it is a perennial problem in wet summers.

As a building material, Andrew notes that "the hemp itself isn't expensive, but not many builders are doing it, so that's where the cost comes in." He thinks that as more builders take this construction method on, the labour cost will likely drop. He also says that it's a material that any home builder could easily work with themselves; they just need to ensure they know how to build and use the forms properly. ✱

See *ReNew 129* for another home using hemp-lime wall construction in an owner-build, with information on how the build was performed.

Reverse brick veneer

Don Batson and Sophie Liu did have plans to reuse the bricks of their double-brick 1940s home, in Melbourne's inner-north, in its recent renovation and extension. Due to unintended engineering miscalculations, however, which meant the floor slab that was poured wasn't strong enough to support double-brick construction, they went instead for a reverse brick veneer option. The results, though a compromise on their original vision, have meant the achievement of their goal of a thermally well-performing home.

Don, who took on the project management of the build, did research using Ecospecifier (www.ecospecifier.com.au)—a website that helps consumers choose from a range of sustainable products—and took just a couple of days to decide on Weathertex to clad the exterior of their home extension. An Australian product, the Weathertex boards are made from 97% hardwood timber (from sustainable plantation and PEFC sources) and 3% natural waxes.

The renovation was a reconfiguration of the internal spaces (bedrooms on the south side, living areas on the north) that required the dismantling of the back (north) half of the house and a small additional extension. They pumped insulation of around R2 into the gap between the double bricks at the front of the house. On the back half, they used recycled bricks for the interior skin (which have been left exposed). An air gap between that and insulation batts made from recycled PET bottles, and another air gap between the batts and Air-Cell Permishield foam and foil insulation, with the Weathertex on the exterior skin, has resulted in an R-value of around 4 in those walls.

With these and the other ESD measures taken in this build, Don and Sophie have taken a house that used to have a 1.8 Star rating, and transformed it into a 6.7 Star home. They have now moved into the house after 13 months of construction, but there are still a few things to do which should see the Star rating rise even further. ✱

↓ The exterior 'skin' of Don and Sophie's home in Melbourne, showing the Air-Cell insulation and outer cladding of Weathertex.

↓ Visible here is the interior skin of brick veneer, with stud work ready to accommodate insulation batts, then Air-Cell.

Photos: Don Batson

Stud frame with fibre-cement cladding

When Glenn and Lee Robinson decided to build an affordable, net-zero-energy house and granny flat in their home town of Bundanoon in the Southern Highlands of NSW, they put a lot of time and effort into researching and choosing the materials with which to build. They wanted the two buildings to have exceptional thermal performance, be very cost-effective and to look as normal as possible so as to fit comfortably into their neighbourhood.

To those ends, they chose to use timber roof trusses and wall framing for low cost/high thermal performance (on the granny flat they added thermal-break strips to the exterior of the wall framing for added insulation—see Figure 1). They went with fibre-cement weatherboards for classic looks plus durability at a reasonable price and double-glazed timber windows for their thermal properties with aluminium cladding on the exterior for low-maintenance and durability. The interior walls and ceilings were lined with plasterboard and painted white for low cost and high light reflectance.

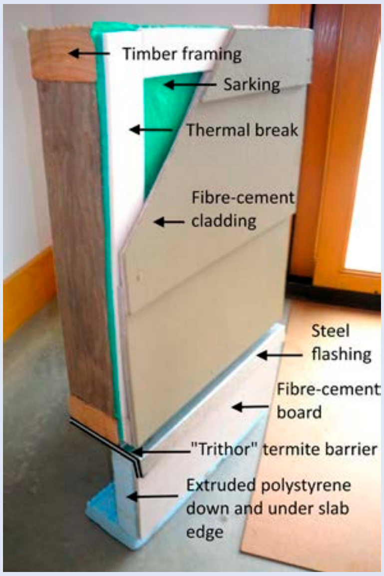
For floors in the main house, an exposed, burnished concrete slab (with insulated edges) was laid for durability and thermal mass. In the granny flat they used a waffle-pod slab with insulation both under and up the sides of the edge beams. This required the use of a special termite barrier called 'Trithor' which allowed them to cover the edge of the slabs (also shown in Figure 1).

To top it all off, they chose a light-coloured corrugated steel roof to reflect heat in the summer. Throughout the build, they were also careful to choose off-the-shelf materials that were inexpensive to install and should be easy to match if they do any future remodelling.

Overall the project has been an outstanding success. The build cost was around $1500/m², the house has produced almost twice as much energy as it used over its first two years, and the buildings blend well into the streetscape. ✱

We plan to cover this affordable and sustainable project in more detail in an upcoming *ReNew*.

↑ Granny flat under construction, showing timber framing, roof trusses and the concrete slab with insulated edges, with the main house and carport in the background.



↑ Figure 1: The internal and external layered elements providing a classic weatherboard look with high thermal performance and vermin protection.

Insulated rammed earth

This wall section is part of a waterfront house at Roaring Beach, Nubeena, Tasmania, built by Rammed Earth Tasmania. It has insulated rammed earth walls 450 mm thick (175 mm rammed earth each side of a 100 mm styrofoam core) and has no thermal bridging—the walls achieved an R-value of 4.3. For many years, 300 mm thick uninsulated walls were the standard, but with the new 6 Star rating for houses, insulation is required to reach this rating, at least in cooler zones. Insulated lintels with a thermal break are also used.

The edges of the foam which can be seen in this completed wall section are covered by the windows and door frames. They typically use soil from a local quarry with some local sand mix and around 10% off-white cement for stabilisation. Techdry plasticure is added for waterproofing.

↑ Insulated rammed earth wall section, with 175 mm rammed earth each side of a 100 mm styrofoam core.

↑ The massive walls combined with insulation make for thermally stable and beautiful homes in even the coldest climates.

Images: Rammed Earth Tasmania

Mullum Creek
Guiding residential development

Eva Matthews explores the Mullum Creek project and the building materials guides that are helping owners meet important environmental design criteria.

Image courtesy Danny Mathews

↑ Artist's impression of a home design from Mullum Creek's 'Living Design Principles'.

IN 1958, Bob and Rivkah Mathews—ordinary people with a passion for nature and social justice—bought a property and built a family home on 20 acres of open paddocks and natural bushland in Donvale, a suburb 20 kilometres east of Melbourne. Over time, they bought adjacent parcels of land, growing the property to some 20 hectares.

When the land was re-zoned from rural to residential in 1972, Bob and Rivkah had ambitious hopes to coordinate the development of neighbouring properties so as to preserve the natural landscape as much as possible. Many of the neighbours, however, had other ideas!

In the late 90s, the three Mathews children—Steven, Danny and Sue—reignited the vision with a commitment to conservation, good design and social responsibility. Embarking on a lengthy and complex planning process, they finally saw that dream approved by council in 2012 for the environmentally sustainable residential development that is Mullum Creek.

The property has been subdivided into 56 lots, with each being oriented to maximise access to sunlight (for solar PV and passive design purposes) and views of the creek and bushland. A cycling/pedestrian track will link with the Yarra Trail, enabling an easy fossil-fuel-free commute into Melbourne and the development has 45% dedicated open space.

To ensure the successful implementation of the Mullum Creek vision—beautiful, sustainable homes with a minimum 7.5 Star energy rating—land purchasers are guided by comprehensive design criteria, developed by an expert collective of building and landscape architects, urban planners and ESD consultants, that have been on board since the project's early days. These criteria seek to uphold environmental principles including by using construction methods and materials that minimise their carbon footprint and impact on the environment.

To this end, owners are supported through financial incentives to access architects and design professionals who are familiar with the site and prescribed design principles. The project consultants have also put together a number of materials guides designed to help owners understand the environmental pros and cons of various products and also to make it easier for them to choose those that will achieve their sustainable design ambitions.

Just 18 months since launching the development, nearly all lots have been sold, showing that there is a healthy desire for people to live in harmony with their environment. Let's hope that the blueprint that has been so thoughtfully developed to minimise the residential footprint for this project is mirrored in similar urban and regional developments—and individual projects—into the future. ✱

Building materials guides

The following guides (with entries chosen for their low impact in production, use and/or eventual disposal) are available on the Mullum Creek website.

While they, and several other useful resources, have been developed primarily for the future residents of Mullum Creek, they can be (and the Mathews family hope they will be) accessed by anyone embarking on a sustainable building project.

TIMBER

Includes information about products, species used, recommended applications (e.g. framing, joinery, cladding), manufacturers and retailers.

CLAY

Includes brands, suppliers, reasons for recommendation (e.g. embodied energy, thermal mass properties, sound attentuation, whether recycled/recyclable).

CONCRETE

Includes brands, suppliers, reasons for recommendation (e.g. insulating properties, recycled content, embodied energy, whether locally sourced/produced, meeting environmental/quality standards).

STEEL

Includes brands, suppliers, reasons for recommendation (e.g. prefabrication, efficient processing, meeting quality standards, efficiency of use, strength grade).

View guides at: www.mullumcreek.com.au

Images: www.all-free-download.com; timber—Peter Kratochvil; clay—Teodoro S Gruhl; concrete—tuku; steel—Peter Griffin

SIPs in the tropics
Habitat in the clouds

With thoughtful design, it is possible to live sustainably and comfortably in the rainforest. Paul Michna describes what his family has dubbed their 'trapezoidal mountain habitat', built using SIPs.

THERE are many challenges, but similarly many rewards, when building a home in the tropics. Humidity and condensation, cyclones, rain, site access, land clearing and cooling in a tropical climate all pose questions to be answered.

Our journey to living in the 'jungle' began back in 2002. We purchased this site, surrounded by World Heritage rainforest in far north Queensland, with plans to develop a home. The area was too wet for camping while building (with about 4500 mm of rain a year) so we brought in an on-site caravan for our initial weekend planning visits. In 2005 we constructed our first home, a shipping container retreat (see *ReNew 95*). Surviving cyclones Larry (2006) and Yasi (2010) taught us valuable lessons for construction and design in a cyclone-prone area (see *ReNew 118*).

This knowledge fed into the design of our trapezoidal habitat in the clouds, Studio Nimbus.

Built using structural insulated panels (SIPs), the main living area and half-length mezzanine bedroom float three metres off the ground on two rectangular concrete block pods. The pods double as cyclone shelters and usable space, with one a bedroom and the other 'wet' spaces: a laundry and bathroom.

The elevated main living area keeps us above the splashback of torrential rain, reduces accidental visits by things that slither, creep, bite or hop and maximises airflow beneath and within the living area. The height also permits the abundant nocturnal wildlife to transit the site undisturbed.

↑ Paul and family built their trapezoidal mountain habitat in far north Queensland using a steel frame and SIPs (structural insulated panels) for walls and roof, resting on two cyclone-rated concrete pods. The sun- and weather-prone east and west walls have no windows, though the SIPs design means they could cut and install windows or skylights in the future if desired. Ventilation is well managed through high ceilings and adjustable openings at each end of the main living area.

Building with SIPs

We chose to build the living area from a metal frame combined with steel-enclosed SIPs—being durable and termite-proof, metal suits the challenging humid rainforest conditions.

The SIPs (walls by Askin, roof by Ausdeck) comprise two layers of steel enclosing expanded polystyrene (EPS) foam insulation. The Colorbond provides a durable painted exterior and interior surface, minimising maintenance—it may need a repaint in 25 years time! Once a year we spray using a very dilute swimming-pool-type algicide on the exterior walls; the next rain then clears the walls of any potential growth. The SIPs provide insulation and sound-proofing and can span long distances unsupported.

They're also much faster and easier to build with. The high cost of the panels (and steel frame) was offset in our build by the faster building time and reduced labour. Labour cost was about 18.5% of $280,000 all up; a version minus pods and slab would come in well under $200,000, and urban prices would

↑ Steel frame construction on top of the concrete block pods.

↑ The SIPs were light enough to be lifted by two people and set in place by four.

likely be less—we are about 1800 km from the state capital.

It took just four days to put up the bolt-together two-pack painted steel frame, requiring one day with a crane and three days with a scissor lift. Five people erected the SIPs walls and roof by hand just as quickly, with the SIPs secured to the frame using self-drilling screws. The SIPs are light enough to be lifted by two people and set in place by four.

We used 14 SIPs for the main roof and another seven over the rear balcony, each 1 m wide x 7 m long x 150 mm thick (R3.94). We could have used fewer, longer panels, but access restrictions on our site meant we needed to use shorter ones. We used 20 wall panels, 1.2 m wide x 100 mm thick (R2.8) and between 4 and 6.4 m long, fixed horizontally every 3 m.

Balconies for the tropics

Studio Nimbus has three balconies, designed for living in this climate: one partially enclosed for wet weather, one open to the elements for sunny weather only and one a practical low-roofed utility balcony, housing the water tank, wood pile and freezer. The front balconies are oriented north-north-east to draw in cool air and morning sun and to exclude the afternoon heat and humidity. The house orientation is also dictated by a dominant weather direction and to provide panoramic elevated views.

Cyclone protection

In a tropical cyclone zone it is best to be prepared. The rectangular pods are seriously strong steel-reinforced concrete shelters. Water tanks provide a 45 tonne protective cyclone barrier. Triangular wings on balcony corners in the main structure disrupt laminar wind flow and may reduce vacuum effect on windows from high speed wind. All features are designed to create turbulence, deflect and degrade cyclonic wind flow.

For additional seasonal cyclone protection, we attach inexpensive standard three-metre farm gates on top of each balcony railing using U-bolt pipe clamps. This takes about 30 minutes in total to install the six gates. They protect the windows from larger flying debris and the mesh disrupts destructive airflow. As our steel balcony posts are 3070 mm apart, the gates make an ideal fit. If you design your place to use standard readily available sizes, things are much cheaper.

Keeping comfortable

Air flow and humidity control are essential for comfortable living in the tropics. The local micro-climate, generally beautiful, is subject to occasional rapid changes in temperature and humidity due to the altitude, with rolling fronts of fog, low cloud and mist. Our passive design works very well, but when we need them, four exhaust fans and three ceiling fans optimise air flow, temperature distribution and humidity control—no air conditioning is necessary.

Interior airflow is further enhanced by a Venturi effect—where outside airflow (wind) across a vent causes air to be drawn out of the house through that opening—through large adjustable openings at each end of the main living area combined with the use of very high ceilings throughout.

Windows are double glazed primarily to minimise condensation. Five large glazed sliding stacker doors and four large awning windows provide air flow, light and green vistas. There are no openings at all on the sun- and weather-prone east and west walls. If we find we need more light in the future, the SIP design permits us to cut and install windows and skylights basically wherever we desire.

> "SIPs are much faster and easier to build with. The high cost of the panels (and steel frame) was offset in our build by the faster building time and reduced labour."

Electricals and lighting

All light, fan and power switches and wiring are wall mounted in a rectangular aluminium duct raised 1.1 m above floor level. Separate channels in the duct allow for electrical, telecommunications and data cabling and extra-low-voltage wiring for a backup battery-driven emergency 12 V LED lighting system. Identical fixtures make for easy repair and minimal spares. Lighting consists of 34 identical powder-coated aluminium PAR38 lights with ceramic edison screw 27 mm sockets which can host a wide variety of bulbs including LED and CFL. Balconies use red lighting, a colour that neither disturbs nocturnal wildlife nor attracts insects.

The rear balcony roof acts as a light shelf (see box next page), providing cool reflected afternoon light into the interior. The building is designed to be as self-cleaning as possible, as heavy leaf fall, moss and algal growth are an issue in the rainforest. A 7.5 degree pitch

Towards energy independence

Sadly, solar PV power is not yet feasible for us. Feed-in tariffs for a grid-connected system are uneconomic and the local weather pattern, particularly in spring, makes an off-grid system difficult. Intense periods of cyclonic rain are not a problem: during cyclonic weather cloud cover is heavy for short periods but interspersed with sunny days. Our solar challenge is how to design a system that can cope with prolonged springtime periods of drizzle that can last 10 to 14 days at times. This would require a huge, expensive battery bank and a lot of generator use.

We've considered two possible power scenarios. First a solar/grid hybrid: on sunny days, refrigeration and clothes washing would draw AC directly from the solar panels. Evening LED lighting could draw off the battery. Refrigeration would switch off between about midnight and 6 am. The grid would be accessed to feed power in when required, though the grid-access fee would eat up about a quarter of our bill. The technology is available for this system type, but it can be expensive. With the long periods of cloudy drizzle we have, the cost of batteries alone spread over, say, a 10-year life would cost us about twice the cost of a grid-only connection—$1200 a year versus $2500 a year for the batteries.

An alternative we've considered is a micro-hydro solution using two mid-head mains-voltage AC generators. We'd need 37 metres of pipe to siphon water over a bend in the creek at some distance from the house. However, there are potential problems, as the creek can run to three or four metres of flood at times, the terrain is extreme and cabling costs would be high. I haven't had much luck with this approach yet: my proof of concept trial to get a constant flow using a siphon was unsuccessful as I didn't use a large enough pipe diameter. In a small pipe there is a larger interior surface area compared to the volume of water that passes through—the more surface, the more friction and the lower the flow, making it more likely the siphon will stop. A larger diameter pipe provides less friction per unit volume of flow.

↑ For seasonal cyclone protection, they attach standard farm gates on top of the balcony railing. They are installed a few hours before a cyclone is due and taken down shortly after.

on the roof sheds debris while windowless vertical side walls are cleaned in the frequent intense rain. Drip grooves and overhang prevent dribble growth. Around the house base, a surround of terrain cloth covered by a layer of coarse local gravel prevents muddy splashback. White inside and out maximises light and minimises heat. Solid walls, hardwood and washable painted metal interior mean minimal dust and this makes house cleaning a breeze!

Plenty of water

Rainwater supplies all our needs; the roof area collects about 450,000 L annually. An extra large gutter directs rainwater to two 22,500 L tanks that fill simultaneously. In order to minimise electricity consumption, we use a generator-friendly multi-stage pump to feed an 80 L pressure tank. The multi-stage pump design reduces the initial start-up power demand and the larger pressure tank means fewer power consuming startups each day.

Our modified septic system can accommodate torrential rain. We sited the trenches below the major root depth of the surrounding buttress root rainforest trees and ran them beneath the water tanks. The tanks act as a shield to prevent rain waterlogging the soil beneath them.

Energy systems

Our energy comes from a combination of mains grid, petrol generator, wood, kerosene and gas. Energy redundancy for cooking, washing and lighting is essential in a remote area subject to weather extremes. Our power board can switch from mains to generator power with the manual flip of a switch to activate one light and one power circuit. The power board, gas line and plumbing are all concentrated in one corner of the building to simplify construction and minimise materials, run lengths and potential energy losses.

We use about 7 kWh of electricity per day. The multifunction wood stove reduces our carbon footprint while supplying most of our dehumidifying, water heating and cooking energy needs. Our wood supply results from our rainforest restoration activities. Tea plants from nearby tea plantations have invaded the rainforest margins and grown to tree size. We selectively harvest these and replace them with native rainforest fruit-bearing plants we find germinating in cassowary scats. We keep comfortable and the cassowary gets a reliable source of its favourite foods!

↑ The interior looking out to the north sliding stacker doors, with mezzanine bedroom. The services duct is visible on the wall.

Sustainable design in the tropics

Sustainable wet tropics design necessitates its own set of rules. Rainforests are expert at reducing organic materials to nutrients—they have had millions of years of practice! Building materials need to be trialled and selected carefully. The structure of Studio Nimbus is built to last so the sensuality of this challenging, beautiful environment can continue to inspire and infuse our lifestyle. ✱

Studio Nimbus was designed by Paul using simple CAD software, with input from his wife Roberta and two sons, based on their experiences living in the rainforest and inspired by endemic housing designs around the world. Building designer Tony Hales drew up the plans that were approved for cyclone rating, and local master builder Jon Nott Building did the construction. For more information, see sites.google.com/site/junglehousedesign.

How does a light shelf work?

A light shelf uses reflected light to illuminate the interior of a dwelling. You get the light but much less heat! Say you have a dark and gloomy basement flat with only small windows providing light: you can significantly increase internal ambient light levels by placing light-coloured angled reflective surfaces outside the windows. Surrounded by tall trees, we brighten Studio Nimbus in the afternoon with light reflected off our rear balcony roof through six 1m x 0.8m awning windows. We find the light shelf is effective on both sunny and cloudy days. You do need to observe the angle of the light at different times of the day, winter and summer, to determine whether a light shelf would suit your location.

Mass effect
The messy realities of mass

Mass in buildings can help moderate internal temperatures, but it can also be tricky to control its effects. Alan Pears examines when and where mass works well—and when it doesn't.

THE way buildings work is very complicated. That's why designers increasingly use computer models that simulate hourly performance over a year to try to deliver good performance. Even that has its challenges! Adding mass to a building is no exception; it can bring significant benefits—and some problems.

This article is an attempt to explore the role of mass in buildings and suggest some paths forward for building owners and designers.

First, 'mass' is not actually what we want. The beneficial feature of mass is that it increases the heat storage capacity of a building so that, for a given amount of heat input or loss, the change in temperature inside the building is reduced. This outcome can be achieved by using a lot of material (mass), materials with a high heat capacity per unit of mass (e.g. water can store about twice as much heat per cubic metre as concrete for the same temperature rise in the material), or by storing energy as 'latent heat' in what are known as phase change materials (PCMs, see more on these later).

High mass buildings tend to sit close to the 24-hour average temperature for the time of year, because it takes a lot of energy to shift the temperature of a heavy building. In much of Australia, especially when 24-hour average temperatures are 18 to 24°C, this means the building tends to be closer to a comfortable temperature more of the time.

Thick, heavy walls slow down the rate of heat transfer into or out of a building, as the 'wave' of heat has to work its way through the thick material. This can delay the heat flow until it cools down (or heats up) outside, reducing heating or cooling energy.

Image: Emma Cross

↑ An uninsulated concrete slab (with fly-ash) and reverse brick veneer are used as thermal mass in this Melbourne house to stabilise internal temperatures. Good insulation and blinds on doors and windows prevent escape of heat when the sun has set. The owners have needed to add active heating for cool mornings and nights, particularly when there's a run of cloudy days; they've found the house works better in the heat than in the cold.

But it can have a downside. I once lived in a house with a west-facing uninsulated cavity brick bedroom wall. It would delay the heat flow from the afternoon sun until after bedtime, so I would cook at night unless the outdoor temperature had cooled enough for me to flush out the heat.

Note that mass does not provide better insulation—but under varying temperature conditions it can have a similar impact on energy use to a small amount of insulation. Confused? Let's look at what this all means in practice.

High mass vs lightweight in operation

Consider two houses of identical design and insulation except that one has high mass (actually, high heat capacity), while the other is lightweight. Let's also assume no heating or cooling equipment is operating.

During daytime, the heat from the sun (and indoor activities) will tend to warm up a house. For the same amount of heat input, the lightweight house will warm up much more. At night when it is cooler, heat leaks from both houses, but the temperature of the lightweight house will drop much faster than that of the high mass house.

→ Lightweight homes can perform well. This 1997 RAIA Vic sustainability award winner is very well insulated and sealed, with low-e double glazing. A small capacity hydronic heater is needed for about half an hour on cold mornings. In summer, with effective shading and the occasional sea breeze, it stays comfortable, with ceiling fans providing adequate cooling.

The impact of the mass on heating and cooling energy consumption can be beneficial or problematic. For example, on winter days, a heavy building with limited solar input may not warm up much above the 24-hour average temperature without additional heating, while the lightweight building may warm up to a pleasant temperature with a small amount of solar input. But if a high mass building warms up using solar gain, it will tend to maintain a higher temperature into the evening and overnight, while the lightweight building will still cool down, possibly needing more heating.

In summer, the high mass building will tend to stay cooler over the day. But once the mass warms up, it will tend to remain hotter overnight unless it is cooled by ventilation (if the outdoor temperature is cool enough) or by air conditioning. In contrast, the lightweight building may get quite hot during the day, but is more likely to cool down overnight as the outdoor temperature drops. Over a series of hot days without cool nights, the temperature of a high mass building will keep increasing, and will tend to remain hot without active cooling.

INSULATION AND MASS

The better insulated a building is, the slower its temperature will change, regardless of its mass, as less heat flows through the building fabric for a given temperature difference. So better insulation enhances the effect of a given level of mass in stabilising temperature by reducing the amount of heat that has to be stored or released to maintain comfort when outdoor temperatures vary.

It also makes sense to place mass on the inside of the layer of insulation, where its impact on indoor comfort is maximised. Mass outside the insulation (e.g. in a brick veneer wall) does still offer beneficial effects by moderating and delaying the temperature difference across the wall, but internal mass generally works better.

HOT AND CHANGING CLIMATE CONSIDERATIONS

Shading windows from sun (or reducing glazed area) and advanced glazing are critically important in hot climates. Enormous amounts of energy can enter a house through a window (almost equivalent to a single bar radiator per square metre exposed to sun). Certainly, a high mass building is less sensitive to this heat gain but, when the outdoor temperature is high, this heat must be removed from the building, regardless of its mass.

With climate change, we are seeing more hot nights and longer hot spells. So our ability to rely on natural ventilation and fans overnight, or for a high mass building to 'outlast' the hot spell is being undermined. This should be driving a review of design practices, because a need for active cooling on at least some nights is becoming more likely. Houses that cannot be sealed up tightly and are not well insulated will incur high cooling energy costs under these conditions. This is not to suggest that design for effective natural ventilation should be ignored, but it does mean designers need to make provision both for good natural ventilation and, when conditions are very extreme, efficient active cooling.

Phase change materials: can we get higher heat capacity without mass?

Phase change materials (PCMs) provide a way of increasing the heat capacity of buildings without adding mass. As a material changes phase from solid to liquid, or liquid to gas, it absorbs a large amount of heat energy without its temperature changing. This is called latent heat: the energy is used to free molecules from the attraction of other molecules.

For example, ice melting in a drink absorbs a lot of heat and keeps the drink cold: as ice melts, it absorbs 80 times more energy than it would if liquid water was heated by 1 degree. When liquid water evaporates, it absorbs over 500 times as much energy as a one degree temperature rise! Of course, when steam condenses or water freezes, it releases the enormous amounts of heat energy it took to melt or evaporate.

Advanced PCMs can be designed to change phase (i.e. shift between solid and liquid) at selected temperatures, so that they act like high mass materials around those temperatures. PCMs are being incorporated into plasterboard, installed in lightweight walls and even incorporated in concrete; however, they can be costly. PCMs can't currently be modelled in NatHERS, although it is being investigated.

Some people incorporate water tanks or containers into the interior of homes. Water stores two to three times as much energy per cubic metre as common high mass materials. But it can leak!

We plan to cover more on PCMs in the next *ReNew*.

↓ A traditional brick two-storey terrace house: these have high mass brick walls and are poorly insulated and draughty buildings with limited solar gains. They are are often comfortable for much of the time in summer—except when they heat up in a long hot spell. In winter, they tend to sit close to the 24-hour average temperature which, in colder climates, means they are miserably cold. Upstairs can be hot in summer, especially if the uninsulated high mass walls are exposed to the sun: they heat up during the day, then cook the occupants at night!


Image: © iStock/marg99ar

↓ A two-storey brick veneer house: the upper storey can get very hot in summer, as it has limited mass, is isolated from the ground, and often has high exposure to summer sun. If the upper storey is well insulated, it can be pleasant in cold weather, as heat from the lower storey and sun offset heat losses. The lower storey tends to be comfortable in summer—as long as windows are well shaded—but may be uncomfortably cool in colder weather unless it has good solar access and good insulation and draught proofing.


Image: © iStock/pamspix

↓ A lightweight highly glazed house: effective shading and insulation are critically important in summer, to minimise the amount of heat flowing into the building. Effective ventilation is also very important to remove heat, and to create air movement which improves comfort. In winter, appropriately oriented glazing can warm up the house quickly on sunny days. But it will tend to cool down overnight, and rooms without good solar access may be cold for much of the time without active heating. Effective insulation, advanced glazing and draught proofing mean it can be made comfortable using small amounts of heating energy.


Image: Peter Hoare.

COOL CLIMATE CONSIDERATIONS

In a climate where the outdoor temperature is always colder than the desired indoor temperature, more mass does not replace the need for insulation and other energy-efficient fabric features. That's one reason why homes in many very cold climates are often lightweight: the large, consistent temperature difference means insulation is the big factor in reducing heating energy requirements.

How to design and manage high mass (really high heat capacity) and lightweight (low heat capacity) buildings

It is possible to make both high mass and lightweight houses work well in most climates as long as they are well designed and well managed, and user expectations are realistic. But different design approaches and management techniques are needed.

LIGHTWEIGHT HOUSE DESIGN

A lightweight house, all other things being equal, will need to be designed with less glazing to achieve the same energy efficiency as a high mass house. And, to achieve very high Star ratings e.g. 9 or 10 Stars, some mass (or PCMs) will almost always be needed to store heat overnight to eliminate start-up loads on winter mornings. This is where interesting discussions can occur about the relative costs of using alternatives such as stored hot water or small amounts of stored renewable electricity to provide morning heating in comparison to the extra cost of upgrading the building from 8 to 9 or 10 Stars!

Fundamentally, the temperature in a lightweight building is more sensitive to the level of insulation, draught proofing, solar gains (mainly through windows) and internal heat generated by lights, appliances and people. This is simply because a given amount of heat energy entering (or leaving) the house has a much bigger impact on the indoor temperature than for a house with high internal mass.

So trapping heat in a lightweight house in winter and blocking heat out in summer (while minimising internal heat generation) are very important. At the same time, large north windows can easily overheat a lightweight house on sunny days in winter—a problem many people would like to have! But without really effective shading, those same windows can cook you in summer. Lightweight houses are more likely to need some active heating and cooling, although the actual amounts of energy needed to provide comfort can be very small if they are well insulated and shaded.

A lightweight beach house I helped to design worked very well. It was very well insulated and sealed, with fairly large areas of low-e double glazing to the north and east, was well protected from west sun. It had a (very small capacity) hydronic heating system. In winter, it was wonderfully warm during daytime, but did cool down overnight, so the hydronic central heating ran for about half an hour on cold mornings. If the extensive shading was not in place in summer, it quickly became a solar oven: on one hot morning the living area hit 35 °C by mid morning! But with effective shading, and the occasional benefit of a sea breeze, it was very comfortable, and very rarely exceeded 30 °C: ceiling fans provided adequate cooling. Even if it had used active cooling, it would not have used much cooling energy—as long as the shading was in place! Of course, access to sea breezes helped moderate this.

HIGH MASS HOUSE DESIGN

A well-designed high mass house will tend to sit within a few degrees of the 24-hour average temperature for the time of year. In many parts of Australia, this is 18 to 25 °C, so the house can be quite comfortable with little or no intervention. But in cooler locations (and in south-facing rooms), the 24-hour winter temperature can be 12 °C or lower, while in the tropics summer daily average temperature can be over 30 °C. Under these conditions, large amounts of heating or cooling energy may be needed unless the building is well insulated and sealed, and has winter solar gain or summer ventilation (and

↓ A high mass house with poor orientation of glazing: in winter, this house will tend to feel cold, and will need heating much of the time if the 24-hour average temperature is low, unless it is well insulated, draught proofed and has advanced glazing. In summer, unwanted solar input can heat up the mass, making the building fairly uncomfortable for significant periods.

Image: Jesse Raaen

↓ High mass house with good solar access, adjustable shading, insulation, advanced glazing, draught proofing and controllable ventilation: a house like this can be remarkably comfortable with minimal active management in many parts of Australia.

Image: Emma Cross.

cool enough overnight breezes).

As mentioned earlier, an uninsulated high mass wall exposed to sun can create an oven, as can high summer heat input from the sun, hot air leakage or unshaded windows.

Long periods of hot or cold weather will slowly shift its temperature until it is uncomfortably hot or cold—unless solar gain or active heating is used in winter, and overnight ventilation (if the outdoor temperature is cool enough) or active cooling is used in summer. Then it may need a lot of heating or cooling energy (or ventilation), because a lot of energy must be added or removed to make it comfortable.

Reducing the heat input in summer (e.g. by shading, insulating and reducing air leakage) will allow the high mass house to remain comfortable through a longer heat wave. But if it doesn't get much solar gain in winter, it may be unpleasantly cool in colder climates without active heating. This is where effective insulation, ventilation systems and adjustable shading can optimise comfort while minimising energy use.

MASS AND KEEPING COOL

Weather records and climate science tell us that overnight temperatures are increasing and hot spells are becoming longer and more extreme. These trends mean we are more likely to need some active cooling at times in most climates in the future, regardless of the amount of mass in our buildings.

Further, many people do not ventilate their homes overnight: this may be because of concerns about security, noise or simply because they don't understand what a difference it can make to their comfort. Regardless of the reason, it means they are not fully utilising natural cooling to improve comfort and enhance the effectiveness of the mass in their homes. Home ventilation systems that can extract heat overnight are becoming more widely available. And even an exhaust fan can help. Small windows that are high off the ground can also provide secure and effective overnight ventilation.

MASS IN SLABS

Mass in a slab-on-ground floor is different to mass in a wall. An uninsulated slab is linked to the stable ground temperature (at 3m depth), so it helps to keep a building closer to that temperature, regardless of the amount of mass in walls. Depending upon your location, this may or may not be desirable. *Your Home* provides guidance on this, see box at right.

OTHER CONSIDERATIONS

When considering high mass design, it is also important to look at overall building cost. Some high mass solutions can be expensive relative to other options.

> "Ideally mass should be located on the room side of the layer of insulation in walls (and ceilings), so that its effectiveness at stabilising temperatures is maximised."

Mass in slabs (*Your Home*, p. 255)

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

In climates with colder winters, such as Melbourne or the southern highlands of NSW, the deep ground temperature is too low to allow passive solar heating to be effective enough. In these locations, slabs should be insulated underneath, which reduces the amount of heat required to achieve comfortable temperatures. In northern Australia, ground coupling still works well, unless the building is to be air conditioned, in which case insulating the slab—especially the edges—is essential. Insulating the edges of floor slabs is beneficial in all but the mildest climates, but protection against termites needs careful attention. www.yourhome.gov.au/materials/concrete-slab-floors

Note: In the thermal mass section of *Your Home*, it recommends slab insulation for climates with low earth temperatures at 3m depth, citing Tasmania, and hot, humid climates with high earth temperatures, citing Darwin. It should also be noted that different soil conditions can affect the way in which the slab interacts with the ground temperature.

> "From a life cycle perspective, the investment of energy in high mass materials has to be offset by lower operating energy use and emissions if there is to be a net benefit."

It is possible to reduce dependence on mass by using effective shading, advanced glazing, and other energy efficiency measures including insulation and sealing that reduce the amounts of heat flowing into and out of a building. And high efficiency reverse-cycle air conditioners with rooftop solar can help to maintain comfort in an energy-efficient building at relatively low capital and operating cost—with 'beyond zero' emissions averaged over the year.

But a well-designed high mass building provides a very stable and comfortable environment with minimal need for active management—which can be very nice.

Where should the mass be?

If mass is 'hidden' by a layer of other material, such as a carpet or plasterboard, the rate of heat flow into and out of the mass is reduced, as these materials act as insulation. So a given area of mass may be less effective in the short term at stabilising temperatures, but the extra insulation may also be beneficial at times.

In principle, to maximise the benefit of mass, it should be exposed to the interior air. And if winter sun shines on it, it can absorb heat more quickly. But it can still be useful even if it is covered. And increasing air movement within the house over the surface of the material, e.g. by using a fan, can increase heat transfer, improving the effectiveness of the mass.

Ideally mass should be located on the room side of the layer of insulation in walls (and ceilings), so that its effectiveness at stabilising temperatures is maximised. However, computer modelling and field measurements show that even an outer layer of mass (e.g. brick veneer or stone) does offer some benefit in many climates, by moderating the effective temperature difference driving heat flow into or out of the building. But the benefit is not sufficient to avoid the need for insulation unless the climate is very moderate.

Life cycle energy and emission issues

Common high mass materials such as brick and concrete have high embodied energy and emissions—large amounts of energy are used to produce these materials. From a life cycle perspective, this investment of energy has to be offset by lower operating energy use and emissions if there is to be a net benefit. In moderate climates and as buildings and appliances become more energy efficient, the break-even period for operating savings to offset the investment can reach decades. And the importance of ensuring a long life and re-using or recycling the materials increases.

However, there is an increasing range of lower emission high mass products. For example, eco-cements that replace some or all Portland cement with materials such as fly-ash and slag from steel production can have significantly lower embodied emissions. Recycled steel reinforcing or using fibres for reinforcing can cut the embodied energy of the concrete: steel can comprise around half of the total embodied energy of reinforced concrete.

More-energy-efficient gas-fired brick kilns can significantly reduce the embodied energy and emissions from brick production. The best kilns use less than half as much energy as the worst. One manufacturer has even begun to produce a zero carbon brick that uses sawdust mixed with the clay to provide much of the energy needed to fire the bricks. Recycled bricks are a good option.

Some other materials such as mud brick, rammed earth (pise), hempcrete and even strawbales can provide substantial mass and heat capacity without high embodied emissions and energy. ✱

Alan Pears is one of Australia's best regarded sustainable energy experts. He teaches part-time at RMIT University and is co-director of Sustainable Solutions, a small consultancy.

Resources:
Your Home:
www.yourhome.gov.au/materials
www.yourhome.gov.au/passive-design/thermal-mass

More on heat and temperature

Heat is a form of energy that flows from a hot to a cold material. Radiant heat is emitted by a hot body or absorbed by a cold one: it does not require a material or air movement. A given amount of heat can be used to change the temperature of a high mass lump of material by a small amount or a low mass lump by a large amount.

Temperature is the driving force that influences the rate of heat transfer—the bigger the temperature difference, the greater the heat flow. It is the equivalent of water pressure or the voltage of electricity.

The other important factor is **thermal resistance**, the R-value of insulation. For a given temperature difference, doubling the thermal resistance will halve the amount of heat energy transferred.

Heat capacity determines the amount of *temperature* change resulting from a given amount of *heat* flow into or out of a material. Many people confuse heat and temperature. For example, if a very well-insulated and shaded lightweight house gets very hot, only a small amount of cooling energy may be required to make it comfortable, as only a small amount of heat is flowing into the building: it just has a big impact on the temperature. On the other hand, if a high mass building becomes uncomfortably hot, a large amount of cooling energy may be needed to bring it back to a comfortable temperature, because a large amount of stored heat must be removed to lower the temperature.

Designed to last
Long live sustainable housing

What would our houses look like if we designed them to last 100 years, or longer? Ande Bunbury, designer of the award-winning Double Century House concept, examines the issues.

WITH many houses in Australia designed for just a 30-year lifespan (alongside some that may only last the length of the builder's warranty before major repairs are required), a massive amount of embodied energy is being wasted in our housing stock. Surely we should be designing buildings to outlast us.

We do have examples here in Australia of houses that are 100 to 200 years old. Overseas, there are many still-useful houses that are even older. But effective longevity requires more than just lasting the distance—this article looks at some of the issues to consider when designing houses that last.

↑ The Double Century House concept includes flexible spaces, passive solar design and durable materials and finishes. The modular design uses standard building material sizes to minimise construction waste, and has a small footprint (134 m²) reducing construction and furnishing materials, energy use in operation and maintenance. Materials include a concrete slab with fly-ash, recycled timber boards, reverse brick veneer walls with double-stud construction and external zinc or timber cladding, and rammed earth internal walls.

Sustainable design

First up, there is no point designing a house to last if it doesn't have all the basics right, such as good orientation and aspect, internal thermal mass (where appropriate) and a location with access to transport and connection to community and services. Tweaks can be made later but if the fundamentals aren't right the house could be an ongoing liability rather than an asset.

Of course, existing homes may not have these fundamentals. It's even more important to make the most of the housing stock that we have and renovate well, when possible.

Sustainable design in our changing climate also means considering a warmer or more variable future climate. For example, with increasing heatwaves in parts of Australia, what is the role for thermal mass? In *ReNew 130* (and a recent series in *Sanctuary*), Dick Clarke and the late Chris Reardon considered the difficult question of design for climate change in detail. Long-lived designs need to be adaptable to different future climates.

Flexibility

One term bandied around when considering long-lasting design is 'loose fit': the idea that spaces should be flexible and adaptable. People's needs for housing change over time—small children want to be in the same space as their parents so open-plan design works well; teenagers want more separation and privacy; eventually, the house may become home to multi-generations, with parents and adult children (and their partners) living together, or it may house empty nesters. A well-designed house should be able to adapt to these changing needs without needing to go through multiple renovations. Flexibility for all via universal design is one approach to this (see box).

Another thing that changes a lot over time is technology. Who knows what cooking appliances, for example, may be available in 30 years? That built-in microwave and coffee machine may look really good in your new kitchen, but do you really want to have to replace your kitchen joinery when the appliance dies? A loose-fit design with adjustable shelves and panels can adapt to suit the new fridge or have space for as-yet-unknown devices of the future.

Simplicity

The simpler a system is the less there is to break down and the easier it is to repair. When selecting a system for use in a long-lived house, ask yourself whether it could be repaired if the original company goes out of business or they stop making that product or component.

For example, I prefer close-coupled solar hot water units over split systems, as they don't need a pump to shift the water from the panels into the tank. Another example, perhaps more controversial, is a preference for timber window frames over thermally broken (insulated) aluminium as the hardware to operate them is simpler and can be replaced, and the frames can be repaired and even partially rebuilt if needed.

↑ A studio/home office designed to be flexible; it could also be used as a bedroom or living area. There are a number of sliding panels that can conceal the heater, black out the windows and hide junk.

↑ The durability of materials subject to wear and tear, such as roofs and external cladding, is one consideration in designing a building to last. Colorbond Ultra comes with a 25-year warranty even in a coastal environment. Zinc cladding can be maintenance-free for 60+ years.

Durability

Many people would probably think of durability first when considering long-lasting design, but I think it's less important than the categories above.

Very few materials will last 100 years without any maintenance. The materials your house is built from, particularly the external skin, are exposed to the elements and wear and tear.

However, some materials can last a long time as long as protective coatings such as paint are kept in good condition. There are also plenty of materials out there designed for a longer lifespan, often particularly targeted for the marine environment where everything degrades so much faster.

To get an idea of the expected durability of a material, you can look at the warranty period offered. Although a long warranty doesn't ensure quality, it is the best we have to go on, along with user and Choice-style reviews. There is more that governments could do here, to regulate for longer warranties and end-of-life disposal requirements by manufacturers, making it more attractive to build in quality.

When it comes to housing, in general, the more solidly built a house is the more durable it is—just think of all those European examples. Masonry materials such as stone, brick, concrete and rammed earth can all last extremely long times. However, there are issues with using these materials as a protective skin; in many climates they may need external insulation to get effective thermal performance. [*Ed note*: see thermal mass article this issue for more on this]. In addition, some of them have high embodied energy.

Inert metal cladding materials such as zinc and copper come at a cost premium upfront but can be maintenance-free for 60+ years. Many examples exist such as church roofs in Europe that have lasted over 200 years.

As another example, conventional metal roof sheeting can come with a premium finish such as Colorbond Ultra, with a 25-year warranty in a coastal (fast-wearing) environment. Even cheap lightweight materials such as fibre-cement sheet can last an extremely long time—think of those 1970s fibre-cement beach shacks. Forty years on and the base material is doing fine.

In terms of longevity, timber needs careful consideration. Depending on the species and orientation, exposed external timber surfaces may need replacement after 25 years. Painted weatherboards can last much longer but require regular maintenance. Internal polished timber floorboards can only be sanded back three times before they become too thin, so for longevity use oil finishes that can be touched up without sanding, or provide coverings to areas with most wear.

Embodied energy

Embodied energy is a major factor to consider; a primary reason we want long-lived buildings is to reduce the waste of those buildings' embodied energy. The energy used to make the materials and products in

Flexibility for all

We can't know who the future residents of a home are going to be, or our own future needs. One thing that many designers now consider integral to sustainable housing design is universal design—making sure the home has features that could easily be adapted for disabled or aged residents. This extends the question of accessibility to the private realm, for example with entry paths, rooms and showers designed wider and without steps for ease of wheelchair use, and switches, taps and other fittings placed in reach. The Livable Housing Design Guidelines (www.livablehousingaustralia.org.au) include 16 guidelines which covers all the things that make a place accessible. Also see the Australian Network for Universal Housing Design: www.anuhd.org.

Image from the Livable Housing Design Guidelines, www.livablehousingaustralia.org.au

↑ To support ease of movement, a width of at least 1200 mm between kitchen benches is one of the 16 Livable Housing Design Guidelines.

our houses is huge, as is the transportation to get the products to site. The construction industry by some estimates is responsible for 40% of waste to landfill—this includes new materials being thrown away because they are offcuts or imperfect, or they were ordered by mistake.

Anything that requires heating in its production (bricks, lime for concrete, aluminium etc) has higher embodied energy, but this can be weighed up against its lifespan, maintenance requirements and where it is made (hence transportation requirements). [*Ed note:* Life cycle assessment (LCA), giving total energy impacts over the building's expected lifetime, provides a way to quantify this, though it is complex. Architects/designers can use rating or LCA tools to enable you to make decisions about the tradeoffs between embodied and operational energy.]

Anything secondhand or diverted from landfill is preferable to new materials (reduce, *reuse*, recycle). Probably the most important thing we can do to reduce the embodied energy in the construction of our homes is to reuse what was there before.

In the end, longevity is not just about whether the materials last, but rather a combination of appropriate design, durability, maintainability, embodied energy and reusability. To make wise decisions, you need to consider all these factors. ✷

Ande Bunbury is an architect based in Melbourne. She won the BDAV 2014 10 Star Challenge with a design for the Double Century House. See www.abarchitects.com.au.

Durability resources:
The Australian Building Codes Board handbook *Durability in Building Including Plumbing Installations* (2015) is available at www.abcb.gov.au/education-events-resources/publications/abcb-handbooks.aspx.

Life cycle assessment articles:
Sanctuary 13, 'From Cradle to Grave'
ReNew 124, 'The Full Cycle: How Sustainable is Solar PV?'
Your Home: www.yourhome.gov.au/materials

Tools for analysing material impacts:
eTool, an LCA tool for the built environment: www.etool.net.au
Ecospecifier: www.ecospecifier.com.au
BREEAM: www.breeam.org

Understanding life cycle assessment

Modelling the full life cycle: why it's important

Simon Lockrey, research fellow at RMIT's School of Architecture and Design, believes we should be using life cycle assessment when modelling buildings. He explains why.

Buildings by their nature are complex systems, as are the sustainability issues to which they connect such as climate change, peak resources and land occupation. Life cycle assessment (LCA) can drive reduction of environmental impacts in buildings, by tying design decisions to impact reductions for contexts now, and those envisaged for the future.

First, a definition from the International Standards Organisation is helpful: LCA is a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle."

The method has long been used to identify environmental impacts over the full life cycle of products, services and systems, covering materials, manufacturing, transport, operational use and end of life. LCA has been widely accepted and adopted within the corporate sector whether it be for something small like a piece of packaging or something as large and complex as a city.

In LCA, environmental impacts are assessed in comparison to a product's function. For a building, this function may be to provide shelter and comfort for occupants for a given period of time, say the proposed building life. Results are often accompanied by a number of sensitivity analyses to test their validity under a range of different circumstances. In the built environment this might include investigating different heating/cooling technologies, alternative building materials, changes to future building energy sources, switching the building aspect, or even modifying the behaviour of occupants within the building.

These varying elements may be temporally, socially, technologically, economically and politically affected; a 'whole systems' analysis is needed.

It is important that building designs consider the whole system in which they are placed, not simply focus on one stage of the life cycle, out of context. For instance, to concentrate on building materials to reduce the embodied energy of a building may be a noble pursuit on paper. However, if the thermal performance of the building envelope is compromised, so much so that operational environmental impacts dwarf those of materials, the strategy would be a failure. Likewise, great attention might be given to the efficiency of heating/cooling services installed in a building, but this shouldn't be to the detriment of material selection, design features and aspect.

LCA can solve these conundrums by identifying the environmental impact hot spots across life cycle stages. LCA can validate or discard particular designs on their own merit, and in the context of all of the other elements of a building system over the life cycle. This system's thinking model is becoming more prevalent across many industries and it is to be hoped that building design will follow suit.

A practitioner's viewpoint: Rating tools and life cycle assessment

Tim Adams, a building designer at F² Design, considers where we're at in finding the balance between operational and embodied energy in buildings.

Our ability to model building fabric thermal performance is now mature and consistent, with skilled use of NatHERS energy rating tools. The total package of combining embodied energy and operational energy is still a little more difficult to quantify with confidence.

The Low Carbon Living CRC (www.lowcarbonlivingcrc.com.au) collaboration between Melbourne University, University of NSW and University SA is carrying out work to develop tools that will give us a better handle on understanding overall impacts for buildings and entire precincts. The complexity of this level of assessment is extraordinarily Byzantine.

If successful we will be able to differentiate and make quantifiable decisions, for instance, between locally produced (low transport miles) aluminium windows that have been made with coal-fired electricity and windows sourced overseas (high transport miles) but made with 100% renewable hydro-electricity.

An often heard refrain in our office is that "there are a lot of tools out there". In an ideal world it would be great if all the tool makers got together and used their collective energies to make one really good one. (Tim discussed the many international tools available in *Sanctuary 26*, 'International Sustainability Rating Tools'.)

If a home will be covered with PV panels generating more renewable power than will ever be used in the dwelling and even powering an EV, is it then acceptable for the design to be a little cavalier with embodied and operational energy? Logically the answer is no: we have the ability to minimise the operational energy requirements at cost-effective levels, so even more excess on-site generation is available for use by others to reduce demand for fossil fuel fired electricity generation.

The poor passive thermal performance of our building stock in the past has meant that operational energy has been dramatically more significant than embodied energy in carbon accounting. As we move to improved results, and even potentially towards 10 Stars where virtually no heating or cooling is required, the energy curves intersect and embodied energy steps up as the main offender.

There is still a way to go with improving our building designs to reach full passive performance. Hopefully by the time we get there, groups like the Low Carbon Living CRC will have developed tools that are easy to use and accessible to the broad cross-section of participants in the planning and building industries.

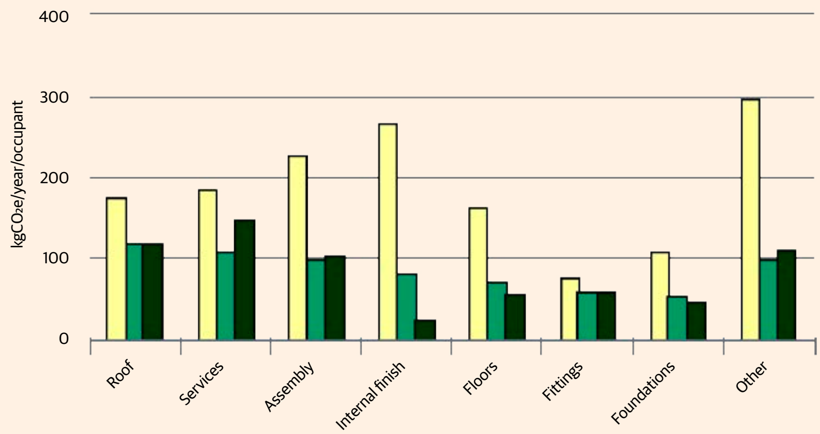


Image courtesy eTool; see etoolglobal.com/portfolio-item/straw-bale-lca.

↑ LCA was used retrospectively to assess this strawbale house design by Viva Living Homes in NSW. The graph shows embodied energy breakdown for a benchmark BCA compliant design (yellow), the original strawbale design as-built (green) and a design with eTool recommendations (black). For the as-built house, total impacts for embodied and operational energy were 1250 kg CO_2e/year/occupant, a saving of 72% over the benchmark design, with 54% of impacts from embodied and 46% from operational energy.

But what's happening in Australia?

Just how much is life cycle assessment (LCA) being used now in residential home design in Australia? asks Robyn Deed.

LCA is more prevalent in the commercial and government sector, but it seems it is possible to use LCA at the residential scale with the tools available now.

WA-based architect Sid Thoo who has a share in eTool, a home-grown company that developed building LCA software eTool and runs assessments, says there are promising signs that LCA is becoming more a part of people's thinking. In one recent case, an LCA was used as a way to demonstrate NatHERS code compliance, rather than using the standard ratings tools.

"It's not as hard as people think," he says, adding that a house LCA can be done by skilled assessors in about half a day, about the same time as a NatHERS energy ratings assessment. It can be done either retrospectively, post-design/build, or as part of the design process—or both.

Tim Grant from Life Cycle Strategies, a consultancy that performs life cycle assessments, and a board member of the Australian Life Cycle Assessment Society (www.alcas.asn.au), says that, at present, there aren't many sustainable design consultancies using LCA at the residential level, but that many are informed by its approach.

Tim says, "I know many designers keep abreast of the relative benefits of key materials. For example, they'll understand that the thermal benefits of improved glass technologies far outweigh their energy inputs."

At the residential level, Tim thinks that those who are doing LCAs are mostly using eTool in Australia. There are other tools available internationally which some may be using, and there's also SimaPro which is used by larger design groups for commercial constructions. He notes that some developers have used LCA to assist with material and design choices for larger housing developments.

One tool used by many local councils in Victoria is Steps, which assigns points to various material and design choices; it's informed by LCA thinking in the points assignment, rather than being a full LCA tool.

A full building LCA instead relies on a database of materials and their quantified life cycle impacts. The advantage of this approach is that it can start with general information on materials and be updated over time with more detailed information as that becomes available, such as the type of energy used in a specific brand's production and the transport impacts for the components.

eTool began in 2010 using the Inventory of Carbon and Energy, a UK-based database out of the University of Bath, that quantifies the embodied energy of general materials. eTool has since expanded to include many more specific materials, though not all materials will have that detailed information available.

Sid Thoo uses LCA to "validate the intuitive design decisions I would otherwise make, allowing me to check that what seems the best decision actually is."

In the early concept design stages, he tends to rely on intuition regarding best orientation, glazing, materials etc. He gets an LCA done (and a NatHERS rating) once the design has received planning/development approval; he can then select and test more specific aspects to improve and refine the overall performance result. From time to time he also creates quick models of just one part of the design or looks up specific materials in the eTool database to provide guidance.

Tim Grant says that an important aspect of LCA that needs to be considered is that of time—the 'designed-for' longevity of the building and its materials. He says, "When using LCA, we are to some extent guessing what's going to happen in the future."

For example, in assessing operational energy for a building over its lifetime of, say, 50 years, we are making assumptions about the carbon emissions of a future grid. If we stick with the current carbon emissions of the grid, we are "very accurately wrong", or we can choose to predict which way we're heading and be "inaccurately correct". At least LCA gives us a way to grapple with such questions. ✷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More than brick veneer
Emerging materials

The world of building materials is ever-evolving, but which of the new materials will make it to market acceptance? Lance Turner looks at some of the products starting to take off now, and what's just over the horizon.

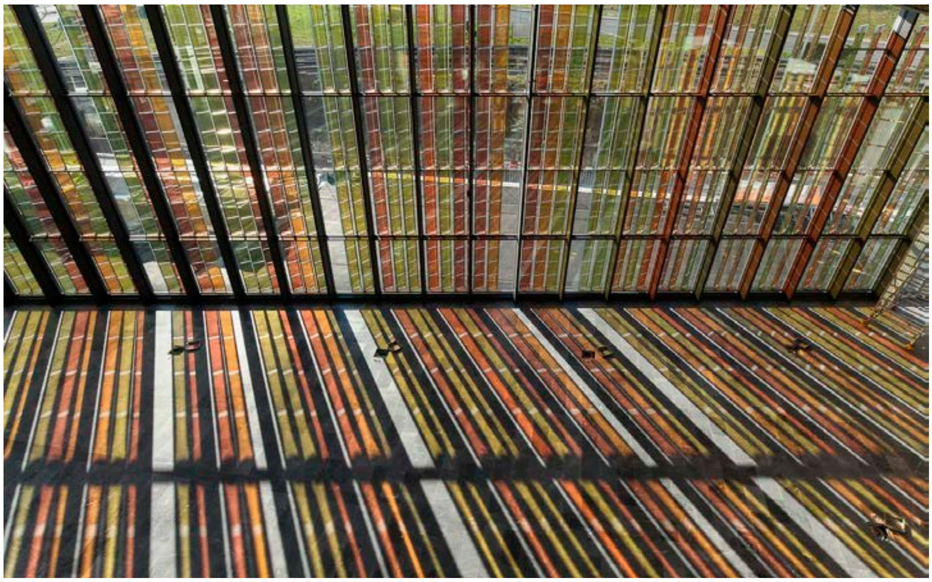


Image: EPFL – SwissTech Convention Center

↑ Building integrated PVs, such as the Grätzel facade at the SwissTech Convention Center (also see image on cover), enable windows to provide light, warmth and electricity.

Solar panels: the new building material?

Solar panels can take the place of some building materials, known as building integrated photovoltaics (BIPVs). For example, they may be integrated into the roof, replacing roofing sheets or tiles, they may form the roof of a carport or verandah (as on the cover of the last *ReNew*!) or they can even be part of a wall or balcony rail. Anywhere a surface gets a good amount of sun is an opportunity to use BIPVs.

Although BIPVs sound like a great idea, reducing costs by displacing some building materials while producing a neater, integrated look, they have struggled to gain a foothold in Australia. There are some amazing examples overseas, but the examples here are far more limited. And, unfortunately several manufacturers, such as Schott Solar, have stopped manufacturing them in recent years due to the low cost of standard panels.

However, there are still options available, mostly in the form of roof materials. The original PV Solar Tiles (www.pvsolartiles.com) have been available for more than a decade, and roofing manufacturers are now getting in on the act, with BIPV systems available from Monier (SOLARtile, see www.monier.com.au/Tiles/SOLARtile), SolTech (not available in Australia as far as we know, see www.soltechenergy.com), Nulok (www.nulok.com.au/solar), Tractile (www.tractile.com.au) and Stratco Solatop (www.bit.ly/Solatop).

The roof is not the only place where BIPVs are being used: it's also possible to install windows that actually generate electricity. This has the added benefit that the windows reduce the incoming energy and so help keep the building cool. The main disadvantage of a PV window is the higher cost should a breakage occur. They'll also reduce solar gain in winter, thus reducing warmth collected passively.

So what's currently available in the solar window arena? A few years ago there were several options, but those manufacturers have either stopped manufacturing them or have disappeared. Maybe they were a little too far ahead of the curve or the high manufacturing costs just didn't add up.

As always though, technology advances and a new breed of lower cost dye-based solar cells are emerging that may change the way we look at windows.

Oxford Photovoltaics (www.oxfordpv.com) has developed perovskite-based transparent solar panels that can be used to both let in light and generate electricity, although they are not yet commercially available. On the other hand, Solaronix (www.solaronix.com) has commercialised a dye-sensitised solar cell that is available in a range of colours and transparencies and has already been used in at least one large commercial installation, the 300 m² facade at the SwissTech Convention Center in Switzerland.

Onyx Solar (www.onyxsolar.com) also has commercially available solar glass panels in four sizes, suitable for windows, skylights, walkways, and even as floor tiles. They also do custom sizes for projects where standard sizes just won't do.

With numerous companies working on transparent solar cells, it shouldn't be long before PV windows become a real option, although they may take a little longer to filter through to Australia.

← Cross-laminated timber is simply massive plywood that can be used to make entire walls, floor or roof panels in one piece.

Image: Hybrid Build Solutions, www.hybrid-build.co

Engineering timber for strength and sustainability

Timber is one of the oldest building materials known, and for many people it is the preferred choice for its visual appeal, ease of use and relatively low cost. However, not all timber is sustainably produced, and some is a downright environmental disaster.

Much of the timber used by the building industry is plantation sourced, most of that being pine. While pine plantations are regrown after harvesting, most plantations originally displaced native forest, so they have environmental baggage attached, along with the ecosystem disruption issues of monocultures. But even monoculture pine plantations provide some limited habitat for wildlife, which then brings with it its own issues of animal deaths caused during the tree harvesting.

Overall, plantation timber has both good and bad sides—it locks up carbon, at least until the timber reaches the end of its useful life (which could be more than 100 years with hardwood, if it is reused rather than dumped when the building is demolished), but it also displaces native forests. Then again, using plantation timber also reduces the need to harvest still-existing forests.

It can be difficult to find truly sustainable timber, but the Forest Stewardship Council's website lists retailers selling FSC-certified wood as well as a list of species that have received certification. See au.fsc.org for more information. The Australian Forestry Standards website (www.forestrystandard.org.au) has information on the AFS and PEFC certifications, which, while arguably less rigorous than FSC, cover a greater number of timber suppliers.

Traditionally timber has consisted of solid sections cut from logs and either air or kiln dried, but there are other forms that can be more suitable for particular building uses while reducing the amount of timber required.

Known as engineered timber, this covers any timber materials that have been manufactured to improve the qualities of the material. An example is plywood, which takes thin sheets of timber veneer and laminates them, with the grain orientation of each sheet at 90 degrees to the preceding layer. This results in a timber sheet with grain running in both directions, giving the finished sheet very high strength.

Plywood is a well-known example, but there are other forms of engineered timber that have been less well used in Australia due to the lack of availability or simply lack of awareness of their existence. Engineered timber beams, such as hyJoist from Carter Holt Harvey (www.chhwoodproducts.com.au/hyjoist), consist of laminated timber flanges bonded to a structural web (either plywood or oriented strand board) to form an I-joist with high strength yet light weight, ideal for domestic and commercial construction.

Other engineered timbers are available from Hyne Timber (www.hyne.com.au) and Wood Solutions (www.woodsolutions.com.au).

While plywood has been around for many decades, a newer form called cross-laminated timber (CLT) is gaining popularity. Effectively plywood on steroids, CLT is much more massive than even the thickest ply, and can be used in place of other load-bearing construction panels such as prefabricated concrete panels. One Australian supplier, Cross Laminated Timber in SA, supplies panels with each layer between 15 and 45 mm thick, resulting in panels up to 350 mm thick, 3.8 m wide and a huge 18 m long. An entire wall can be made in a single CLT panel, resulting in extremely fast construction times. The Forté apartment block in Melbourne (www.forteliving.com.au) is a recent example of CLT building.

While engineered timber is set to make huge inroads into building in Australia, any timber can gain improved properties with the right treatment. Treated timber has been common here for decades, but some forms of treatment, particularly CCA (chromated copper arsenate, also called copper chrome arsenic), is very toxic and has poor environmental credentials.

Less toxic treatments have been developed, but a new kid on the block that is not so well known is Accoya (www.accoya.com), an acetylated wood that has the properties of hardwood while being made from plantation softwoods. The acetylation process greatly reduces the wood's ability to absorb water by changing the free hydroxyls within the wood into acetyl groups. This is done by reacting the wood with acetic anhydride, from acetic acid. Because the ability of the wood to absorb water is greatly reduced it becomes more dimensionally stable and, because the digestion of wood by enzymes initiates at the free hydroxyl sites, it is no longer digestible and therefore extremely durable.

Framing the build: alternatives to timber and steel

By far the most popular framing material in Australia is timber, usually plantation softwood. However, wood may not always

Image: Doug Cooper

Engineered timber, such as these Hyjoist beams, can provide high strength with much lower materials usage and weight.

be suitable, especially if you are in a termite-prone area.

Steel is a popular alternative material for both wall framing and roofing, and while it is light, strong and has a very long lifespan, it does have some downsides.

The main issue with steel in building is its thermal conductivity. In walls it acts as a thermal bridge, bypassing the insulation between the studs. This necessitates the need to insulate over the steel framing itself on the outside walls, adding to costs and construction time. The energy cost of steel manufacture is also an issue as it is one of the highest embodied energy materials per square metre of floor area other than concrete.

Another issue is condensation—steel-framed walls have a lower humidity buffering capacity and so can be more prone to condensation issues than wood-framed walls.

Lastly is the issue of fire resistance. Wood behaves in predictable ways in a fire and there are indicators that firefighters can look for to gauge the integrity of the structure. This is not the case for steel framing, which is prone to sudden collapse when a particular temperature is reached. As a result, experienced firefighters will often not enter a steel-framed home, instead fighting the fire from the outside. An interesting article on these and other issues related to steel framing can be found at www.bit.ly/GBABWSF.

If you can't or don't want to use wood or steel, what are your options?

One option is to not use framing as such at all. There are many prefabricated panels, such as CLT mentioned earlier, that eliminate the need for framing for the most part. Other options include SIPs (structural insulated panels, see Bricks, Blocks and Panels on p. 43).

Bamboo is not often thought of as a framing material but, used correctly, entire homes can be built from this amazingly strong and potentially sustainable material. Being a very fast-growing member of the grass family, bamboo can grow where trees (and many other plants) cannot, allowing the use of otherwise low-value land. Bamboo is light and as strong as steel per kilogram of material, making it versatile.

One drawback for building is its inconsistent size—each pole varies in diameter along its length, and may have slight curves or twists, making it not suitable for the average home design. But given that the developing world has been building amazing structures from bamboo for centuries, it's just a matter of adapting designs to suit the material.

Bamboo Living (www.bambooliving.com) in Hawaii has done just that and lays claim to supplying the only code-certified bamboo structures in the world. Almost the entire design is built of bamboo, including framing, flooring, roofing and wall cladding. Ibuku Designs (www.ibuku.com) makes amazing buildings from almost nothing but bamboo, and shows there are almost no limits to the size of building that can be built with this versatile material. (See *Sanctuary 28* for a longer discussion on the sustainability of bamboo for building purposes.)

While these styles of home are obviously not suitable everywhere, for the more tropical areas of Australia it could certainly work quite well, taking into account cyclone protection.

Another way of eliminating framing is with tensile structures. These are structures where the whole outer envelope is in tension, so that there are no elements undergoing compression or bending forces. The Sidney Myer Music Bowl in Melbourne is an example of a tensile structure.

Tensile structures often consist of one or more supporting structures or towers, from which are strung multiple cables in tension. The structure is covered in a membrane to complete the structure. This method of construction is only suitable to certain designs and locations, but can be used to provide strong, flexible roof structures for all manner of buildings. Examples include roofs on stadiums, museums and airports.

Image: Bamboo Living

Bamboo can be used to build entire homes, such as this one from Bamboo Living in Hawaii.

A concrete example: more eco-friendly options

Concrete is the mainstay of the building industry. Made from cement (a binder), aggregates (gravel and sand) and water, it's well known that it has high embodied energy from the process of kiln firing the binder and mining of the aggregates. It has been estimated that the CO_2 emissions from one tonne of structural concrete can be up to around 180 kg, or around 410 kg per cubic metre, although the current figure given by The Concrete Centre in the UK puts it around 100 kg/tonne; it will vary depending on the location of manufacture.

More eco-friendly versions replace part of the cement binder with waste materials such as blast furnace slag (waste from iron production) and fly-ash (waste from coal-fired power generation), while aggregates can be replaced with crushed recycled concrete.

One eco-friendly option available now is geopolymer concrete, which removes all Portland cement from the mix, replacing it with a geopolymer to activate fly-ash and slag as the binder.

A geopolymer is a polymer (long chain molecule) which is based on silicon rather than carbon, so it is basically a mineral-based polymer.

The amount of cement that is replaced by more eco-friendly materials varies depending on the concrete product and the manufacturer, with some manufacturers replacing virtually all of the cement and aggregates with eco-friendly alternatives. Examples of more environmentally friendly concretes include Wagners EFC (earth friendly concrete, see www.wagnerscft.com.au/products/efc) which reduces the greenhouse emissions of the cement portion of the concrete by 80% to 90% compared to standard concrete.

Independent Cement & Lime (www.independentcement.com.au) make their Ecoblend concrete, which contains a minimum of 30% cement replacement materials in the form of slag and fly-ash. This blend reduces CO_2 emissions of the cement by around 29%, as well as having other advantages such as reduced heavy metal content and water use.

Taking a different approach is Eco-Cement from TecEco, which contains magnesium oxide (also called magnesia) as a binder instead of Portland cement. Compared to Portland cement, magnesium oxide requires less energy to manufacture, and it absorbs CO_2 as it hardens, locking up carbon.

Magnesium oxide-based concretes have other advantages, including higher strength than regular concrete and the ability to be made into pervious (porous) concrete simply by leaving out the fines (small particles such as sand).

Interestingly, magnesium oxide-based concretes were actually in widespread use before Portland cement was developed in 1824. Blending magnesium oxide mixes was something of an artform and continued up until the mid twentieth century. However, by the late nineteenth century Portland cement based concretes had become the dominant form of concrete, despite the negative attributes of lower strength, hydrophilic properties and the health issues associated with its use (powdered cement can cause illness and even lung cancer).

Another approach to reducing the environmental footprint of concrete is the use of additives to reduce the need for Portland cement. Boral's Envisia product (see www.boral.com.au/envisia) uses Boral's cement activator called ZEP to achieve a Portland cement reduction of up to 65%, while improving some of the material's qualities, compared to regular concrete.

But what about the aggregates in concrete? These include crushed rock and sand, both of which are mined, often at considerable environmental cost.

As mentioned, some eco-concretes replace these materials with recycled materials such as crushed concrete. An example of this is MetroMix's GREEN RCC, developed in conjunction with Fairfield City Council, where the coarse and fine aggregate is 20 mm recycled crushed concrete instead of gravel and sand.

There are other ways that concrete can be strengthened while displacing some of the usual aggregates. This includes adding fibre materials such as fibreglass, or the use of sawdust as an aggregate, such as with Timbercrete (www.timbercrete.com.au), where the use of timber wastes from sawmills offsets the use of other aggregates, reducing the environmental footprint of the concrete by locking up carbon, while making a lighter and better insulating material.

Lastly, another concrete-like material is Hempcrete, which is made from a mixture of hemp hurd (the inner part of the stalks), lime and water. Hempcrete hardens by absorbing CO_2, locking up carbon while forming a (non-structural) vapour permeable infill material.

↑ Magnesium oxide based concretes not only capture CO_2 while hardening, they can be made into interesting materials such as this pervious concrete from TecEco, designed to reduce run-off from hard surfaces.

Plant-based insulation developments

Even insulation has environmental costs. Mineral fibres, while often making use of waste products like furnace slag, require considerable energy to manufacture, as do glass fibres. They can also be an irritant for installers and even house occupants if the roof is not well sealed from the living areas. Sheet and spray foams are usually based on petrochemicals with the associated sustainability issues, and can also be toxic in manufacture.

There are some interesting insulating materials emerging onto the market. These include rice husks, which can be used directly as an insulation, as can rice hull ash (which can also be used in the production of cement).

A material with great potential is mushroom fibre (mycelium), which is not only a good insulator but can be used to replace styrofoam and other petrochemical foams. The leading developer of mycelium-based products is Ecovative Design (www.ecovativedesign.com). They are developing mushroom fibre and agricultural waste based thermal and acoustic insulation for buildings in sheet form, as loose fill and even as the core of SIPs.

Malama Composites (www.malamacomposites.com) makes a range of foams suitable for insulation and many other tasks from castor oil. They claim to have eliminated virtually all of the toxic materials used to make conventional foams and list their foams as non-toxic.

This is just a selection of the many new materials being trialled and tested; only time will tell what makes it to full-scale production. ✱

Thank you to Dick Clarke for assistance with this article, adapted from his article 'Emerging Materials to 2020' in *Rethink Building Materials*.

Image: Ecovative Design

↑ Mushroom fibre (mycelium) is being developed for insulation materials in buildings by Ecovative Design. The material is completely biodegradable and they have even developed a process to allow insulation to be grown in-situ to fill existing wall cavities.

Go with the flow
A micro-hydro buyers guide

A micro-hydro turbine can be one of the cheapest sources of reliable electricity—if you have the right site. Lance Turner looks at what's available.

Image: Eco Innovation

↑ Hydro turbines are small compared to other renewable technologies, and on a suitable site can have minimal environmental impact.

SOLAR panels are the energy generators of choice for most domestic renewable energy systems, but there are other forms of renewable energy generation that can provide supplementary or even primary power generation if you have the right site.

One possibility is a micro-hydro system: the production of energy from water, with domestic-scale systems sized up to 100 kW. If you have a rural property with a suitable water source, then micro-hydro may be a good option, particularly if a high tree canopy precludes the use of solar panels or wind turbines.

The kinetic energy stored in flowing water can be considerable. You just need to look at the deep pools often found below large waterfalls or how the rocks in a creek are worn smooth by the flow of water. To get an idea of the forces involved, try aiming the jet from an ordinary garden hose at your hand. You will feel the force of the water striking your hand and being deflected. This is basically how many hydro turbines work.

Run-of-river versus dammed

Hydro systems fall into two broad designs—run-of-river and dammed systems.

Run-of-river systems simply take water from a high point of the river or creek, pass it through the hydro turbine and return it to the river or creek at a lower point. Only a portion of the water in the water source is diverted through the system.

In a dammed system, the water source is dammed, producing a water reservoir. The height of the water behind the dam produces the required head for the hydro turbine (the head is the term commonly used to describe the vertical height of the water column that is producing the pressure to run the turbine).

Most domestic systems are run-of-river types, as these produce the least environmental impact and are the cheapest to install. They are also the type your council and/or water authority is most likely to approve. After all, damming a water source can cause considerable environmental disruption and should be avoided.

Some run-of-river systems do use a small dam, known as pondage, to ensure an adequate flow into the intake pipe. The amount of pondage can be small or may be increased to provide more reliable energy output from the turbine during times of lower water flows in the water source. It is possible to use pondage that is separated from the water source completely, to prevent any negative effects on the water source.

Layout of a system

The basic layout of most micro-hydro systems involves a turbine, mounted at some low point on the creek or river, being fed by a supply pipe running from a higher point in the water source. The weight of water in the pipe causes a relatively high water pressure at the turbine end of the pipe, thus providing a force capable of driving the turbine.

Flow rate (in litres per second of water flowing through the turbine) and head (the vertical height that the water falls) are the two major factors governing the amount of power available from a site.

Several different types of turbine have been developed to cope with a variety of situations, such as a high head with a low flow rate, or a low head with a high flow rate.

Turbine types

Turbines generally fall into one of two categories—impulse or reaction turbines.

IMPULSE TURBINES

An impulse turbine consists of a turbine runner (also called a rotor or wheel) connected to a generator. Water flows from the water source through a pipe called a penstock, where the resulting pressure is proportional to the vertical height from the water intake to the turbine (the 'head'). The water exits the penstock via one or more jets, which are nozzles with small holes so that the velocity of the water flow is increased dramatically. The water leaves the jets and strikes the turbine wheel, causing it to rotate. The resulting mechanical power is usually used to drive an electrical generator. The water then exits the turbine housing and falls below the turbine to the 'tail water', which usually flows back into the water source.

These turbine types don't function if submerged in water, so they must be situated above the maximum flood level of the water source. This often leads to significant loss of head—the smaller the head, the lower the pressure at the turbine and hence the lower the available power. This is one reason why this sort of turbine isn't used in low-head applications.

Examples of impulse turbines include Pelton, Turgo and Banki Crossflow.

The Pelton wheel is probably the best known and most commonly used of the impulse turbines. The Turgo is very similar, but has a slightly higher efficiency. Both types run at relatively high speeds, allowing them to be directly coupled to a high-speed generator, but Turgos will spin at a greater speed for the same-size jet diameter. Turgo turbines can also be arranged to spin at half speed, allowing efficient operation at low heads.

One manufacturer, Platypus Power, makes a hybrid runner which has properties of both Pelton and Turgo runners.

The Crossflow turbine is somewhat different. It uses a cylindrical rotor through which the water passes twice. It can be used with virtually any head, from one to 200 metres. These systems are good for water pumping as well as power generation.

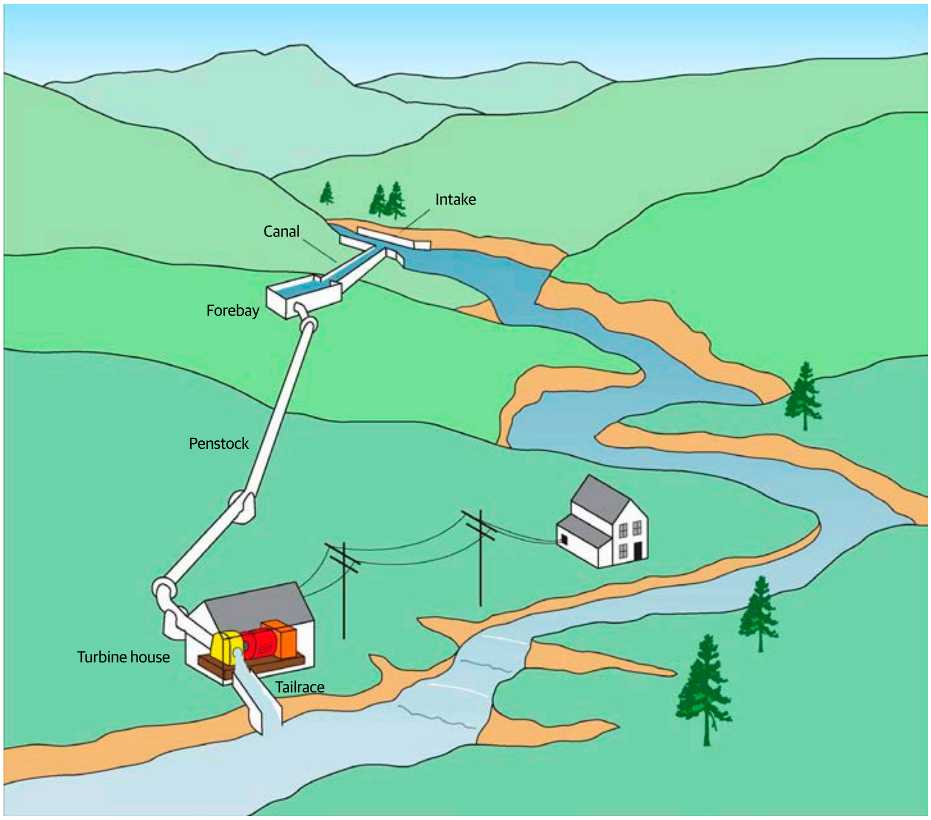


Image: US DOE Office of Energy Efficiency and Renewable Energy.

↑ A typical run-of-river hydro system. The pondage in the forebay smooths out flow to the turbine.

REACTION TURBINES

The blades on reaction turbines are submerged in the water itself. As the water flows over them, lift forces are created, similar to the way lift is generated by the wings of an aircraft. These forces cause the turbine blades to rotate: think of them as similar to a boat propeller used in reverse.

The water exiting the turbine is discharged via a 'draft tube' which creates a negative pressure (suction through siphon action) on that side of the turbine. This means that the fall of water after the turbine can also be included in the net head, which can be very significant if there is not a lot of head to start with.

This class of turbine includes the Francis and Kaplan types. The Francis turbines are the most efficient of the reaction turbines.

The Ampair UW100 (www.ampair.com/hydro/uw100) generator is a reaction turbine designed to be fully submerged in a water flow to generate electricity.

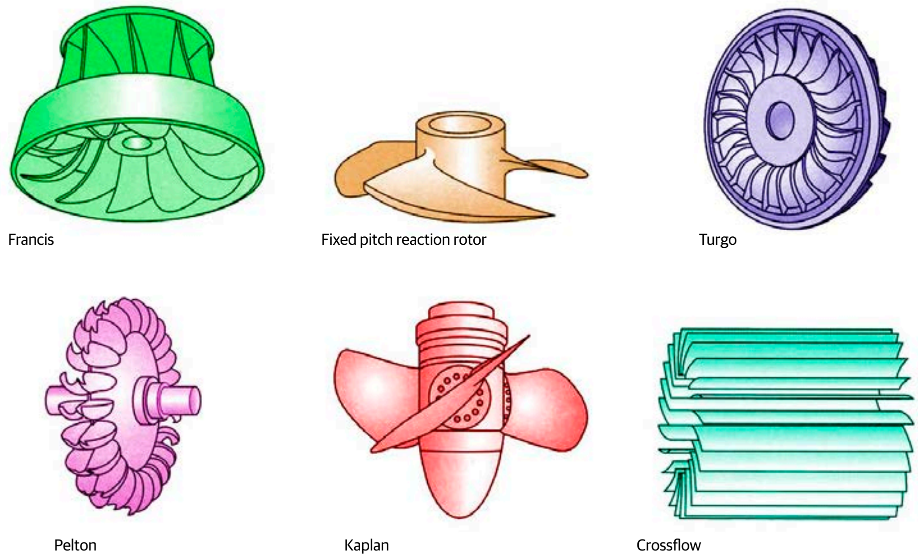
Reaction turbines tend to be bigger and more expensive than impulse types, so if you're lucky enough to have a choice between a high-head, low-flow site or a low-head, high-flow site, it's best economically to opt for an impulse turbine.

Runner materials

Hydro turbine runners are made from a variety of materials. Metal runners may be made from stainless steel, aluminium, bronze or even mild steel, while other materials used include moulded plastic and fibreglass reinforced plastic composites.

Regardless of the material used, turbine runners usually have a long life unless damaged by debris entering the system. For particularly low pH (acidic) water (a rare occurrence in hydro systems), plastic or composite runners should be used as metal ones may corrode over time.

Some runners are moulded or cast in one piece and must be replaced as a unit should they be damaged, whereas others have replaceable blades or cups allowing for more economical repairs.



↑ The different types of hydro turbines. The Pelton, Turgo and Crossflow are impulse turbines; the rest are reaction turbines.

AC or DC?

In terms of the way the power is used, there are two common systems available—DC, or battery-charging turbines, and AC turbines.

DC turbines are designed to feed their power into a battery bank for use at a later stage. These are well suited to sites that may not flow all of the time but do have regular or seasonal flows. Some installations use micro-hydro turbines to provide power during the winter months when water is most abundant, and rely on other energy sources such as solar during the hotter, drier part of the year.

If you have a good flow of water all year round, an AC turbine may be the best option. These produce power at 240 volts AC, just like mains power, so you can draw power from the turbine directly without the need for batteries, inverters and the like. For a property with both a suitable water source and a reliable grid connection, it is even possible to have a grid-interactive hydro system, although that will depend on the policies of your local electricity provider.

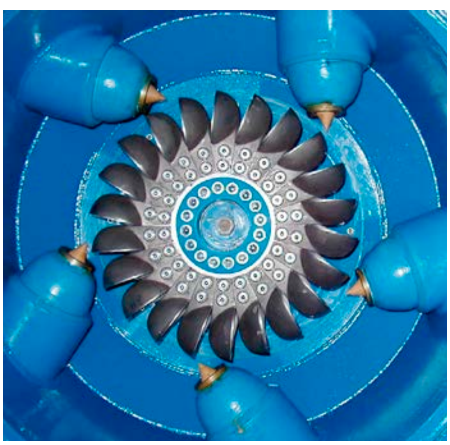
The disadvantage with batteryless AC mains voltage systems is that, unless the turbine is grid-connected, you are limited in the amount of instantaneous power you can draw from the turbine. For example, if you have a 1.2 kW system, then that is the most power you can draw from the turbine. Loads larger than this will need to be powered from some other source. However, you could use an AC turbine to charge a battery bank via a battery charger, just like a DC turbine.

Just to confuse matters, some turbines are called AC turbines by the manufacturer but produce AC power at lower than mains voltages and are fitted with a rectifier at the turbine to provide DC, which is sent to batteries as with a DC turbine.

Load regulation

Load regulation of most turbines occurs by dumping the excess energy into some form of load. This is often a heating element, such as in a hot water system. Load regulation is required to avoid large voltage fluctuations and to keep the turbine running at a near-constant speed. Regulation systems range from simple on/off switching to variable load dumping or diversion, where the dump/diversion load connected to the turbine varies to balance the main load.

As an example, if you have a 1 kW turbine and are using 200 watts from it, then the other 800 watts will be fed into the dump load. If your load increases to 650 watts, then the excess 350 watts will be dumped or diverted. This system can be achieved in several ways, but one method is to switch in (electrically connect, either through relays or electronic switches) dump load elements of varying sizes in the right combinations to form a load of the correct size.



↑ Impulse turbines, such as this Pelton unit, often use multiple nozzles to increase power.

Environmental issues

Hydro turbines are a great form of renewable energy when used correctly, providing all your energy needs with almost no greenhouse emissions. However, there can be environmental issues to consider.

The first is water diversion from the water source. While very few studies have been done on the effects of micro-hydro systems, at least one study (www.bit.ly/1DBjrAD) has shown that diverting water can affect populations of some types of fish.

Arguably the most effective and least damaging form of hydro intake is the coanda effect screen—only water makes it through the screen, with everything else effectively diverted without damage, including fish of all sizes.

It is also important to make sure the tailwater is diverted back to the water source with minimal losses, not simply dumped on the ground.

Another issue is pipework. Pipes can usually be laid on top of the ground, but in some cases might require burial, with the resulting disturbance to the soil, and possibly plant roots and habitat. Burying pipes must be done with care!

↑ This novel design is called a gravitational water vortex power plant and produces turbine efficiencies over 70% using high flows at very low heads. It was developed by Austrian company ZOTLÖTERER and is not available here, although we can't help thinking it could be an interesting DIY project. See www.zotloeterer.com/welcome.

Civil works

This covers the parts of the system that extract the water from and return it to the water source, including head (penstock) and tail (draft) pipes, dams and other parts of the water supply system. Civil works may involve as little as a few tens of metres of plastic piping with a screen filter at the collection point, right through to construction of a weir or dam, along with the other associated parts. These include trash racks and coanda effect screens (see www.bit.ly/1HMLFP6), which deflect solid material and fish from entering the feed pipe, as well as control valves and even flood control systems. Be sure not to underestimate the effect the civil works will have on the cost of the system—it can become very expensive if you can't do it yourself.

Some councils charge a fee for water taken from a stream, even if it is returned at a later stage. There will be restrictions on what types of works your council or water authority will allow—some systems will be easy to gain approval for, some will be difficult or impossible to have approved. Check with your council and/or local water authority before planning a system. See www.bit.ly/1ynYcp2 as an example of what might be required for system approval.

Buying a turbine

This can be a complex process as you have to determine head and flow rate at the selected site, ease of access, type and amount of power required from the turbine and possible environmental disruption to the area. Remember that to minimise the effect you have on the local ecosystem, you must not divert all of the water from the source to run through your system. If you are unsure, set yourself a limit of, say, 50% of the total flow at the lowest flow rate period, usually during summer or the dry season.

Once you have these details worked out, you can then start thinking about the type of turbine you want. The table at the end of this article will help you decide which turbine is most suitable for your requirements. If more than one turbine seems ideal, then look at other factors, including price and maintenance requirements. ✷

About the table

The table on page 78 lists the brands and models of turbine that we received data from suppliers for. While we endeavour to cover all turbines available in Australia, inevitably some may be missing due to lack of response from the supplier or other reasons, so if you don't see what you are after in the table it is worth doing further research.

Calculating available power

So just how much power can you expect to get from your creek or stream, and how do you calculate the size of turbine required? The total available power (in watts) from a turbine running in a particular flow of water can be determined by the calculation:

Power (watts) = $n \cdot g \cdot h \cdot q$

where:

n = turbine efficiency (as a fraction: 60% is 0.6)

g = acceleration due to gravity (9.81 m/s²)

h = head (in metres) *

q = flow rate (in litres per second)

For example, a turbine with a 50% turbine efficiency running at a flow rate of 20 litres per second on a 10 metre head would have a theoretical turbine output of 981 watts. This is not the electrical output, which would be less, depending on the efficiency of the alternator/generator.

* For still water, this is the difference in the height between the water inlet and turbine outlet. Flowing water has an additional component added to account for the kinetic energy of the flow. The total head equals the pressure head plus velocity head. However, as flow rate varies it is often best to ignore this component when doing calculations. You must also consider frictional losses in the pipe—too small a pipe means a reduction in the effective head. Frictional loss tables are available online.

Table 1. Micro-hydro systems.

Brand (Made in)	Model	Runner type	Runner material	Output voltage	Rated output power	Head range (metres)	Flow range (litres/sec)	Generator type	Regulation	Warranty (years)	RRP inc GST ($)	Comments
Aqatek (New Zealand) Electric Systems Ltd ph:(0274) 437 007 bjhowell@xtra.co.nz www.electricsystems.co.nz	Aqatek 1000	Crossflow	Stainless steel	12, 24, 48 VDC	Up to 1 kVA	2.5 to 90	0.2 to 3.5	Permanent magnet	Shunt	3	NZ$1850 inc GST	Requires charge control system, typically a load diversion system costing $600 to $800 depending on site specifications.
Mainland (New Zealand) Alternative Power NZ Ltd (03) 547 6397 altpower@xtra.co.nz www.alternativepowernz.co.nz	Mainland SW series	Turgo	Greenspoon fibreglass reinforced plastic	12, 24, 48, 96 VDC	Up to 1000 W	5 to 150	Up to 20	3-phase brushless	Load dump regulation	2	NZ$4785 plus GST and freight	Price includes spare nozzle, spanner, regulator board with a Tristar 45 controller and air dump load. Ex Nelson, NZ.
PowerSpout (New Zealand) EcoInnovation Limited enquiry@powerspout.com www.powerspout.com	PLT 14,28,56	Pelton	Nylon GF30	12/24/48 for direct battery connection	Up to 1.6 kW. Can be stacked up to 16 kW. Use online calculation tools to determine watts, pipe and cable size	3 to 130	0.1 to 8	3-phase brushless PMA adjustable	External battery regulation extra	3, subject to service schedule. 5 years on wet side rotor	From US$1599	Includes freight to many global destinations, freight surcharges may apply. Excludes import duty, GST, VAT etc. All manuals online. Discounts for stacked turbines. Some other options available, only common options listed in this table.
	PLT40,80			40 and 80 V for connection via 150–250 V MPPT regulators					No regulation needed with suitable MPPT regulator		From US$1599	
	PLT150, 200			150–200 V for connection via 450–600 V grid-tied inverters					No regulation needed with suitable grid-tied inverter		From US$1599	
	TRG 14,28,56	Turgo		12/24/48 for direct battery connection		2 to 30	7 to 15		External battery regulation extra	2, subject to service schedule. 5 years on wet side rotor	From US$1599	
	TRG40,80			40 and 80 V for connection via 150–250 V MPPT regulators					No regulation needed with suitable MPPT regulator		From US$1599	
	TRG150, 200			150–200 V for connection via 450-600 V grid-tied inverters					No regulation needed with suitable grid-tied inverter		From US$1599	
	LH150, 250	Propellor	Stainless steel	For connection via 150–250 V MPPT regulators		2 to 5	25 to 55		No regulation needed with suitable MPPT regulator		From US$1599	
	LH400			For connection via 450–600 V grid-tied inverters					No regulation needed with suitable grid-tied inverter		From US$1599	
Pelena (Australia) Pelena Energy www.pelena.com.au	Crossflow Single Nozzle	Crossflow	Stainless steel	Depending on generator type. Typically 230/400 V 50 Hz	0 to 85 kW	8 to 50	20 to 232	Brushless synchronous alternators or induction generators (for grid connects over 10 kW). Option for DC generation.	Pelena Electronic Load Control for standalone units. Customer-specific PLC control for grid-connected induction generators.	3 for turbine, 1 for generators.	POA, with the smallest packaged units starting at $65,000.	Stainless steel is the main material of construction. These turbines have been designed primarily to service a range of heads, flow rates and required power outputs to maximise commonality of parts, especially spare parts like bearings, seals, and belts (where used). In process of designing low-cost, low-power turbines. Check our website for updates.
	Crossflow Two Nozzle				0 to 131 kW	8 to 42	20 to 426					
	Crossflow Three Nozzle				0 to 137 kW	8 to 33	20 to 566					
	Crossflow Four Nozzle				0 to 74 kW	8 to 18	20 to 557					
	Pelton Single Nozzle	Pelton	Stainless steel		0 to 150 kW	25 to 140	10 to 137					
	Pelton Twin Nozzle				0 to 250 kW		10 to 274					
Platypus Power (Australia) Ph:(07) 4055 8057 plapower@netc.net.au www.platypuspower.com.au	PM1000	Hybrid impulse	Stainless steel	12, 24, 48	0.75 kW	8 to 100	0.5 to 15	Permanent magnet	GVX 25	2	$6200	
	U3000			12, 24, 48, 110	1 kW	4 to 50	1 to 30		GVX 25		$7100	Ideal for long transmission.
	Q2/150			240	1.8 kW	20 to 80	3 to 12	Induction	SG104		$8550	Maximum size for PP series 240 V/50 Hz units is 30 kW, POA on units above 10 kW. Grid-connect units also available up to 10 kW.
	Q3/150			240	2.3 kW	20 to 90	3 to 15		SG104		$9100	
	Q4/150			240	3.2 kW	20 to 90	5 to 45		SG104		$9405	
	PP5/150			240	5 kW	25 to 110	7 to 48		SG104		$10,750	
	PP7/150			240	7 kW	25 to 110	7 to 55		SG104		$12,760	
	PP10/200			240	10 kW	40 to 110	16 to 60		SG104		$14,890	

Terms: Output power is the maximum output that the system has been designed to produce given maximum head and flow ratings for that system. In most cases, available power will be less than the maximum rating.

Output voltage gives the system voltages that the turbine is available in. DC turbines are designed for use with battery-based renewable energy systems and are usually made for the most common voltages found in these systems.

While **generator type** descriptions vary, they are almost all of the multi-phase permanent magnet alternator type. Those producing DC simply include a rectifier in the turbine or at the controller.

Regulation systems vary; you should look at the specifics of a particular turbine control system to ensure it is suitable for your use. Manufacturers/suppliers can provide detailed information on how their regulation systems work.

Micro-hydro: power by induction

Christine Booth tells us about the micro-hydro system she and her partner Graham Cashion developed to power their eco-accommodation business.

IN 2008, Graham set his heart on harnessing water from a small creek above our property at Branxholm in north-east Tasmania. I thought he was crazy. At 2008 electricity prices, I estimated it would take at least 20 years to recover the capital costs. Nevertheless, Graham was so set on the idea that he purchased 3 km of 150 mm galvanised steel pipes and fittings secondhand from a mining company, trading-in our old diesel Mercedes 300D with the transaction!

There were major bureaucratic hurdles to overcome over several years to bring the project to fruition, including a Land Management Tribunal—a two-year delay—and complications with a Forestry Tasmania lease. We also needed to complete an environmental impact study before being granted a non-consumptive water licence.

With paperwork completed, licences in place and initial inspections approved, we quickly started work. Hard work, too, but with assistance from a 70-year-old family friend and excavator driver, Graham had the pipeline running off the property and up the main hill within two weeks.

We now had a 150 mm pipeline traversing 2.5 km up a 97 m hill—not straight up, but with some flat bits and some dips too.

The next big decision was to determine what capacity generator to purchase. For that, we needed to determine the optimal flow rate for a winter season and the working head. That is, the actual head (97 m) minus all the frictional losses. Given the high cost, we couldn't afford to get it wrong.

I dug out some old water flow charts and, armed with a $40 pressure gauge, a secondhand mechanical water meter and some welding gear, we determined a working head of 88 m.

Having made several enquiries of Chinese-based companies, but feeling uncomfortable that they seemed too keen to give us the answers they thought we wanted, we decided instead to purchase a 7.5 kW Australian-made induction generator from Marcus Axton, owner of Platypus Power based in Far North Queensland.

Over the next few months, Graham tested the pipeline and improved its performance with well-placed air bleeds. The generator and inverter were installed. Marcus fine-tuned and commissioned the system, and the switch was flicked on in 2013. Since then, the scheme has been providing uninterrupted power, except in the dry months.

We monitor the water flow in the creek and when the flow drops to a pre-determined level we turn off the micro-hydro. This ensures that an environmental flow is maintained.

We have now generated over 45 MWh of electricity and haven't paid an electricity bill for nearly two years. We were also successful in receiving over $4000 in renewable energy credits, which is sufficient income to pay for two years of forestry lease, council rates and water licence charges.

You can read more about Graham and Christine's micro-hydro on the Tin Dragon Trail Cottages website (www.tindragontrailcottages.com.au).

↑ Aya Narumi (WWOOFer) and Graham above the tail race. A water wheel, old steam boiler and half-constructed hot house are in the background.

↑ The grid-interactive inverter is on the left. On the right is the micro-hydro turbine controller.

↑ The 7.5 kW Platypus Power micro-hydro turbine.

Cooking Challenge
ReNew enters the kitchen

For our recent cooking challenge, we asked *ReNew* readers how they're reducing their energy use in the kitchen. In true *ReNew* fashion, we got entries addressing the problem from a range of DIY angles.

AS ALAN Pears highlighted in *ReNew 130*, while the kitchen is a small part of energy use in the full food system, it can be a significant part of household energy use, particularly for low-energy-use households. From improving our understanding of the energy efficiency of appliances and cooking techniques to improving the insulation in saucepans, Alan presented a range of things to think about when you get into the kitchen.

The entries in our competition reflected that. Several tackled the topic by looking at equipment, with pressure cookers, solar ovens and haybox cooking featuring. Several looked at techniques, such as not cooking with a half-empty oven, defrosting food in the fridge (or on the bench) and even cooking multiple things in a stack of pots, to use the escaping heat.

And the winner is...

The ATA crew particularly like Jan Heskes's entry, making that our winner: it's a practical, simple approach to reducing energy use. We've included the winning entry in full, along with parts of several other entries that reflect the range of responses. Jan wins a GoalZero portable solar USB charger kindly donated by Laughing Mind and valued at $169.

↑ Four loaves of bread, one large lasagne, 12 chocolate chip and walnut biscuits, 15 herb and mushroom quiches and 12 tofu patties—all cooked in one cooking session of 90 minutes, including pre-heating the oven, compared with about 250 minutes if each item was cooked separately.

WINNER:
Never cook with a half-empty oven

Jan Heskes

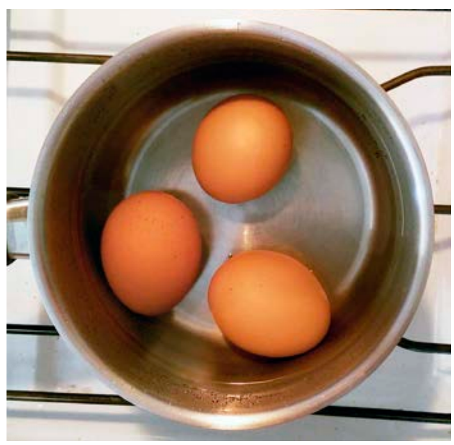
Much as we would like to, we cannot always afford to have the latest energy-efficient appliances in our home. However, by using what we do have more thoughtfully, we are still able to significantly reduce our energy consumption.

Our kitchen contains a standard-sized stove with a fan-forced electric oven and gas cooktop. The stove is a few years old and would have been energy efficient for its time. Before turning on the oven I plan and prepare as many dishes as possible to bake while the oven is heated. Surplus food produced is stored in the freezer for future meals. The freezer is also used efficiently by avoiding operating partially empty. With ongoing planning, food is defrosted passively and reheated either quickly in the microwave or, if possible, in conjunction with accompanying dishes. As a result the oven is generally only used about once a week in our house even though nearly all of the food we consume is homemade.

Performing under pressure

David Gobbett

Pressure cooker, pressure cooker, pressure cooker...and did I mention using a pressure cooker? Reduces cooking times and at lower temperatures, once pressure is reached.



Egg-cellent eating

Pauline Grayson

Here's a handy tip I learnt about boiling eggs. In a pot of water, bring the water with the eggs to the boil (cover on). Turn off the heat. Leave for 3 minutes for soft boiled eggs and about 10 for hard boiled. Feels great every time I switch off the heat knowing I don't need it to get perfect eggs!

Works like a dream

Kate Prout

I have a small benchtop electric oven. Even though the oven is small, I have cooked, among other things, a family-sized Christmas ham, albeit with a bit of charring on the top. An electrician told me the benchtop oven is more efficient as it only heats the space it takes up, rather than the bigger area of a standard oven. If I ever need to replace this, I will look for a similar model with better insulation.

I also have a DreamPot, which is a cross between a haybox and a slow cooker—no power needed and super insulation without the bulk of a haybox/blanket wrapping.

I eat a lot of salads and fruit, much of it from my garden (so no fridge storage costs). In winter I usually have a reserve of soup/stew and heat up bowlfuls in the microwave or potfuls on the gas cooktop. I often choose recipes that require less cooking time and one-pot cooking, but that's because I want to eat soon and not make a lot of washing up, not primarily to save power.

When I am inspired to cook, I make a big batch and refrigerate remnants for lunch the next day, or freeze for future reference—surely everyone does this? Food spends 20 minutes on the cooktop then into the DreamPot for several hours, or overnight for curries, stews, poached chicken etc. Meat cooked this way becomes really tender. When I was working full-time I would start the curry in the morning and come home to a delicious hot cooked meal without any use of energy (beyond the initial gas). Also good for cooking beans, chickpeas, lentils etc.

Handmade, home-cooked

Selene Moonbeams

I love cooking in my sweet little thermal slow cooker which I made from recycled beanbag beans, an old doona cover and a metre of cord from some old curtains.

First, I bring my ingredients (vegies from the garden, lentils, chickpeas, herbs, pasta, quinoa, water and anything else that comes to hand and takes my fancy) to a rapid boil in my stainless steel camp pot atop my tiny gas hiking cooker. Then I secure the lid tightly and snuggle it all into my dinky little pot cosy. I made this from an old car sunshield my friend found discarded by the side of the road plus a wee bit of gaffer tape.

I pop the pot and pot cosy with its piping hot concoction into the doona cooker and tie the little beanbag hat with the cord, making sure there are no holes for cold air to penetrate.

Everything stays snuggled up for the day and when I'm ready, I open up my delicious, piping hot cooked dinner. Total energy use about three minutes!

Slow cooking, or fast and furious

Virginia Anne Lyon

I use my Tulsi solar oven for much of my day-to-day cooking. To the four pots it came with, I've added two black-painted bainmaries that fit the shallow oven area. I do most of my cooking in it—roasting meats and vegies, and making casseroles, soups, stock, quiches and cakes. It's important to be careful with temperatures, especially when cooking meat. The table it's on is a rotating overhead projector stand from the tip, which allows me to easily orient it to the sun during the day.

I use my rocket stove when fire regulations allow and either there isn't enough sun to cook or I want to do something fast and furious like stir-fry or omelettes. It uses small sticks. I'm planning to try a different design fabricated from a steel fencing pipe, incorporating a hotplate and drop-in fuel feed. My latest acquisition is a NZ-certified wood heater that burns softwood efficiently and cooks my meals in winter. I've also recently learned about retained-heat cooking and have improvised a cooker from an old sheet, pillowcases, a laundry basket and polystyrene beads!

A few more tips from readers

Tim Fisher: If you have a set of saucepans where one fits on top of the other, you can make use of the heat given off from what you are cooking in the smaller pan to heat water etc in a larger one on top. Another tip is to use a smaller pan, as it will take less energy to heat the pan itself. Or you can pre-heat your frying pan on top of the saucepan which is cooking your rice or vegetables.

Rod Munro: I have insulated our slow cooker, allowing me to set the thermostat on low and cook for a shorter time. Plus, we use much smaller pans when possible, with poached eggs a favourite in a very small fry pan with a lid.

Low cost solar heating
Using free heat from your roof

After reading an article in *ReNew*, Alan Cotterill decided to design a closed loop heat exchange system to supplement his home's heating with free heat from the roof. A couple of iterations later, he describes the resulting effective system.

IN EARLY 2014 I commenced efforts to use the heat from our roof cavity to contribute to winter heating. I decided on a closed loop system, which would take in room air, duct it through the roof and return it to the house at a higher temperature. A closed loop system avoids the issue of drawing down insulation fibres and dust from the roof cavity.

Useful attic temperatures

My home combined with our very cold but sunny winter days in Wagga seemed especially suitable for this system to run with reasonable efficiency. The house has a grey Colorbond steel roof and a large roof area relative to the internal floorplan, due to a high pitched roof and the wide verandahs and garage being included under the main roof structure. The east-west orientation of the long axis of the house and the north-facing roof area being covered with solar panels have not prevented useful attic temperatures. Measured 60 cm below the peak of the roof cavity, the average maximum attic temperature was 28 °C for the two weeks starting 16 July 2014 and 37.8 °C for the two weeks from 19 August 2014.

A first attempt

My first prototype forced room air through a system of ducts in the roof using a centrifugal exhaust fan mounted on its side on a shelf in the laundry. The air was distributed to three 12-metre runs of 100 mm flexible aluminium ducting before returning the air to the house. The returned air was reasonably heated but the total volume of returned air was inadequate to contribute significantly to winter heating.

↑ A 150 mm inline fan (white object in the ducting at right) distributes air to five 12-metre runs of black-painted 125 mm aluminium flexible ducting.

↑ A 10 cm strip of sisalation is cut out along the roofline, 800 mm below the roof peak. Note the Insulwool at the top edge of the cut.

↑ The inside/outside thermometer has its outside probe located near the peak of the roof cavity.

Redesigned for greater impact

To address the issue of inadequate heating impact, in April 2014 I started work on redesigning the system, by increasing the number of ducts, increasing duct diameter, experimenting with different fans and other improvements. Increasing duct diameter increases the surface area for heat exchange, but has the potential that unheated air flows down the middle of the wider duct. The spiral corrugations of the ducting set up a lively turbulent air flow to resist such streamlining.

The optimised system has a 150 mm intake vent in the laundry ceiling feeding a 150 mm Blauberg inline radial fan via a short length of 150 mm semi-rigid aluminium ducting. Immediately above the fan, an air distributor opens into five 12-metre runs of 125 mm flexible aluminium ducting. Three of these runs return heated air to the open-plan living area. The other two runs return to the main bedroom and the study.

Each of the five runs rises sharply in the roof cavity to the maximum heating zone 60 cm below the peak of the roof cavity. The runs of ducting sit on plastic gutterguard which is stapled to horizontal lengths of timber fixed to each roof truss. The gutterguard is ideal to prevent sagging of the ducting while still allowing full air circulation around the ducts.

The factory-fitted power lead on my inline fan comfortably plugs into the Heatermate thermostat, installed 60 cm below the peak of the roof cavity. The thermostat automatically turns the system on when the attic temperature reaches 24 °C and turns it off when the temperature drops below 24 °C.

Optimising the airflow through system

I tried a number of fans before I settled on the Blauberg 150 mm inline fan. This fan has two speeds—low (using around 30 W of power), with a specified airflow of 467 m³ per hour to open air, and high, rated at 552 m³ per hour.

I improved airflow rates significantly by removing the vent cover from the intake vent in the laundry and smoothing out any sharp curves in the ducting configurations. The higher flow rates have meant slightly lower temperature rises in the returned air, but this was more than compensated for by the higher airflow.

Using five 12-metre runs rather than the original three runs has provided higher heat transfer with minimal fall-off of total airflow (when compared to the fan's free airflow rating). Fewer runs meant faster air transit times in each duct, and this resulted in lower returned air temperatures due to less time for heating. Higher airflows also magnify the effect of duct resistance, with significantly less total airflow through the system compared to the same fan with a larger number of runs.

Fortuitously, the airflows in the five runs are well balanced. With the fan on high speed, the velocities I measured at the centre of the outlet of each return air vent were 4.4, 4.3, 4.2, 4.1 and 4.3 metres per second. The airflow rate at each return vent was calculated by multiplying the central air velocity by the cross-sectional area of the duct; to allow for friction/drag slowing air flow near the wall of the duct, this figure was reduced by 50%. The resulting estimates are for total airflow rates of 387 m³/hour on low speed and 462 m³/hour on high speed.

Reducing resistance to heat transfer across the wall of the aluminium ducting

The reflectivity and absorptivity values of the aluminium foil ducting are not conducive to maximum transfer of heat from the roof cavity to the air inside the ducting. To improve heat transfer I trialled replacing one of my 12-metre runs of flexible aluminium ducting with flexible PVC ducting of the same diameter. Prior to the change, the temperature rise at low speed was 5.8 °C with a 10 °C temperature difference between room air and attic. After the change, the PVC duct produced air 0.4 °C hotter with the same temperature differential. For this small gain, I decided against using PVC ducting because of the problem of off-gassing of VOCs (volatile organic compounds).

I got more benefit by using seven cans of spray paint to paint the ducting black. After this, with a 10 °C temperature difference, the air returned to the rooms was 1.4 °C hotter when compared to the unpainted ducting—the overall temperature gain was now 7.2 °C. This was a useful improvement.

Maximising the temperature differential between peak of roof cavity and room air

To maximise heat build-up in the roof cavity from the winter sun, at the start of winter I close off our two rooftop 'whirlygig' rotary ventilators on the roof (which help extract hot roof cavity air in summer). I do this by stuffing half an insulation batt into each whirlygig's lower tube.

Reflective foil/sisalation directly under the roof reduces the amount of heat passing into the roof cavity. With this in mind, I cut out an 80 mm strip of sisalation just below the highest roof batten, 800 mm down from the peak of the roof cavity. Heated air between the corrugated metal roofing and the sisalation can now convect upwards and escape into the peak of the roof cavity; each corrugation in the roof acts like a mini solar heating tube.

The otherwise undisturbed sisalation wraps in a continuous fold over the peak of the roof cavity and prevents heated air escaping by convection through the ridge of the roof. At the upper edge of the gap in the sisalation, small wads of Insulwool have been packed

↑ Measuring the airflow and air temperature at one of the five eggcrate ceiling vents. The little digital anemometer is typical of those readily available for under $100.

Cost of roof cavity heat exchanger

- 150mm Blauberg inline two-speed radial fan: $200
- Fifteen 4 m lengths of 125 mm flexible aluminium ducting: $240
- One 3 m length of 150 mm semi-rigid aluminium duct: $30
- Six ceiling vents—five 125 mm and one 150 mm: $70
- Four 150 mm PVC Y-branch sections (to make up air distributor): $60
- Five 150 mm to 125 mm duct reducers: $40
- Heatermate thermostat: $38
- Jaycar inside/outside thermometer: $20
- Three-metre extension lead: $10
- Five rolls of duct tape: $15
- Seven cans of black spray paint: $28
- Plastic gutterguard/timber: from shed.

Total cost: $751

between each corrugation of the colorbond and the sisalation/batten to ensure maximum diversion of rising hot air into the roof cavity.

I also fabricated a removable 200 mm wide laundry door insert panel using scrap timber from my shed. This sits firmly in place against the laundry door jamb, with the laundry sliding door closed against it. A rubber sealing strip on each vertical edge of this panel ensures a snug fit. I left a 200 mm by 300 mm opening at the bottom of this panel, which forces all air to enter the laundry at floor level on its way to the air intake duct in the laundry ceiling. This has the advantage that cooler floor level air will be drawn into the system, maximising the temperature gradient and resulting in more energy being brought down into the house. It also minimises the noise of the air intake (which is fine when the fan is on low, but annoying on high), and still allows the cat to access its food in the laundry!

Assessment through a Wagga winter

Over the last winter, I recorded maximum daily attic temperatures and scored each day on fog/cloud/sun. For the two weeks after 16 July 2014 there was only one day when the maximum attic temperature was below 24 °C; seven days had a maximum over 30 °C, with the highest temperature being 33.8 °C. Only a couple of those days were free of cloud or fog.

After all the fine-tuning detailed earlier, for a 10 °C temperature difference between room air and the attic, with the fan speed on low, the returned air was 7 °C warmer than when it was drawn in. With the fan on high speed the returned air was 6.5 °C warmer. With a 20 °C temperature difference the temperature gain on low speed was proportionately even greater at 15 °C.

Over the two weeks from 16 July, with the system running for six hours daily and the fan speed on high, the average temperature gain was 7 °C. I calculated that the power (heat) collection rating of the system was 1100 watts continuously over the six hours, giving a daily average energy collection of 6.6 kWh (see box). As the fan consumed 60 W, this gave a CoP (coefficient of performance) of 18: for one watt of power drawn, 18 watts was gained.

These numbers improved substantially earlier and later in the winter. For the two weeks from 19 August, with the fan speed on low, the thermostat-controlled system now ran for 8.5 hours daily. The heat collected averaged around 1300 W and the average daily energy collected was 11 kWh/day. Based on the fan consuming 30 W, the CoP was 43!

I found that the main period requiring winter heating extended over 18 weeks. I found it practical to run the fan on high for the middle six weeks while running the fan on low for the two six-week shoulders either side. Extrapolating the numbers over this 18-week winter heating period, I calculated the total energy brought into the rooms from the roof cavity was 1200 kWh.

Further thoughts

My closed loop roof cavity heat exchanger is a supplementary heat source to my central gas heating, which maintains room temperature at 18 °C from 7.30 am to 6 pm, 22 °C from 6 pm to 10 pm and 14 °C overnight. Any heat brought into the house from a supplementary source reduces the amount of gas used. I calculated our home heating gas usage over the 18 weeks was 22,000 MJ. Heating usage was derived by subtracting our average daily gas usage in summer (which amounts to hot water heating and stovetop use). Allowing that burning gas for central gas heating is only about 60% efficient, the 1200 kWh (1200 x 3.6 = 4320 MJ) of heat I actually brought down from the roof cavity is actually saving

↑ The laundry door spacer.

7200 MJ of gas (4320 x 100/60). Therefore my roof cavity system provided 33% of my home heating over this 18-week period.

A similar-sized house with orientation for maximum passive solar gain, double glazing and better insulation would require the consumption of far less energy to heat it and my heat exchanger would provide a much higher percentage of winter heating needs. My efforts before this coming winter will be to continue to improve the house in these areas as best I can. ✷

Warning

All mains electrical wiring should be done by a suitably qualified person. Never work in a roof cavity without a helper in the house to ensure your wellbeing. If your roof cavity contains electrical wiring, we recommend that electricity be turned off when working in the roof cavity, regardless of whether wiring work is being done.

Calculation of heat collected

I calculated the heat collection as:

Power (watts) =

air flow rate through the ducts (m^3/hour, calculated as 387 m^3/hour on low speed and 462 m^3/hour on high speed)

x density of air at 20 °C (1.2 kg/m^3; using 20 °C gives a good average)

x specific heat of air (1.0 kJ to heat 1 kg of air by 1 °C)

x average temperature gain of returned air (°C, depends on temp difference, fan speed)

x 1000/3600 (conversion from kJ/hour to joules/second to give watts).

For example, for the July period, with the fan on high and an average temperature gain for the returned air of 7 °C, I calculated:

Power (watts) = 462 m^3/hour x 1.2 kg/m^3 x 1.0 kJ x 7 °C x 1000/3600 = 1078 (rounded to 1100 in the article).

Shop with the ATA

Why not buy your gifts from the ATA Shop? We stock 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 fill out and return the form at the bottom of the page.

18 W LED outdoor bulb

Price: $49.50
At over 80 lumens per watt, this Par38 bulb is an energy-efficient replacement for the 150 W bulbs commonly used in driveways and outdoor entertaining areas.

ATA's *Off-grid Homes* eBook

Price: $5 (free for ATA members!)
The latest eBook in the ATA's sustainable living series includes the best articles from *ReNew* and *Sanctuary* on how to live with a renewable off-grid electricity supply. With guides on solar panels and batteries, plus case studies.

EcoSwitch

Price: $19.95
Standby power accounts for 5% to 10% of all energy use. With an EcoSwitch, you can conveniently control power to one or a group of devices without having to climb under desks or behind cabinets. Winner of *New Inventors* People's Choice Award in 2007.

Low-cost mains power meter

Price: $29
Measure the power usage of your mains appliances with this low-cost meter. It comes with a large display and a 1 m extension cord for those hard-to-access power points.

5 W LED dimmable bulbs

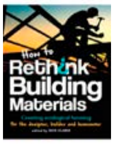
Price: $14.60
These economical LED lights offer brilliant performance with wide, evenly spread light. They draw only 5 W yet produce 450 lumens—equivalent to the downward-directed light from an average 60 W incandescent or the total light output of a 40 W. Available in bayonet or Edison screw.

ValveCosy

Price: $20
An elegant solution for a largely overlooked problem, this insulating cover is designed to fit neatly over the pressure/temperature relief (PTR) valve on your hot water service. It reduces heat loss, conserves energy and saves you money.

Sanctuary: modern green homes issue 31

Price: $11.95
Sanctuary's winter 2015 issue considers alternative ways of living for reduced costs and environmental impact: tiny homes, modular and prefab housing and flexible shared living. Plus great examples of reuse-building—and much more!



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Resurrecting discarded power tools
Black & Decker 'Orange' drills

Julian Edgar shows us how to assemble a recycled electric power drill for nearly nothing.

↑ Almost like a new one! It's easy to assemble a good working drill from a few faulty ones.

WANT a high quality mains-powered drill that will cost nothing and last nearly forever? You can—just assemble one good power drill from a bunch of old and broken Black & Decker drills.

But first, why would you bother?

Black & Decker must have sold tens of thousands of their 'orange' drills in Australia in the 1970s and 80s. In those days, well before cheap Chinese-made drills flooded the market, these power drills were relatively expensive—and well made. They were also designed to be repaired as required, rather than just thrown away.

And they were tough. Drop one on concrete and it just bounced. Overload it by driving a 50mm hole-saw through chipboard and you could make the windings smoke. But if you then stopped drilling and free-ran the motor for a minute to cool it, you'd have likely done no damage.

So, unlike the vast majority of modern-day drills, these drills are durable and easy to repair. Furthermore, although the drills were produced in different models over the years, many parts are interchangeable. If you have (say) three broken B&D orange drills, the chances are that you can easily make one working drill—and it will then last you another decade or two.

Collecting

It's worth picking up every old orange B&D power drill that you can find. At rubbish tip shops you'll often find drills with the cord cut off (so they don't have to test and tag it)—buy them for a dollar anyway. Some drills have chucks that are old and worn—grab them. Others will be covered in paint splatters or abrasions—pick them up and take them home.

A surprising number of these old drills will be fully operational—and still be available free or for only a few dollars.

Testing

The first step after collecting a drill is to test it.

Make sure that the chuck rotates smoothly and grips drill bits correctly. There shouldn't be any lateral movement in the chuck and when you rotate the unpowered drill by turning the chuck, the motor should spin smoothly.

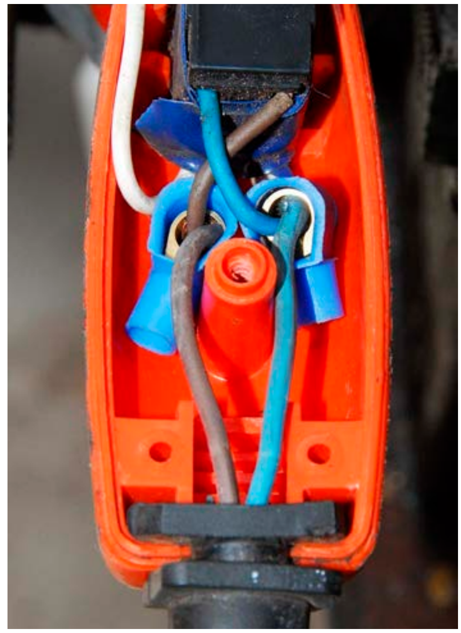
If the cable and plug are still intact, power-up the drill and check it works correctly without odd noises, or sparks from the commutator (the part of the drill motor's rotor that the brushes rub against).

Disassembly

If you have a defective drill, the first step is to pull apart the handle, revealing the speed control (integrated into the trigger switch), wiring and brush holders. Older drills have normal Phillips head fasteners in the handle, but later models use tamper-proof fittings. Screwdriver bits are available for these tamper-proof fittings, or you can remove the screws by drilling out their heads—although note that the screws are quite hard.

The gearbox on the front of the drill—cast aluminium cased in older models and plastic on later models—is held on with normal Phillips head screws, so these can be easily removed. While you are looking at the

↑ These drills are very basic inside, and quite robust. Parts are often interchangeable between models.



↑ With a couple of connectors you can fit a new cord.

gearbox, check to see if it's a single-speed gearbox or the rarer mechanical two-speed gearbox, with the speeds selected by a side-mounted lever. (On later drills with the single-speed gearbox, often two speeds are provided via an electronic controller.)

With the handle disassembled and the gearbox removed, the armature (the part of the motor that rotates, see centre-top in photo above), complete with its rear bearing, can be pushed out the front. Be careful not to damage the carbon brushes; these can be removed first if required.

Inspection and repair

With the drill apart, inspect the following:

- commutator for a glazed or worn surface
- bearings for play
- carbon brushes for wear (often one is much more worn than the other)
- gearbox teeth for wear or a lack of lubrication (the grease tends to get flung off the gears)
- power cable where it enters the drill handle (look for splits in the insulation).

If you find anything badly worn, see what's inside your other donor drills! For example, the single badly worn brush can be replaced with the lesser worn brush from the other drill, the gearbox can be swapped, or even the whole armature changed for another.

If the cord has been cut off short or is damaged, the safest approach is to cut the cables inside the handle. Remove the cable remnant from the rubber stress relief at the handle end. Place a drill bit in a vice and then screw the rubber stress relief grommet over the drill, enlarging its internal passage. You can then feed a new cable down the grommet, making the connections inside the handle. To make these joins I use screw connectors of the sort used in 240 V house wiring (commonly called BP connectors). Older drills use screw terminals on the switch, so that's even easier. Ensure that the new cable is firmly anchored so that it cannot pull on the wiring connections.

Note that all these drills are double insulated and no earth lead is required. Replacement cables can be sourced from discarded vacuum cleaners; these cables are long and have appropriate power ratings.

If the chuck is damaged it can be removed and another substituted, although it's often quicker and easier to swap the whole gearbox assembly, chuck included.

Cosmetics

To make your drill look nice again, marks can be removed from the plastic housing by wiping it over with paint thinners. Polish the plastic with a car paint cutting compound. The aluminium gearbox housing can be wire-brushed to remove marks and corrosion.

Conclusion

To produce one good drill from some old discards is satisfying and fun. You need to have some experience with mains power and know your way around electric motors a little, but the drills are surprisingly simple inside and very straightforward to repair—especially if you have a source of free spare parts available! ✱

↑ Check the chuck for proper operation—if it sticks, replace it.

Warning

You must have good knowledge of mains electrical wiring when repairing devices such as power tools. If you are not sure about anything in this article, find someone with the required knowledge and skills to make a safe, effective repair. Please beware, as working on mains voltage equipment can be dangerous and is restricted by regulations. If you don't have the required qualifications, don't proceed.

The ATA branches continue to share practical solutions and information on sustainability, renewable energy, building design and energy efficiency. Here's a summary of recent branch events around Australia.

Adelaide: Recent meetings have included a technical talk on double glazing, an investigation of Low Carbon Living, insights from an award-winning sustainable architect and discussions around off-grid storage systems and factors affecting solar uptake.

Brisbane: Brisbane has restarted activities with its March meeting investigating sustainable living in the inner city and, in May, showing the film *The Future of Energy*: a great time to reconnect with your local branch.

Cairns: The Cairns branch has been running an ATA stall at the Tolga Markets and also attended the local ECOfiesta event.

Canberra: The Canberra branch has re-formed around a new committee and has run some great events already, including exploring the financial and environmental issues around residential gas use and hearing the background to the ACT feed-in tariff issue. Most recently their meeting investigated the renewables industry in the south-east and applications for real-time weather data.

Geelong EV: The Geelong branch continues to meet monthly to discuss current workshop projects and new technology in the EV field. This branch specialises in the practical issues around converting fossil fuel vehicles to electric drive.

Melbourne: This year Melbourne has investigated the possibilities enabled by thermal imaging as well as exploring shading, retrofits and green roofs. They also had a presentation on LiveWell Clusters, a new model of community engagement around the issue of climate change.

Melbourne EV: In addition to their hugely successful Melbourne EV Expo, the branch has continued to host presentations on the cutting edge in EV design including investigating battery types, modular batteries and electric aerial vehicles.

Sydney Central: This year their meeting topics have included real-world application of lithium batteries and hybrid power storage, microinverters and the usefulness of 'big data', sustainable building materials and alternative cities/new economic models.

Sydney West: The branch continues to meet monthly at the Hawkesbury Earthcare Centre, a partnership between ATA and the Henry Doubleday Research Association. The centre supports a strong sustainability education program for the local community.

Tasmania North: This year the branch has had a presentation on a local council's community energy efficiency program and other sustainability initiatives. They also hosted a screening of *Wings of the Sun* on the development of the Solar Impulse aircraft.

Toowoomba: The new Toowoomba branch held a very popular inaugural event on the topic of hybrid PV systems, plus a meeting investigating going off-grid. The local branch would love to meet more local ATA members.

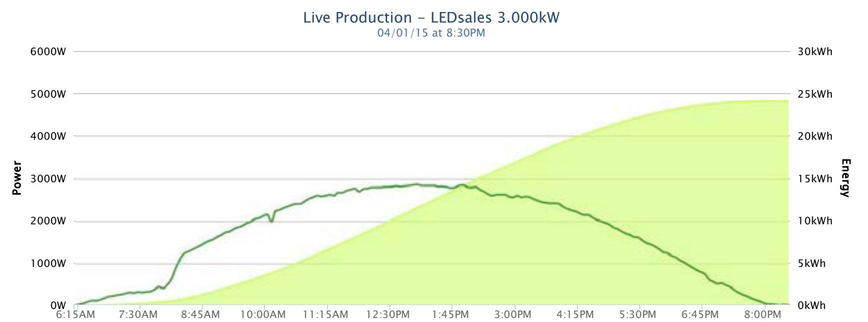
To join in and for all enquiries about branch activities, contact Doug Rolfe, ATA Branch Officer: 03 9631 5407, doug@ata.org.au or www.community.ata.org.au/branches.

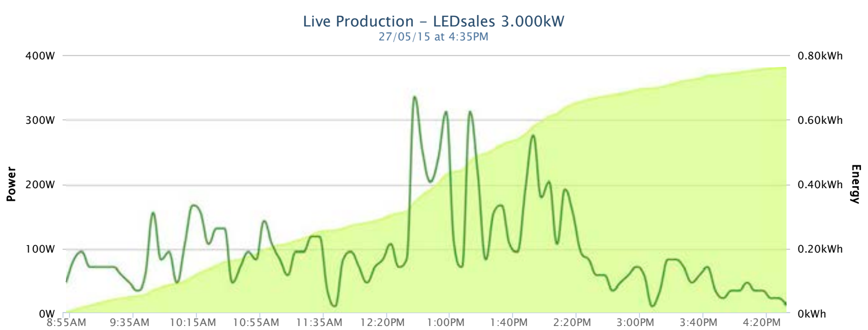
Solar in Tassie: PVOutput update

There's more to PVOutput than team data. Individual system data can be very interesting and can help you estimate how well your system might run.

WE looked at the ATA PVOutput Team members two issues ago and not a lot has changed since then, so instead we thought we'd show some real-time data from a team member's system, Lance Turner's 3kW Canadian Solar array and SMA inverter system in north-west Tasmania.

The top graph is the best generation day since the system was installed in December 2014. Total energy generated was 24.1kWh, not bad for a 3kW system. The bottom graph shows the worst day so far, 27 May 2015; due to heavy cloud and rain the system managed just 761Wh. Note that the graph scales are not the same.

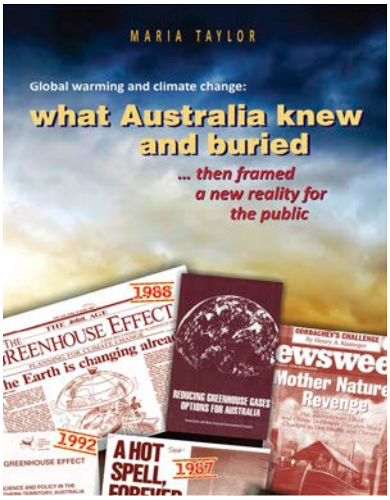




However, despite the low array tilt angle of around 15° and shading in the early morning from a nearby timber plantation, a sunny June day can easily generate 8kWh.

So far we have exported (surplus solar generation) around twice the energy that we have imported (energy use on cloudy days and at night), so the system is certainly living up to expectations. Sadly, we only receive 6c/kWh for exports and pay nearly 30c/kWh for imports! ✱

Why the climate change message changed in Australia



GLOBAL WARMING AND CLIMATE CHANGE

What Australia knew and buried… then framed a new reality for the public

by Maria Taylor
ANU Press December 2014
$28 print or free online

ISBN 978-1-925021-90-5 (print), 978-1-925021-91-2 (online)

THIS book is an essential read for anyone with a serious interest in the history of Australian climate policy and the lessons that emerge from it. It's based on a PhD thesis by journalist Maria Taylor, which included analysis of many media articles on climate, as well as interviews with many of the players.

Australia's well-informed and progressive approach to climate issues from the 1980s to the early 1990s is carefully documented. As Taylor points out, it is a shock for many involved in this battle since the mid-1990s to see how Australians once stood out as informed and responsible, and how competently the issue was treated by leaders and media.

Taylor then explores how, why and when the message changed. It is a bleak story, but an important one. It highlights the enormous power of a web of industry groups, conservative think tanks, neo-classical economic policy makers and media owners. Both major political parties contributed to the reframing.

The book also analyses the role of the media in detail. The shift in media coverage was partly due to the deep change driven by the emergence of the internet, declining profitability and centralisation of traditional media. Experienced and ethical journalists left, so articles that provided context and perspective were replaced by "he says, she says" articles focused on artificially framed debate, conflict that reinforced uncertainty and a culture-war model based on environment versus economy. Powerful media owners imposed their agendas. And publicly owned media were intimidated into providing 'balanced' reporting that reinforced anti-scientific views.

> "It is a shock for many involved in this battle since the mid-1990s to see how Australians once stood out as informed and responsible."

The author provides many insights I found valuable and she filled in a few holes in my understanding of the story. I found it hard to put this book down, even though I found some of its content, on the tactics used to subvert effective action on climate, confronting. ✷

Review by Alan Pears

This book is available for download or order at press.anu.edu.au/titles/global-warming-and-climate-change

The Pears Report
The policy bizarre

Is Australian energy and climate policy beyond rational discussion? Alan Pears reviews recent developments and presents his recipe to improve the effectiveness of appliance Star ratings.

I CAN'T write this column without discussing the ongoing debacle that is Australian energy and climate policy, although I would much prefer to ignore it.

The Energy White Paper (EWP) has been published (www.ewp.industry.gov.au). It was as awful as I predicted. Anyone who relies on it for business planning will likely lose a lot of money. It is completely out of touch with reality: its focus is on growing fossil fuel exports, ongoing privatisation and outdated approaches to reform of electricity and gas supply.

One potentially significant element of the EWP was the proposal to develop an Energy Productivity Plan. In principle this is a very good idea, as it could drive energy efficiency and improve cost-effectiveness of energy utilisation. But don't hold your breath. There is no timeframe, no clear institutional framework, nor any firm resource allocation. And the kinds of policy measures needed to implement such a plan are anathema to our present Australian government and the powerful interest groups that dominate energy policy.

We have also had a consultation on the National Carbon Offsets Standard. This is not exactly riveting stuff for most people, but it is very important. It sets the rules on how businesses (and their products) and households can be certified as being 'carbon neutral'. Unfortunately, the consultation paper forgot to discuss GreenPower, while it focused, instead, on the fine print of the fundamentals. It did not confront the issue of how to ensure voluntary abatement action be treated so that it is 'additional' to other abatement action.

From a narrow carbon accounting perspective, almost all Australian voluntary abatement action, including installing rooftop PV, energy efficiency improvement and buying GreenPower, does not reduce Australia's greenhouse gas emissions. It simply makes it easier for the government to meet its weak target and leaves more room under the target for others to emit more. This is, to put it mildly, disempowering!

We've also seen the first auction under the Emission Reduction Fund. The average price polluters were paid to offset emissions was $13.95/tonne. However, few of the funded measures will deliver direct abatement through reducing emissions. Most involve storing carbon or not clearing land. And a fair proportion of this won't occur before 2020. An unknown amount of it is just a continuation of activities that were already being supported under the previous government's Carbon Farming Initiative. Environment Minister Hunt continued to use creative economic analysis to suggest this was cheaper and more effective than carbon pricing.

Australian energy and climate policy is just so bizarre that it is beyond rational discussion, I'm afraid. If you want my more detailed views on all this, my submissions are available at the relevant government websites. My Energy Green Paper submission is at www.ewp.industry.gov.au; the White Paper does not change the relevance of my comments on the Green Paper. My submission on Australia's 2020 emission targets is at www.dpmc.gov.au/taskforces/unfccc and my submission on the national carbon offsets standard is at www.environment.gov.au/climate-change/carbon-neutral/ncos/review

At least there do seem to be some signs that progressive state governments are beginning to move to fill the vacuum created by our truly remarkable national government.

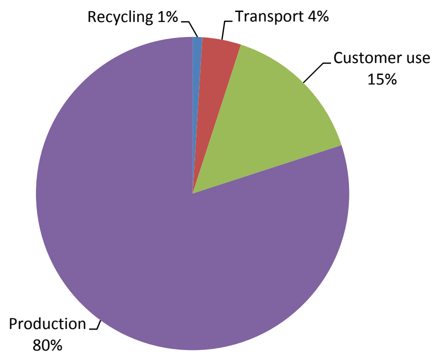
"For efficient products such as iPads, embodied emissions comprise over half of lifecycle impacts. Operating energy use is only 15%."

Reframing appliance energy efficiency

To date, Australian appliance energy efficiency policy has focused on new appliances and, within that, on information (via labels) and mandatory minimum performance standards. Despite extremely limited resources, lack of high-level political support and white-anting by anti-regulatory econocrats, this has been a fairly successful approach. As I pointed out last year (www.theconversation.com/energy-smart-appliances-cut-australian-power-bills-by-billions-25816), a typical Australian household is saving around $300 on annual energy bills and the overall cost has been minus $119/tonne of CO_2e avoided. Not bad value!

But we can do a lot better. Here's my recipe for success.

First we need to sharpen and broaden our approach to new appliances. We need simplified labels on a wider range of products such as lamps and fans. Instead of the present label, these would carry simplified Star ratings only, but also carry a QR scan code, so a smartphone user can access background information. For products with relatively low energy usage, it can be difficult to justify a 'proper' energy label. But a rating that's simply printed on packaging has minimal cost. This approach could also be applied to many products like digital photo displays: Choice found that the worst of these were serious energy wasters, but no one knows which are the good ones.



Mode	230V
Sleep	0.26W
Idle—display on	3.21W
Power adapter, no load	0.09W
Power adapter efficiency	80%

↑ Power consumption of an iPad Air 2 and, left, life cycle emissions covering transport, use, production and recycling. Source: apple.com

We also need to incorporate automated diagnostic monitoring into new appliances, so they tell us if they are not working properly. This is not hard for modern products that include sophisticated monitoring and computing capabilities. One example that does this is the Siddons Bolt-on heat pump hot water service.

We need to sort out the consistency of messaging via labels. A 4 Star fridge is very efficient, while the best TV or air conditioner is 7 Stars. Our 6 Star homes would be illegal in many countries. No wonder people are confused. And lack of effective promotion of what labels mean allows confusion to be misused by salespeople. For example, a home salesperson might tell potential buyers that a house is 6 Stars, so they don't need to think any more about energy efficiency. Unfortunately that's not the case.

Our mandatory performance standards are generally weak, as shown by the wide range of Star ratings of products on the market. We could adopt stronger approaches. For example, the Japanese 'top runner' program requires all products to be at least as efficient as today's best performer within a few years. Or we could just say that anything using more than twice as much energy as 'best on market' is illegal!

We need to look beyond new products. Many people buy secondhand products, but there is no information on their energy performance. As a basic step, requiring energy labelling consumption data to be included on appliance specification plates seems obvious. At least the secondhand retailer or enthusiastic buyer could gain access to the information. We could go further and require all registered secondhand sales agents to place clear information on energy use on appliances they sell—using the information on the specification plate as a source.

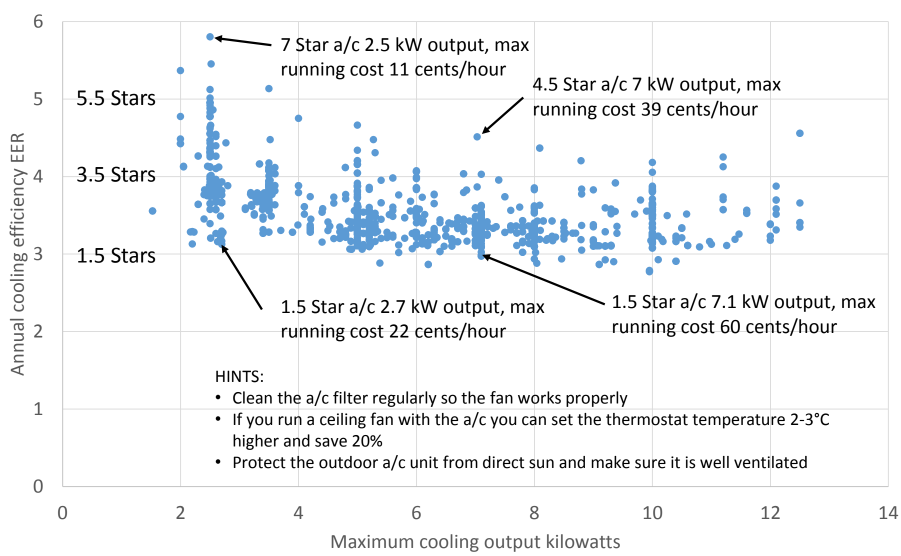
We also need to remove old, inefficient equipment from the stock. Old, often faulty fridges can use up to eight times as much energy as modern equivalent products. Many industrial boilers are up to 50 years old, and appallingly inefficient. Replacing (and recycling the materials from) these items would deliver big environmental and economic benefits, while cutting consumer energy costs. But we need to be able to identify such disasters. This can be done by analysing energy usage data, but it will require some effort by governments and energy companies. At present, energy suppliers have little incentive to do this.

Lastly, we need to be thinking in lifecycle terms. Apple, for example, includes full lifecycle analyses of all their products on their website. For efficient products such as iPads, embodied emissions comprise over half of lifecycle impacts. Operating energy use is only 15%.

More broadly, one Australian study suggested that effective recovery and recycling of waste materials, particularly metals, would cut Australian greenhouse gas emissions by over 5%. And the concentration of valuable rare metals and other materials in wastes can be tens of times higher than in ores we now mine. Failure to capture and use these valuable resources and energy savings is just dumb.

But when neo-classical economic theory and powerful incumbent groups drive policy, it's not surprising that we end up with dumb policies. ✱

Alan Pears is one of Australia's best regarded sustainable energy experts. He teaches part-time at RMIT University and is co-director of Sustainable Solutions, a small consultancy.



↑ The graph illustrates the difference in energy use for reverse-cycle air conditioners in cooling mode for 1.5 Star to 7 Star appliances (for single-phase units under 3.6 kilowatt input). EER=energy efficiency ratio: units of cooling per unit of electricity used. An EER of 3 is 1.5 Stars, each increase of +0.5 in EER earns an extra Star.

Q&A

Do you need to know how much power your appliances really draw, whether you can add floor heating to a wooden floor, or if EVs are really a green solution? Ask *ReNew* your question via renew@ata.org.au.

Wattages of electrical appliances

Q —

I was wanting to know about the actual cost of usage of my home theatre unit and stereo system. The rated input of the home theatre system is 500 watts. Does this mean when I turn it on I always use 500 watts, or when I turn the unit to low volume I use only, say, 50 watts? Likewise with the stereo system.

In the past I have been loath to use both for fear of wasting electricity. I only became aware of the massive wattage after I bought these units. All the specifications are packed away and are inaccessible when you buy them and the staff of the shop claim not to know the power usage of them.

—**Phil Wildman**

A —

The 500 watt rating is what's known as PMPO, or peak music power output. This means the maximum peak (short-term) output power into the speakers. For example, a large explosion in a movie might push the system close to that if you had the volume close to full, but 500 watts is a huge level of power when converted to sound, or even vibration in the subwoofer, so those levels are rarely seen. Plus, it is a short-term rating, which means it's usually only for a fraction of a second or so. The peak power output comes from the large reservoir capacitors in the power supply of the amplifier; the power supply itself would not be able to sustain 500 watts output.

In reality you are probably using 10 to 20 watts most of the time. Some power is lost in the power supply and amplifier circuitry, but a good percentage of the power going in converts to audio output. Even 10 watts is a very good listening level.

You can check this at http://myhometheater.homestead.com/splcalculator.html. If you put in a typical speaker sensitivity of 85 dB with 20 watts output power, and select speakers near a wall (the most common position), at three metres (10 feet), you get a sound pressure level of 94 dB at that distance—a lot.

So your audio devices are using only a tiny fraction of their rated power, otherwise they would either burn up or deafen you! To know exactly how much they are using, you could use a good quality energy meter such as the Powermate Lite or the Steplight Plug-in Power Meter.

—**Lance Turner**

Electric quad bike needed

Q —

As a member of the ATA, I recently read your very good article on electric vehicles. I am a farmer and use a quad bike on the farm, and I'm writing to ask if you could name any companies who sell good electric quad bikes. Hoping you can help me.

—**Peter Pattinson**

A —

There is an electric quad bike in the Products section of this issue. It is relatively low cost, but we can't state how rugged and reliable it might be (we don't know as we haven't tested one). For larger requirements, the Polaris Ranger EV might suit, but it certainly isn't a standard quad bike size. Apart from those two options, and the smaller-sized bikes from Electric ATV in QLD (www.electricatv.com.au), we are not aware of anything similar.

It seems there is a huge gap in the market in Australia for a good, rugged and powerful electric quad, such as those from Eco Charger (www.ecochargerquads.com) and Eco Electric ATV (www.ecoeatv.com) in the USA.

—**Lance Turner**

Underfloor heating

Q —

I have the idea of installing an underfloor hydronic heating system at my dwelling. The floor itself is constructed using Jarrah timber in a bearer-joist and floorboard format. There is an average working space underneath the floor of one metre.

The usual approach of placing the floor heating system on top of the existing floor raises the issue of hiding a perfectly good floor. We all know just how good timber is at insulating against heat transfer and, with this in mind, would it be practical efficiency-wise to place a hydronic heating system on the underside of my floor ?

—**Les Hodgson**

A —

You are right in assuming that the floor will provide too much insulation. Some people do go this route, but you need a floor that is well seasoned hardwood so that it doesn't dry out with the heat, and shrink or crack. I personally wouldn't put floor heating under a wooden floor.

I think you would be better off using hydronic radiators or skirting systems such as www.thermaskirt.com.au. They are simple to fit and are said to give a similar effect to in-floor heating—although I haven't experienced such a system, so can't say for sure.

—**Lance Turner**

EV battery life

Q —

Thank you for the articles on electric vehicles (EVs) in *ReNew 131*. The article on using EVs as a storage device didn't mention the impact on battery life which I suspect it would have—or consider the economic impact of this when using an EV to maximise returns on a solar PV system. Surely increasing the number of charge/discharge cycles must shorten the battery life, even if the depth of discharge is constrained to, say, 80%. It's interesting to note that Nissan encourages this practice by marketing a Leaf-to-Home bi-directional charging/discharging system (in Japan).

I've also heard from others (not necessarily reliable sources) that fast-charging reduces battery life. Different battery technologies obviously have different abilities to handle charging and discharging.

Is there any reliable data on these two aspects?

—**Barry Abbott**

"Your audio devices are using only a tiny fraction of their rated power. To know exactly how much they are using, you could use a good quality energy meter such as the Powermate Lite or the Steplight Plug-in Power Meter."

A —
Kristian Handberg, author of the article in *ReNew 131*, responds: The additional cycling of EV batteries definitely needs to be considered. However, a number of insights suggest that the impact on the battery life is low. Tesla and Nissan's batteries are holding up well (www.bit.ly/1B2Lc9x and www.bit.ly/1G9jTJK). Degradation is very low if the additional battery cycling is done near a 50% SOC point (www.bit.ly/1BVN7rz). And for a given power output, the degradation-associated C-rate for a 24 kWh vehicle battery is significantly lower than for a smaller (e.g. 7 kWh) household battery. Nissan has dealt with a warranty issue arising from consistent charging above 80% SOC, but there are no limitations on fast-charging or cycling. And although this may change, the used EV market does not currently undertake battery condition assessment as part of vehicle valuation.

—**Kristian Handberg**

Point-of-use water heaters

Q —
I'm looking for information on instantaneous electric water heater taps for sinks. I'm considering them to address the water and energy inefficiencies associated with the long pipe runs from my current water heater to kitchen, bathroom and laundry sinks.

I'm aware of instantaneous tap water heaters without storage and with integrated lever taps for this application, and these are what I'm most interested in hearing from people about.

With the shower, similar issues and savings opportunities arise, but the much less frequent use (typically once a day per person) make showers a much smaller opportunity to save water and energy by this means.

However, shower-specific instantaneous water heaters are available (which differ from sink units), so I'm happy to hear any ATA views on those as well.

For example, has there been a *ReNew* article reviewing any of these in relatively recent times? I remember seeing adverts for these in *ReNew* at some time in the past.

—**Paul Riordan**

A —
We haven't reviewed such units, although several have appeared in the Products section of *ReNew*. These include units from www.rezi.com.au, www.stiebel.com.au, www.heyprestohotwater.com.au, www.gleamoushotwater.com.au, www.microheat.com.au and www.zipindustries.com.

They are all of similar efficiency (i.e. 100%); the main issue is the electrical circuit. The tap-integrated units generally work with a regular 10 A power point or standard wiring, whereas the 15 A and greater units (shower models seem to be rated around 5000 to 6000 W, or 20 to 25 A) need a dedicated circuit. The larger units are all three-phase and are not usually suitable for domestic installations unless three-phase power is available in the home.

These units can vary enormously in price and some are more repairable than others. Make sure you get one with an easily replaceable element if possible, and ensure spare elements are available.

The other thing to be aware of is the level of heating provided. Most of the single-phase units, especially the tap-integrated units, will only raise the water temperature by 10 to 20 °C for a reasonable flow rate, which might be fine in warmer climates, but if you have colder water temperatures they may not do the job. Check the specifications for each unit at the maximum flow rate required.

—**Lance Turner**

Are EVs really green?

A —
There have been a number of articles and letters in newspapers recently regarding just how green an EV really is if it is run on a fossil-fuel supplied generation system. While this varies greatly depending on which state you drive your EV in, the results according to the federal government's CO_2 accounting methodology are that, in almost all circumstances, buying an EV will reduce personal transport energy CO_2-e emissions, even if it is entirely charged from a grid fed from brown coal.

For instance, in Victoria, where brown coal (the highest CO_2 emitting electricity generation fuel in Australia) is the dominant energy source for the electricity grid, for city driving, using an iMiEV charged from the grid instead of a Mazda 2 will still give a 14% CO_2-e emission reduction. The best improvement is in Tasmania (where there is significant hydroelectric power generation). There, the CO_2-e emission reduction of an iMiEV compared to a Mazda 2 is in the order of nearly 80%. One article compared the Tesla to a diesel VW Golf and found in favour of the Golf in Victoria; however, the comparison should be to a large luxury car rather than a city car like a Golf—and in every state except Victoria, the Tesla would win over the Golf anyway.

But remember: the bottom line is that if you really want to eliminate fossil fuel dependency, you will need to go further. Your options are a tailored combination of grid-connected solar PV, subscribing to Green Power and/or installing a battery backup system.

In summary: EVs are a 'green' choice for reducing personal emissions. However, if you want to make a significant difference, don't buy electricity produced by burning brown coal! If you want to go further into the data, see my article in *ReNew 120*.

—**Bryce Gaton**

Write to us

We welcome questions on any subject, whether it be something you have read in *ReNew*, a problem you have experienced, or a great idea you have had. Please limit questions to 200 words.
Send questions to: renew@ata.org.au

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ATA member profile
Shaping the built environment

Long-time ATA fan and more recent member Natasha Palich discusses her combined passion for architecture and advocacy with Eva Matthews.

"I'M a bit worried about where the planet's heading." This understatement belies the level of Natasha's concern about our impact on the environment, which she has translated into activism of various sorts throughout her adult life. In her early days it was campaigning with The Wilderness Society. Following university and in her professional career as an architect, it has seen her involved in paid and volunteer advocacy roles, as well as bringing sustainability principles to each home she is commissioned to design.

Natasha studied architecture at Melbourne University in the early 90s, "when sustainable design wasn't a dedicated study stream anywhere really." Graduating in 1995, she practised her craft in a number of firms over the next few years. However, when a job with the Australian Institute of Architects came up, Natasha was excited to revive her activist tendencies in an advocacy role within her field. She was editor of the *BPA Environment Design Guide*, developing sustainability information for the industry, and later remained involved on the AIA's sustainability committees.

Starting to miss the learning acquired through experience, Natasha jumped back into work as a project architect for a medium-sized firm for a few years, trying to incorporate sustainability practices into that forum. In 2004 she took the next step and set up her own practice, while also working part-time in local government advising on and developing sustainability tools and strategies. One decade on, she continues this trend of having her fingers in a few pies that combine her advocacy and architectural practice, currently also working one day a week as coordinator of the Municipal Association of Victoria's Council Alliance for a Sustainable Built Environment. This is a trend she would like to maintain ongoing, as well as her teaching, training, writing ...

In her architectural practice, Natasha says she doesn't have a signature style—she likes clients to show her things that inspire them, and she uses that for her inspiration. Most important to her is that she designs a home that is comfortable: "Clients need to like it and it needs to make them feel good. You can achieve this with good design and material choices."

In terms of bringing sustainability principles into the design, sometimes Natasha gets clients who are "super keen" and informed and have clear ideas about what they want to achieve, and she enjoys working with and learning from them. On other projects, she is the one introducing sustainability concepts and encouraging responsible choices.

Working mainly on renovations, Natasha says she enjoys the challenge of dealing with existing conditions and smallish budgets. Add in the factors to consider around what materials or systems to use—embodied energy, whether to consign still-functional items to landfill, for example—and you start to see the line that needs to be negotiated between what a client thinks they want, what they need, what looks good, what will perform well, and what they can afford short- and long-term in order to bring about the best solution.

In terms of building materials, Natasha likes using (recycled) timber internally. Externally she uses metal cladding and cement sheet a lot. She notes, "There are some interesting cement sheet products around that are reducing their carbon footprint. This is one of the most interesting areas coming out." Despite the many exciting advances being made in building materials, however, Natasha recounts a 2007 RMIT University study that showed that "the single most effective thing to reduce the environmental impact of materials is simply to use less of them—so, make buildings smaller, utilise smart design, ask clients 'do you really need two bathrooms, do you need floor-to-ceiling tiles...?'".

She further notes that, on a larger scale, we need to change the way we plan our cities. "We need to challenge people's expectations of what housing is. The housing we're providing isn't broad enough in its typology to meet the needs of communities living in a globally warmer world." ✱

↑ Incorporating sustainability into the renovation of her 1940s home, architect Natasha Palich and her partner (also an architect) turned what was "probably a minus Star into a 6 Star house". She recycled hardwood timber from the roof structure (removed to accommodate a second storey) into decorative slats on the front facade, and sent as little as possible of the house to landfill. Windows were designed for cross-ventilation—"effective cooling that is so easy, and free!"

For more on Natasha's practice, visit www.sensearchitecture.com.au.