ReNew

Technology for a sustainable future

Issue 123

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Thermal imaging
using technology to improve efficiency

Urban strawbale
the ups and downs of a DIY home

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Home-grown: Tindo solar PV, solar ferries; **E-waste:** collecting now; **DIY:** free heat from the sun & lithium lawnmower retrofit

Electric Bike Buyers Guide inside

Contents
Issue 123, April – June 2013

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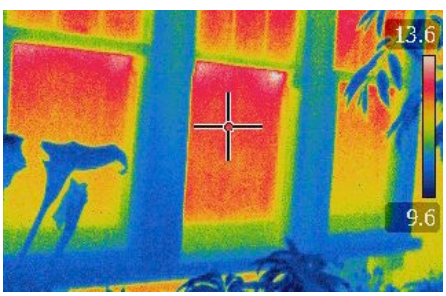
Take charge!
Energy storage, electric bikes and much more

↑ Building an urban strawbale home is rewarding but not without its challenges. Page 22.



↑ Thermal imaging can be a useful tool in improving energy efficiency. Page 30.

Features

↑ Community-owned wind power in Europe. Page 34.

↑ Find out more about a cleaner, easier way to travel in our electric bike buyers guide. Page 66.

← **Cover image: CSIRO, photo by John Marmaras.** Researchers working in a battery bank at a wind farm in Hampton, NSW. They are researching the ability of an UltraBattery bank to smooth out variability of wind power as it enters the grid. An UltraBattery is a hybrid energy storage device made up of a supercapacitor integrated with a lead-acid battery. See www.csiro.au/ultrabattery for more info. Our special feature on energy storage starts page 49.

↑ A lithium battery retrofit for a lawnmower. Page 76.

Regulars

Urban strawbale
The ups and downs of a DIY home

Owner-builder Nikki McCoy shares her home, building experiences and lunch with Beth Askham from *ReNew*.

↑ From the street, the house certainly stands out, with neighbours watching the build with interest and, in some cases, scepticism. Most plants in the garden are edible.

THERE has been no shortage of vision and hard work poured into this lovely strawbale house built on a suburban block in Melbourne's west.

Built with non-toxic materials to be energy-efficient, long lasting and with a small footprint, it was a pleasure to visit and take a look at this home over lunch.

The house has the beautiful feeling inside that is characteristic of strawbale houses. It's a settled quiet that puts you at ease. "The straw was chosen for its insulation quality and also for its beauty. Straw also creates such a melodic ambience in the house," says owner-builder Nikki.

The first thing I noticed is how the house enables the many social and creative visions of its makers. Designed to feel and function a little like a small town hall, the central space of their urban strawbale home includes a stage (complete with power and AV concealed in the floor) and a commercial kitchen where Nikki plans future cooking classes, drawing inspiration from their abundant edible garden.

The house is the product of two years visioning, planning and designing and one year of hard work by a committed team led by Nikki. The core building team was made up of Nikki and her son, his friend and two building apprentices in the process of retraining from chefs (is this why the kitchen is so great?), with skilled tradespeople coming in and out as needed.

They ended up spending $340,000 instead of their budget of $270,000, but still feel like it was economically worth it, especially as their suburban block cost them only $100,000.

Nikki says, "We chose the vacant lot (500 m^2) as the land was close to main street shops, ten minutes walk to the railway station and most importantly, right next to the beautiful, magnificent Werribee river."

They did the design themselves, and included a lot of what they wanted in their three-room house. It has two-storey high ceilings, storage cupboards that stretch almost to the roof (accessed by a ladder), a 19,000 litre galvanised water tank, a Wattworks greywater treatment system and solar hot water. In summer it keeps them cool with fans, insulation, moveable outside shades and semi-transparent inside blinds. As they plan to stay for a while, they also designed the single-storey house for wheelchair access.

It's more like a sculpture than a house, and indeed Nikki spent six months placing the render onto the straw walls. "We used strawbale walls with render made up of hydraulic lime, sand and water and a mineral silicate finish which makes it both breathable and waterproof." Three layers of render later and the walls are a beautiful white with each window nook sculpted by Nikki into different forms; some are curved and some have straight edges.

It's worth mentioning that in the building of the house, no toxic glues, paints or sealants were used. Nikki says, "A lovely thing about working with non-toxic paints and glues and with straw and lime render is that there were no strong chemical smells when working. Everything was non-toxic and if you got some lime render on your skin you would just wash it off with some vinegar."

Earth tube

Nikki said that looking at what others had done was really helpful. She drew ideas and

Energy-efficient temporary living
Making a shed liveable

Vadim Pantall explains how he and his family converted an ordinary shed into a comfortable off-grid home while planning a more permanent dwelling.

WE wanted to set up the way we live on our farm to have minimal impact on the surroundings and to be as self-sufficient as possible, but without losing too many luxuries. Some of the decisions were made for us, given the farm was never going to get a phone or mains water, and power was a little distance away and therefore would have needed a few poles (at a fair cost) to get it to our dwelling.

Our current dwelling is a shed converted into a house, so we call it the Shouse. Below is how we provided for the energy and water needs, as well as what we did to make the Shouse liveable for our family of three.

↑ The Shouse and solar panels soaking up the sun.

Well supplied with water

Council required us to have a minimum 90 kL of water storage. When pricing tanks, it worked out only a few thousand dollars more to get a tank that was significantly bigger, so we settled on a 255,000 L steel tank. With over 200 acres we figured space wasn't an issue! This tank filled up in a winter and a half, with no water consumption. We've since also added an additional 23,000 L tank and have plans for more as I do have a bit of a fear of losing our whole water supply should a pipe burst or the water in one tank get contaminated.

Off-grid generation

For the first few years we ran on a diesel generator. Unfortunately, much of this energy was wasted as the generator produced more power than we needed. It was actually quite convenient for us and not for the power companies that while we were looking at both grid and renewable options (including combinations of both), a couple of things happened.

WA was having significant power price increases, and these didn't (and still don't) look like easing up. Also, we had a few arguments with Western Power about some changes in billing practices for a house we were renting. It was perfect timing for a power company to annoy us, so we settled on not hooking up to the grid at all!

We checked out a couple of options and initially signed up for a package that would use the diesel generator, but included batteries and an inverter. This would reduce our generator run time to around four hours a day. Renewable generation could then be an add-on for the future.

We ended up signing up for a system that was virtually the same except that it included six solar panels on a solar tracker. The tracker was calculated to reduce the generator run time to around an hour a day—subject to how strictly we kept to the consumption goals we'd set. But not surprisingly (to those who know me), prior to the installation of the tracker, we ended up upgrading again to include two six-panel trackers.

The installation has a Victron inverter, Xantrex solar charge controller, Sungrid panels and 740 Ah battery bank sized to provide us three days of energy storage for those cloudy periods. We also got an

↑ The 12 solar panels on their trackers provide most of the Shouse's energy needs during summer.

↑ The energy system is contained in a separate room at the end of the Shouse.

additional 'Blue Panel' control panel inside the Shouse next to the kitchen so it's only a glance to find out all the data for the RAPS we'd ever want to know.

We find it's critical to know how much electricity, water, diesel and gas we are using. These don't just come from an endless supply down a line—when you are actively involved in their generation or resupply you truly appreciate them. An added benefit is that it will teach our son, Jed, to be really aware of his impact on his surroundings. My wife Simone and I both love our coffee, but watching the meter drop down to less than two hours left on a 740 Ah battery bank when you turn on the coffee machine ensures you appreciate that cup a lot and you think about when you use it.

Due to its poor quality power output, the old small Chinese diesel generator was replaced with a better quality 9 kVA water-cooled diesel generator. But as it's summer now, and we have the two trackers, we don't really need it much. We'll ultimately see how it goes in winter.

It took a fair while to get the system set up properly. Teething problems included waiting for months for the contractor to turn up to start the job—no matter how much noise you make, someone else's job is always a higher priority. We then had a number of incorrect settings put into the unit which caused some short- and medium-term issues with its performance. It was telling us all sorts of things that were or weren't happening, then one day when it said the batteries were full, everything just shut off due to low voltage.

It took another 4–5 months of juggling to get the settings completely sorted. And if that wasn't bad enough, about 7 months after the trackers were installed we found out that one whole tracker wasn't connected. It turned out there were a few dodgy connections, which then got fixed. Through all this the batteries became sulphated, meaning they weren't accepting or providing full capacity. So we are now in the process of sorting out the battery problem. With the second tracker working, we have had several days peaking at 2800 W, with good solid power once the sun comes above the trees on the horizon and until about 5pm when it ducks behind the trees to the west—at least 10 good generating hours.

↑ The remote panel for the Victron inverter (top) and the Oregon rain monitor let Vadim keep an eye on things.

Heating and cooling

We picked the spot on the farm with the second best view (given we will be building a proper house on the farm one day soon) and good protection from the wind, while still allowing the Shouse to face north. The verandah provides some protection from the sun heating up the walls, but still allows some sun through to warm the dark tile-covered concrete slab in winter.

We didn't want the place to be too hot or cold due to big windows, or to have to use small windows and block the beautiful view of our farm. We ended up getting Pilkington Comfort Plus glass in all windows, which provides better thermal properties than plain glass, but wasn't as expensive or difficult to research, source and fit as double glazing.

These have performed well so far, although the building contractor who fitted them damaged quite a few either in transport or while fitting. Now we've done it once, we feel more confident that we know enough about glazing and building eco-style, so we plan to use double glazing for any future windows.

External walls all have R1.9 Aircell under the tin and the roof has R0.9 glass wool foil-faced blanket. We also installed Tontine polyester batts in the walls and ceiling (R2.5 for external walls, R2.0 for internal walls and R4.0 for the ceiling). These were deemed to be the most user friendly with the best long term durability. They are also recycled from a troublesome material, plastic bottles. They

Watch that heat loss
Using technology to improve efficiency

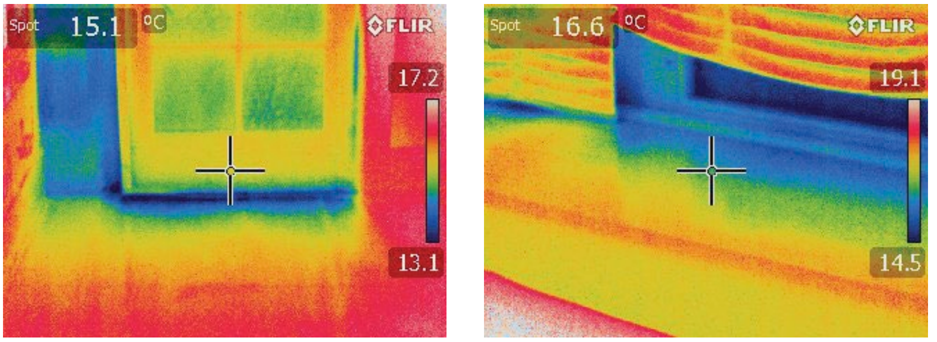
David Coote describes how he is using thermal imaging and air change measurements to drive his residential energy efficiency retrofit.

AS I write this article the temperature is forecast to reach over 40 °C in Melbourne. Energy efficiency experts suggest that even in this very hot weather, with well-designed and well-built houses we should need only a small amount of air conditioning. Conversely, compared to Europe and North America, we have a generally mild winter climate, so we should need minimal, if any, active heating in a well-built house that is thoroughly sealed and properly insulated, and has well-managed energy gain from insolation.

Eaves, shading from vegetation, appropriate window location and site orientation can all contribute to reducing solar gain in summer and taking advantage of solar energy in winter. Some of these factors, such as site orientation, window location and eave design, are best introduced when the building is designed. Others can be readily retrofitted to existing buildings.

Overseas experience indicates that up to 90% reduction in energy use for heating and cooling is achievable with higher quality construction. A number of local studies have highlighted that achieving this performance in Australia's residential and commercial buildings could reduce the annual national cost of heating and cooling by billions of dollars and substantially reduce our greenhouse gas emissions.

All very nice, but how can the average household get there? To optimise any system, it's useful to first identify and characterise the problems. In this article I describe how we used some modern tools to examine the thermal performance of our house. In follow-up articles, I'll show how we used this data to improve its energy efficiency.



↑ Small gaps under curtains and gaps around external doors and windows can allow a lot of heat to flow into or out of a home. Thermal images courtesy Efficiency Matrix, www.efficiencymatrix.com.au

Energy efficient—with room for improvement

Casa Maree and David is a double-brick Spanish mission style house, built in 1930, with a mix of single-glazed sash and casement windows. The house faces west. Eaves on the north side do an excellent job of shading the windows from direct summer sun. When the sun is closer to the horizon during winter, these windows are not shaded, which contributes to heating the house.

We installed ceiling and underfloor insulation soon after we moved into the house in 2005 and since then we have added 1.5 kW PV panels, an instantaneous gas-boosted solar hot water system and a modern, efficient wood heater in our sitting room (in which we burn wood mainly from local arborists). We've also installed LED and compact fluorescent lighting and energy efficient appliances.

Making a substantial amount of the thermal energy and electricity we use has us approaching near zero energy status. But, although the house is much more comfortable and energy efficient than when we moved in, there's still room for improvement.

The house is a bit draughty in places and some rooms away from the wood heater are cold in winter, requiring supplementary heat from a free-standing electric heater. And, as anyone who uses a wood heater will know, it takes time to light it, cut wood and clean out the ashes. Reducing its use would not be unwelcome.

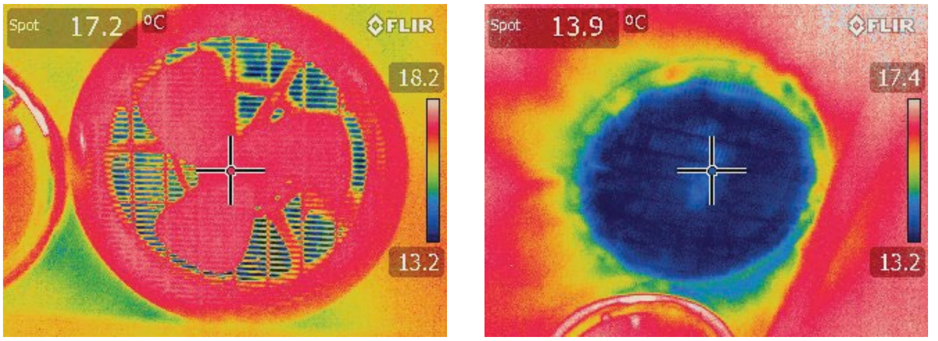
In addition, after a few consecutive hot days in summer the house gets very warm inside. If we were to install an air conditioner we would want only a small unit, to be used sparingly.

Given all these issues, we would like to do more energy efficiency retrofitting.

Assessing energy efficiency

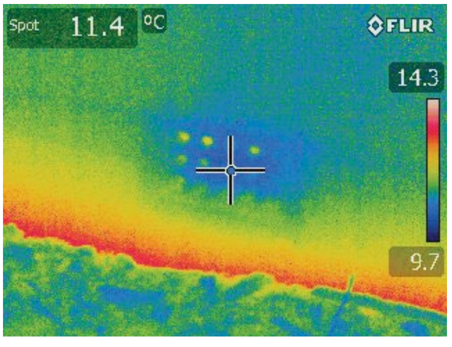
Two complementary techniques used extensively overseas to assess housing energy efficiency are thermal imaging and blower door tests.

A thermal imaging camera captures infra-red radiation to show the temperature of a surface. This can highlight where heat is leaking and where insulation is or is not working. It can also help to identify damp areas caused by leaks and condensation.



↑ Exhaust fans are a source of air leakage, which is demonstrated when comparing a static measurement (left) to the blower test (right). Here you can see the effect of cold air entering the home from the roof cavity.

"Many windows have leaks around them, including recently installed double-glazed units. If the window is poorly fitted, the air passes around the window and thus the efficiency benefits are greatly reduced."



↑ Those wall vents may make the house look original, but they leak a lot of heat through unwanted air movement.

Blower door tests measure the air tightness of a house by using a powerful fan to either pressurise or depressurise the house and hence give an indication of how leaky the house is overall. The blower also accentuates heat losses caused by leaks, making them more detectable by the thermal imaging camera.

I like to do some research into technologies before I use them. Posts on the Green Building Advisory Forum (www.greenbuildingadvisor.com) gave guidance from northern hemisphere experience with thermal imaging. I found out that it's best to have at least a 10 °C temperature difference between the outside and inside temperature when capturing the thermal images, and that exterior walls shouldn't have had direct sun on them for several hours. In addition, moving items such as furniture away from the inside surface of exterior walls will help reveal a number of issues, particularly areas affected by moisture.

To capture the thermal images, I considered buying a cheap thermal camera or modifying a cheap digital camera to perform infra-red imaging. Both of these options are quite feasible, but the research I did indicated that to get good resolution requires cameras that cost thousands. The dedicated infra-red cameras also have a number of other useful features.

I planned to hire a thermal camera from Tech Rentals for about $300 and split the cost with a number of households, but I was a bit concerned about whether I would get good results from the thermal camera without training or experience. Through word of mouth we had a good offer from a company interested in residential thermal imaging and blower testing, who had experience in using a commercial thermal camera and associated software. So early one crisp spring morning John from Air Leakage Measurement Australia (ALMA) turned up with his blower and camera.

ALMA's perspective

John began working in building energy efficiency because he believes this is a good sector to target for greenhouse gas emission reduction. He notes that the UK, USA and parts of Europe and Scandinavia have been testing for air leakage for some time now.

He says that measuring the volume of air pulled through the house using blower testing shows how much is leaking in through cracks and gaps in the building. Blower testing can be used in combination with the thermal camera to show visually "exactly where the air is leaking in. These areas are then caulked or sealed using draught-reducing products."

At ALMA, he says, they rarely find an Australian house that would comply with even the most lax UK standard. Although this is unfortunate, as he points out this is a great opportunity to remediate our housing stock and significantly reduce our greenhouse gas emissions.

ALMA provides a report listing problems detected and recommendations on how to fix them. They've found one frequent source of significant leaks is downlights. The regulations controlling downlight installation require that insulation doesn't cover the light, which means the fittings act as a conduit for heated air to pass straight into the roof space. Downlight covers are now growing in popularity; these enable the insulation batt to be cut to fit around the cover, thus stopping the conditioned air from escaping. Note that there are limitations to the use of covers—they can't be used with all types of lighting, and they need to have sufficient air space in them to avoid overheating.

Another interesting finding from ALMA is that many windows have leaks around them, including recently installed double-glazed units. If the window is poorly fitted, the air passes around the window and thus the efficiency benefits are greatly reduced.

ALMA doesn't have published data on the energy savings achieved by people who have followed up thermal analysis with remediation work. Anecdotally, they say customers are reporting savings of 20% to 40%. There is an excellent opportunity for research to quantify the savings achieved by a systematic retrofit process in Australia. Comparing the retrofits in terms of actual savings/cost against those predicted by a model would be extremely useful for householders.

Our results

In our house, John took about 70 thermal images. The blower results and thermal imaging clearly illustrated a number of items we could tackle. Having the false colour representation with temperature coding is a

Communities and wind power
What's the deal?

Jarra Hicks shares experiences of community-owned wind power in Europe and considers the implications for wind power in Australia.

↑ On Samso Island, wind turbines are a welcomed part of the landscape.

WE ARE currently facing a dilemma in Australia. Wind power often gets a hard rap in the press and is met with suspicion, if not concern, by communities. Yet it is currently the most deployable and cost-effective form of renewable energy, especially at larger scales.

Although a diversity of renewable energy technologies operating at a variety of scales will likely be essential to transforming Australia's electricity supply to largely, or wholly, renewable sources, there is no doubt that wind power will play an important role in the next decade and beyond. Wind power is projected to be the major contributing technology for achieving Australia's 20% by 2020 renewable energy target. But will this be possible in the current socio-political context? How can we ensure wind power is delivered in a way that builds social acceptance and contributes positively to communities?

A recent trip to Denmark and Germany provided a comparison point.

On the ferry to Samso Island, Denmark

Samso Island is beautiful. Its quaint old-fashioned Danish towns, complete with reed-thatched roofs, lie between rolling hills of wheat, strawberries and potatoes. Craggy cliffs frame stony beaches, and its well-kept roads and very little traffic make it a haven for families who love bike riding. All in all it's an idyllic miniature of Denmark.

On the ferry over to the island, we pass 10 offshore wind turbines. I run around the ferry trying to find the best vantage point. I am spellbound: they are beautiful. Slender, graceful blades travel swiftly, smoothly through the air—and with each turn they generate emission-free electricity and income for their local shareholders.

A slightly embarrassing moment follows when I realise that no one else is taking any notice of the turbines and that I am one of those 'nutty tourists' who gawks at perfectly normal things. 'Windmills' are a part of life in this region of Europe. While they don't dominate every view, they are common in the landscape and 'normal' in people's psyche.

A diversity of wind development models

From my guesthouse on Samso Island, I look out across rippling grass plains and a lake to fields speckled with turbines. The undulating farmland looks a lot like Australia: grassy paddocks interspersed with homesteads every few kilometres and small towns dotted throughout. The most striking visual difference is the presence of wind turbines here and there. All sorts of wind turbines: tiny 6 kW ones on a simple 10 m pole; larger ones on 20 m lattice towers; the big 100 m tall 2 MW ones more common in Australia; and, of course, the classic, old grain or water-pumping windmills that have been in the landscape for over 100 years.

In Denmark, wind development comes in all shapes and sizes and, more often than not, local people are involved in owning and benefitting from the presence of wind turbines in the landscape. Germany is much the same, with more than 50% of its installed wind capacity owned directly by the citizens (Gipe, 2012). Sometimes, wind power supplies just one home or farm; other times a group of homes, a town or a region become net electricity exporters, as happens with the larger wind farms common in Australia.

Samso Island (pop. 2800) generates 100% of its electricity and offsets all its transport emissions with 11 onshore and 10 offshore (1–2.3 MW) wind turbines, all of which are owned by local people and the local municipality.

Climbing the e-waste mountain
Keeping electronics out of landfill

Jeff Angel, executive director of the Total Environment Centre, describes the complicated process of getting e-waste recycling happening in Australia.

← Old computers are a huge source of e-waste.

WE can see the discarded TVs and PCs on the verge and we know there are lots of old computers and monitors at the back of the office along with retired mobile phones in the drawer. And there are millions of batteries in consumer products. We know they contain important resources such as rare earth minerals and that the plastic, lead and glass can be recycled. Yet there are over 230 million electronic items in or on their way to Australian landfills. So how do we stop this mountain of waste?

Until recently Australia did little to recycle e-waste—the bigger items and their peripherals. There were voluntary schemes where you had to pay when you got to the collection centre. Some councils began drop-off days—and the flood of materials was astounding. Developing producer responsibility in Australia has been slow, with tepid approaches endorsed by bureaucrats and industry, and feel-good media releases from ministers wanting to appear to be doing something.

A complication has been the desire to have a national regime rather than starting off independently at the state level. The force of federalism is strong despite several states such as NSW having strong product stewardship laws and promising action. Consequently, environment ministers met interminably—discussing proposals for studies, receiving reports on trials, issuing communiques.

This was the policy landscape for e-waste during the early 2000s. However, a campaign by the Total Environment Centre and Environment Victoria over seven years finally brought the issue to a crunch point.

Initially, industry was resistant—some didn't like green regulation and some wanted to protect the market differentiation they gained from brand-based recycling schemes. An understandable requirement of industry associations is that there should be no free-riders; otherwise, those that are participating, with a cost burden, believe they are at a competitive disadvantage to non-participants. There is also the usual opposition to adding a (small) additional cost into the price of products to cover the recycling program.

A combination of media and public information programs by environment groups, actions outside recalcitrant departmental offices, the use of social media to lobby ministers, as well as the release of recycling plans based on successful overseas models, eventually brought the problem to a decision point.

But under COAG rules you have to produce a 'regulatory impact statement' (RIS) which is intended to assess the benefits and costs of policy options using an economic methodology imposed by the Office of Best Practice Regulation (OBPR). Yes, the OBPR, which does not have any environmental or social responsibilities, can interfere. It was

Images: ewasteguide.info

↑ Most e-waste is currently shipped to developing countries such as China, where environmental controls are limited at best. At left we see a popular method of separating copper wire cores from the plastic insulation—burning it! At right we see the toxic pollutant contamination resulting from such methods.

established as a way of appeasing business concern about over regulation and perceived costs on them. It can potentially stop a much-needed environmental protection measure.

This almost happened with e-waste recycling (and it did stop a national tyre stewardship program), until the OBPR accepted the inclusion of a 2009 'willingness to pay' study that quantified the support for e-waste recycling. In the same year, the Total Environment Centre signed a compact with the Australian Information Industry Association outlining key principles for the national program. Next stop Perth, where in mid-2010, federal and state environment ministers officially agreed to a national e-waste scheme.

Not finished yet, as Commonwealth legislation was necessary. This led to a Senate Inquiry and passage of the Product Stewardship Act 2011—an umbrella law that allows any product to be subject to a voluntary, co-regulatory or mandatory program, provided certain criteria are satisfied. A year later, after deliberation by a stakeholder advisory committee, the regulations for the National TV and Computer Recycling Scheme came into effect.

Its key goals are:

- an 80% recovery rate by 2020, as collection infrastructure is rolled out
- 90% material recovery rate by 2014 (per item, a standard that can be reached by Australian recyclers)

A complicating issue during all the negotiation was the switch to digital TV, which hadn't even considered the recycling of the old analogue TVs. Stopgap measures were put in place where the switch was to occur, mainly in regional areas, but that didn't ameliorate the problem caused by the bigger consumer changeover to digital TVs across the nation.

Another urgent task prior to implementation was to settle on definitions of what would be targeted and matching this with Customs' product codes so that imports were captured. All the brands are liable parties, above a small business threshold, and the industry collects revenue to fund the system. It was also agreed by government that there could be multiple collectors.

The result

Free drop-off sites are now slowly being set up, although there is some concern about their adequacy given the stockpile waiting to be recycled. However, as a consequence of the scheme, the rate of recycling is slowly rising.

That still leaves small electronics and all those portable batteries in products from torches to electric staplers. While car batteries are mainly recovered and recycled, the smaller portable ones, with their heavy metals, are not. They can contaminate landfills and thus groundwater, as well as material in recycling bins. These are the next e-waste challenge.

Currently the Product Stewardship Advisory Committee is assessing the next priorities for recycling. There are many more products waiting to travel the long road to recovery. ✱

For drop-off points check out: www.environment.gov.au/settlements/waste/ewaste/drop-off-points.html

Recoverable materials

Electronic devices contain a vast array of precious materials, most of which can be recovered.

Around a third of all the material is ferrous (iron-based) metal, mostly mild steel, and this is fully recyclable. Other materials found in larger quantities include plastics (some containing brominated fire retardants), glass (both containing lead and lead-free) and other metals like aluminium and copper.

Materials found in smaller quantities, but just as valuable, include gold, silver, lead, tin, tantalum, cadmium, indium and mercury.

Given the right processes, almost all of this material can be recovered and reused in new products.

According to precious metal recycler Umicore, one tonne of mobile phones contains around 350 grams of gold, 3.6 kg of silver, 151 grams of palladium and 5 grams of platinum, not to mention all of the other lesser value materials, so there is considerable value in discarded electronics.

Aussie-made solar
Inside Tindo's factory

Tindo Solar is the only Australian solar panel manufacturer. Alan Strickland takes us on a tour.

TINDO Solar began production of photovoltaic panels early in 2012 at their factory in Mawson Lakes in the northern suburbs of Adelaide. Managing Director Adrian Ferraretto had considerable experience in photovoltaic system design and installation, and he established Tindo to focus purely on manufacturing high quality panels.

The name Tindo means sun in the language of the Kaurna Warra people of the Adelaide plains where the factory is situated.

The factory is brand new and highly automated. If run continuously over a year the plant could manufacture panels with a total generating capacity of 60 MW. Adrian plans to mount a 100 kW system on the factory roof and has a 30 kW system on his own home.

One point of different with the Tindo panels is that each comes with an onboard inverter. Tindo's Karra 250 panel generates 250 watts DC and incorporates a microinverter so the output of each panel is 240 volts AC.

↑ Unlike many overseas factories, the Tindo factory is mostly automated.

In a grid-interactive system using conventional panels, the panels generate direct current and are connected in a series or series-parallel array to a single inverter. In such an arrangement, the panels must be closely matched in output. The array's overall performance is limited to that of the lowest performing panel. This means that if enough panels are shaded such that the array's output voltage falls below the inverter's minimum input voltage, the array's output will be zero.

AC panels that generate 240 VAC via onboard inverters and are connected in parallel aren't limited to the weakest link. The total array output will be the combined power output from all panels. A maximum power point tracker in each microinverter maintains its panel output at its optimum efficiency as the radiation level and load vary.

The AC array can be expanded by connecting extra panels in parallel with existing units. No matter how many panels are connected, the maximum voltage involved will be 240 VAC.

The AC panels can also communicate with a web-based system which allows owners to monitor the performance of each individual panel using a PC or smart phone.

Making the panels

The Tindo plant manages all stages involved in panel assembly. Prior to this are several specialised processes to manufacture the cells themselves. This usually begins with the purification of silica or other silicon compounds, and may involve forming silicon into ingots, cutting it into wafers and conversion into cells.

The Tindo process begins with the arrival of rectangular cells in boxes of 100 from Korean manufacturer STX. Each cell is 0.18 mm thick and has an efficiency of 17.4%. Selecting cells of this precise efficiency means that the total

↑ Once the panels are partially assembled they go through the electroluminescence tester to check for defects.

power output of each panel remains within its specification of 250 watts DC.

At the beginning of each shift the soldering machine's performance is checked by constructing a test string of cells. A known tensile force is then applied in an attempt to pull the string apart. The machine cannot begin normal service unless the soldered joints can withstand this force.

In the first stage of production, 10 cells are placed in line, ribbon conductors are soldered onto their backplanes and the cells are connected together to form a string. Robots then align the cells about their X and Y axes in the string and trim the ribbon conductors to length. After trimming, six strings are laid out side by side and bus strips are soldered at the tops and bottoms to create a series group of 60 cells.

Next, a multi-layer sandwich is laid up. Into the sandwich goes a sheet of low iron glass, a film of ethylene vinyl acetate (EVA) encapsulant, the group of 60 cells, another film of EVA and then a PET-Tedlar backsheet.

"Tindo's highly automated environment needs just eight people."

Before bonding the layers together, the sandwich undergoes quality control to reveal any micro cracking. A current of 10 amps at 40 volts is passed through the cells. Any micro cracks that are not visible to the naked eye now display as bright spots under X-ray electroluminescence testing. Any faults are repaired and re-tested.

After this check, the sandwich is transferred to an oven in which it is heated and physically compressed under total vacuum. This melts the encapsulant, bonds the layers together and removes any air bubbles.

Another quality control stage then visually checks for cracked, discoloured or misaligned cells and for foreign bodies and air bubbles in the encapsulant. Once the unit has passed this check, a barcode is attached so it can be tracked through the rest of manufacturing and after delivery.

The framing process then begins with the trimming machine cutting excess EVA and backsheet from around the laminated sandwich. After trimming, the sandwich is mounted into an extruded aluminium frame, and secured and weatherproofed with silicone sealant.

The final check of quality and performance is a 1000 watt/m^2 flash test to ensure the panel generates its specified output.

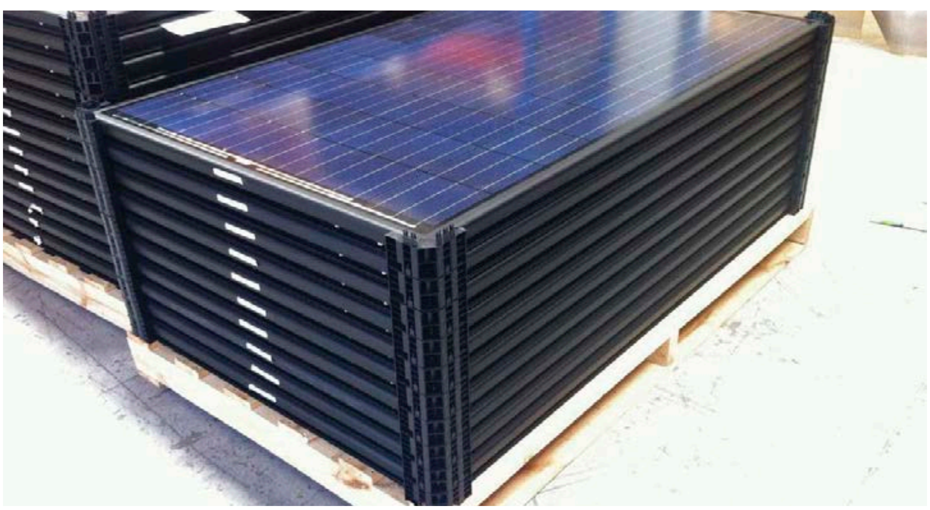
The final stage is to fix the microinverter onto the rear of the panel.

Company focus

Tindo is the only manufacturer of solar PV panels in Australia and is currently focusing on the local, rather than the export, market.

Tindo's philosophy runs counter to the notion that Australian manufacturers cannot compete with imported solar panels. Adrian Ferraretto accepts that Tindo could not compete if they manufactured using the manual methods of low labour cost countries.

However, Tindo's highly automated approach means that its total cost of labour is less than that of a typical more manual factory. A manually intensive system might require around 100 people, whereas Tindo's highly automated environment needs just eight. ✷



↑ The end result is a 250 watt solar panel that looks like any regular DC panel from the front but is a self-contained mains electricity generator.

Solar in China
Manufacturing on a grand scale

Peter Reefman recently took a trip to China to talk to a number of solar power system manufacturers. He gives us some of the highlights.

IN October 2012 I visited China to meet with several companies about potentially supplying a key new solar photovoltaic product into the Australian market: a grid-connected system with energy storage. What that means in a nutshell is a hybrid between off-grid and on-grid systems, set up to store surplus energy rather than selling to the grid at a low feed-in tariff but, on the other hand, to use the grid for needs that go outside the solar/battery power capability.

I had another hat to wear, as a renewable energy advocate passionate about doing what I can to help mitigate climate change. Plus I was excited to play some kind of role in helping the Chinese solar manufacturing industry, as I see it as integral to providing affordable renewable energy to people all over the world.

Below is a very abbreviated version of my full travel blog, which can be read at www.energised.com.au.

↑ Some solar factories are more like cities than factories. This company employs 180,000 people, with 40,000 just at this one factory, and has built its own 1 megawatt solar installation for panel testing!

Shenzhen, Monday 22 October

The company I visited this afternoon was, in a word, amazing. The company representative almost immediately understood why I would want a system like a grid/battery solar hybrid and felt it would be very good for her company to develop. Great!

I had a brief and easy meeting with the heads of product development. The representative explained to them in Chinese what I wanted and they all nodded in agreement that what I was proposing was something they wanted and needed to do. They seemed genuinely grateful to be given a look into the Australian market complete with a discussion of rebates, politics, etc.

The head also 'got it' from a technical perspective and said it would be a simple redevelopment of an existing off-grid product rather than a whole new product. He asked when we needed them by. I said it would be good to see something by the first quarter of next year. He scoffed and said he'd have an approved 'all in one box' system for us ready to ship from China within a month. Wow! By the way, the company had a fully independent testing and accreditation facility within their complex. This enabled them to have products accredited to European standards almost simultaneously while they were being developed. Australian standards would have to come later but it seemed that was not an issue.

We then did a detailed tour of the complex. Wow again! From the surgical computer circuit-board room, to the vast floors of general production it really was quite amazing. The only thing that seemed to be an issue was the lift which refused to work. We took the stairs ...

All up I really liked this company and hope they can produce a hybrid system for a price that's feasible in the Australian market. I think they can.

Shenzhen, Tuesday 23 October

After an hour's drive in today's company's fully electric van (made by them!), we arrived in the middle of a Shenzhen satellite city.

The drive itself was a jaw-dropping trip along the very hilly lush green coast of Goungdong on a wide freeway that literally cut through

Know your renewables
Battery basics

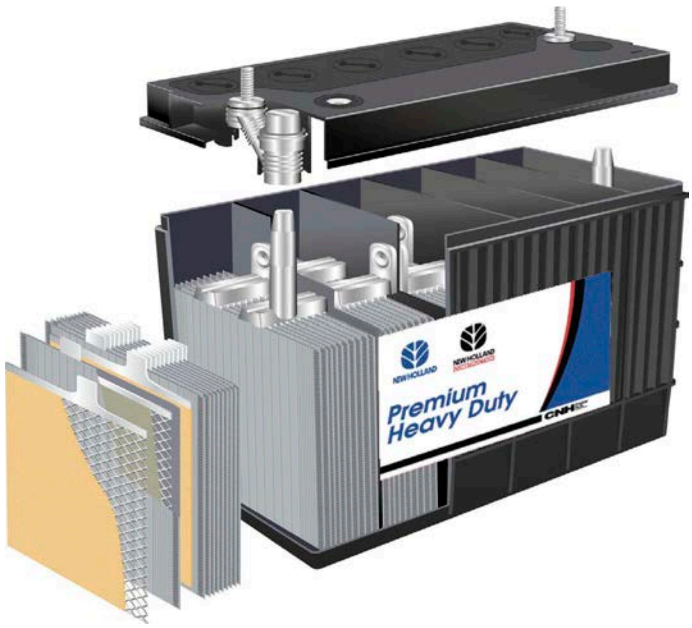
We all use them, but what do you really know about batteries? Lance Turner takes a quick look inside.

BATTERIES are used everywhere, from powering electronic devices to vehicles and even homes. But how much do you know about these devices?

Batteries are used to store energy and they do this using chemical reactions. When you discharge a battery, a chemical reaction takes place. For what's called a primary battery, when the battery is flat, that's it: you have to throw it away (or better, recycle it).

Secondary cells, which are the focus of this article, are rechargeable. When you recharge them, the chemical reaction that occurs during discharging is reversed, so that the battery is ready for reuse when charging is complete.

Because they are so common, and are still the mainstay of renewable energy systems, we look at what happens inside a lead-acid battery.



→ A typical lead-acid battery. Note the multiple plates and separators, and the six individual 2 volt cells that make up the 12 volt battery.

Structure

First, let's look at the physical components of a battery. There are two terms that are similar, but not interchangeable—battery and cell. A cell is the simplest chemical unit for a particular battery chemistry and a battery comprises a collection of cells. For a lead-acid battery, a single cell has a terminal voltage of around 2 volts. So, a 12 volt lead-acid battery actually has six cells. That's why there are six plugs on the top of many lead-acid batteries. Many people refer to single cells, such as an AA torch cell, as a battery, and it has become common usage, but in reality, they are cells.

Inside any basic cell you have three main components: a positive electrode, called a cathode; a negative electrode, called an anode; and an electrolyte. The electrolyte is a liquid or similar material that allows electrons (electricity is simply a flow of electrons) to move around inside the cell from one electrode to the other. Figure 1 shows the basic concept behind a cell. In batteries, the electrodes are commonly known as plates.

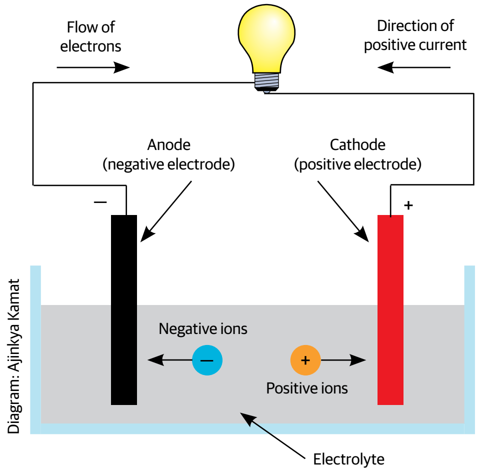
There will usually be other components inside a cell or battery. For instance, the plates usually have insulating separators between them to provide robustness and reduce the chance of shorts between the plates. There is usually more than one of each plate type in a cell—to provide sufficient surface area and plate material to generate high currents when needed—and plates of the same type are then joined by linking bars to effectively make one large plate. There are also risers to take the connection from the plates to the outside world and, of course, there is the case holding it all together.

In the most common type of lead-acid batteries, called flooded cells, the plates are immersed in a bath of liquid electrolyte, with a reserve of electrolyte above the plates. In gel cells, the electrolyte is a gel rather than a liquid. In absorbent glass mat (AGM) batteries, the liquid electrolyte is soaked into the fibreglass separators so there is no free liquid acid in the cells.

The chemical process

A charged lead-acid battery has the following basic internals. The positive plate is made of a lead support structure with lead-oxide (PbO_2) pasted onto or into it. The lead oxide is the active component of the positive plate. The negative plate is made from lead (Pb). The electrolyte is sulphuric acid (H_2SO_4).

During discharging, both plates are converted to lead sulphate and the electrolyte loses most



↑ Figure 1: A simple cell.

of its sulphuric acid content and becomes mostly water. When recharged, the plates are returned to their original compositions.

One useful side effect of the electrolyte changing composition is that it also changes density. By using a simple device called a hydrometer, which contains a graduated and carefully weighted float inside a glass tube, the density of the electrolyte, and therefore the state of charge, is easily checked, at least in flooded cells.

Battery voltage

Cells and batteries come in different voltages, depending on the number of cells and the battery chemistry. Different chemistries have different voltages. For example, lead-acid cells are around 2 volts each, whereas lithium cells are between 3.2 and 3.7 volts, depending on the type of lithium cell (there are numerous lithium-based cell chemistries).

The voltage of each cell is the 'nominal' voltage, but the actual voltage of each cell, and hence battery, varies, depending on the state of charge as well as whether the battery is being charged or discharged. For example, a 12 volt lead-acid battery will actually range from around 10.5 volts for a completely flat battery through to 15 volts or so for one being fully charged at the peak of the charging cycle.

Depending on the type of battery, charging systems will use a number of different charging rates to ensure each cell of the battery is fully charged during each cycle. This is to ensure small differences in capacity don't cause some cells to be overcharged and some to be undercharged.

For lead-acid batteries, a battery can be fully charged by the external source, without individual charging of each cell. For lithium batteries, each cell must be 'balance' charged to make sure all cells are fully charged without overcharging any of them. Charging systems called a BMS (battery management system) are used for lithium batteries to ensure this. Sometimes they are built into the battery, and sometimes they are external, but they are always neccessary if the battery is to last as long as possible.

"Cells and batteries come in different voltages, depending on the number of cells and the battery chemistry. Different chemistries have different voltages."

Storage capacity

How much energy a battery can store is called its capacity. This can be expressed in a number of different ways, but for deep-cycle batteries (batteries that can be deeply discharged without damage) it's usually stated in amp-hours. This means that the battery can produce a certain amount of current for a certain number of hours. For example, a 120 amp-hour (Ah) battery might produce 12 amps for 10 hours. This would mean it is rated at the C10 rate (also known as the C/10 rate)—it is discharged at a rate so that it will be flat after that period of time.

You might think that a 120 Ah battery that can produce 12 amps for 10 hours would produce 1 amp for 120 hours. Not so, at least not with lead-

Battery installation and maintenance

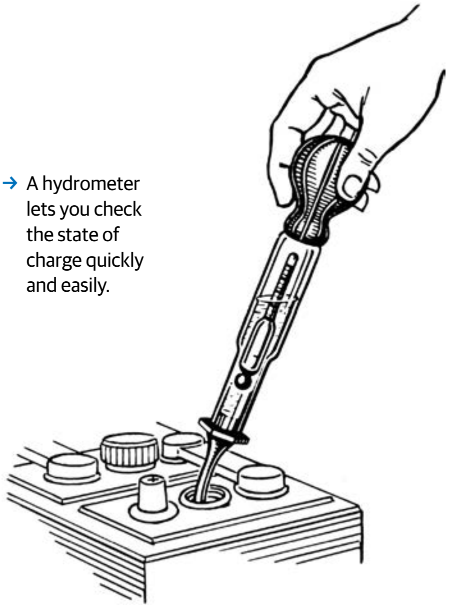
Regardless of the type of battery you choose, it must have a good home and be well looked after if it is to have a full lifespan.

In renewable energy systems, the battery is usually housed in a "battery shed", inside a box to protect it from little accidents, such as tools being dropped across terminals. A flooded lead-acid battery, which can generate explosive hydrogen while recharging, is normally housed in a sealed box that is vented to the outside. Fully and partially sealed batteries should still be housed in a box for safety and protection.

Batteries should never be placed on a concrete floor, but rather on wood or plastic bearers for thermal insulation. If flooded-cell lead-acid batteries are located in their own shed or similar enclosure and are not in a sealed box then the shed must be vented and electrical equipment should not be installed inside the same shed, otherwise a spark from the equipment may trigger a hydrogen explosion.

Maintenance ranges from a monthly check for terminal tightness with sealed batteries through to regular checking of electrolyte levels, cleaning off any acid accumulation and checking specific gravities with flooded cell batteries. A well maintained battery bank will generally live longer than a neglected one, so an hour or so a month is a good investment.

→ A hydrometer lets you check the state of charge quickly and easily.



Insights into using lithium batteries

Gordon Garradd explains his lithium RAPS setup and gives us some insight into designing a system using lithium batteries.

WITH lithium batteries slowly appearing in off-grid renewable energy systems, sizing calculations need to be reconsidered. For instance, a lithium bank can generally be more deeply cycled than a wet lead-acid bank and so, if multiple energy sources are available and many day's backup capacity is not needed, battery banks can be sized smaller, reducing cost.

My system is an example of a lithium battery-based renewable energy system. The system comprises:

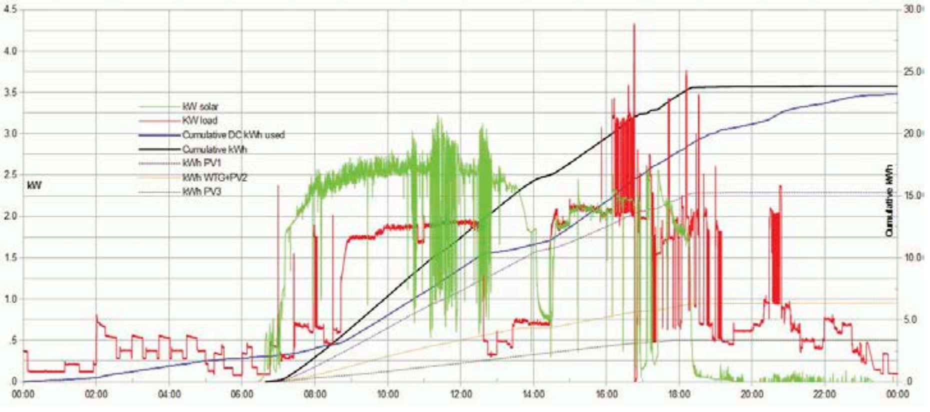
- 3.5kW of tracked panels connected to two Outback FM80 charge controllers (PV1 and PV3 on the graph)
- 900W of PV panels and a Chinese 200W wind turbine generator (PV2 and WTG on the graph) connected to a BlueSky SB50 charge controller
- Sixteen 400AH CALB $LiFePO_4$ cells arranged as eight pairs to give 800AH at 26V, giving about 21kWh of storage. Cost around $9000.
- Latronics LS4024 inverter.

The wind turbine doesn't produce a lot of energy here, due to very low annual average wind speeds, but it did peak at 450W output in a recent storm.

Gordon's battery bank is rated at around 21kWh. On some days he uses more energy than the bank's capacity due to the high input from the charging sources. Note that it would normally have a cover over the terminals for safety.

The battery voltage is fairly constant overnight, and generally stays over 26.5V. I ran the batteries down to about 75% DOD in the few days of tropical cyclone Oswald passing over, and the voltage only just got down to 26.0V on the third overcast morning under a bit of load.

Data for the system is logged at one second intervals for voltage, three charging inputs and load. A number of graphs are prepared each day to keep a close eye on the system. The graph below is an example of one day's logging showing gross production and use.



This complex looking graph gives a great deal of information about system performance on one day. Note the consistent solar input, except for a few cloudy periods, and the considerable peaks in load of over 4kW. Total DC energy used is more than the battery bank capacity!

We use various high power (2.4kW) power tools, saws, etc on the system, and I also do a fair bit of MIG welding, which is easily handled by the inverter and batteries.

Actual AC energy used tends to average about 85% or a bit more of the DC energy, representing overall inverter efficiency over a wide range of loads. I have determined that the overall charging efficiency with the $LiFePO_4$s is equal to the gross charging multiplied by a factor of 0.93.

I'm also in the middle of constructing a pumped storage hydroelectric system for a few kilowatt-hours of non-battery energy storage to reduce any generator use. I've got 24,000 litres of storage in two tanks at 85 metres of head, which will be run down to turbines to produce power.

The graph shows just how small the battery bank capacity is compared to the daily loads. On this day we used more than the total capacity of the batteries, which is about 21kWh. We can do this because most of the energy is being generated at the same time that it's being used, so the batteries are barely or not at all discharged by this energy use. If most of our energy use was at night then battery cycling would be quite deep and a larger battery bank would most likely be needed. ✱