

From earth, cans and tyres

Earthship Ironbank



It's taken a few years, but Australia's first permitted earthship is almost ready to set sail in its new life as B&B accommodation, and as a living laboratory. Owner-builder Martin Freney describes the voyage so far.

IT'S BEEN three years since I first wrote in *ReNew* about my earthship research and my own building project in Ironbank, in the Adelaide Hills. In that time, I've completed my PhD looking at the environmental impacts of earthships compared to other forms of building and living, and Earthship Ironbank is almost finished.

The exciting news is that Earthship Ironbank has become the first permitted earthship in Australia, with planning approval granted three months after submission (the only design tweaks needed were the addition of exit lights and outward opening doors, as these are required for a B&B) and building approval granted in six weeks.

The one thing I couldn't get approved was the wastewater system, which includes irrigating food with greywater and flushing the toilet with biologically treated greywater. The greywater system was constructed but not commissioned—this will be done at a later date if I can influence the laws on this to be changed (fingers crossed).

I enlisted a crack energy assessor who knew how to convince the ratings software to predict the performance of a home with earth tubes, a greenhouse and many tonnes of earth piled up around its earth-filled tyre walls. The result was a 6.3 Star rating, but in reality I believe the home will be 9 or 10 Stars and I'm going to try to prove it...

A living laboratory

I intend the earthship to be a living laboratory yielding new knowledge about sustainable housing. It's going to be a B&B, giving me the opportunity to survey the many different occupants about living off-grid, with questions



↑ Martin's almost-completed earthship in Ironbank, in the Adelaide Hills, South Australia. The design is based on the Simple Survival Model, adapted for use in Adelaide's warmer climate. The north-facing greenhouse sits in front of the main room which serves as bedroom, living area and kitchenette. An airlock entry room is at the east end of the greenhouse, and a bathroom at the west.

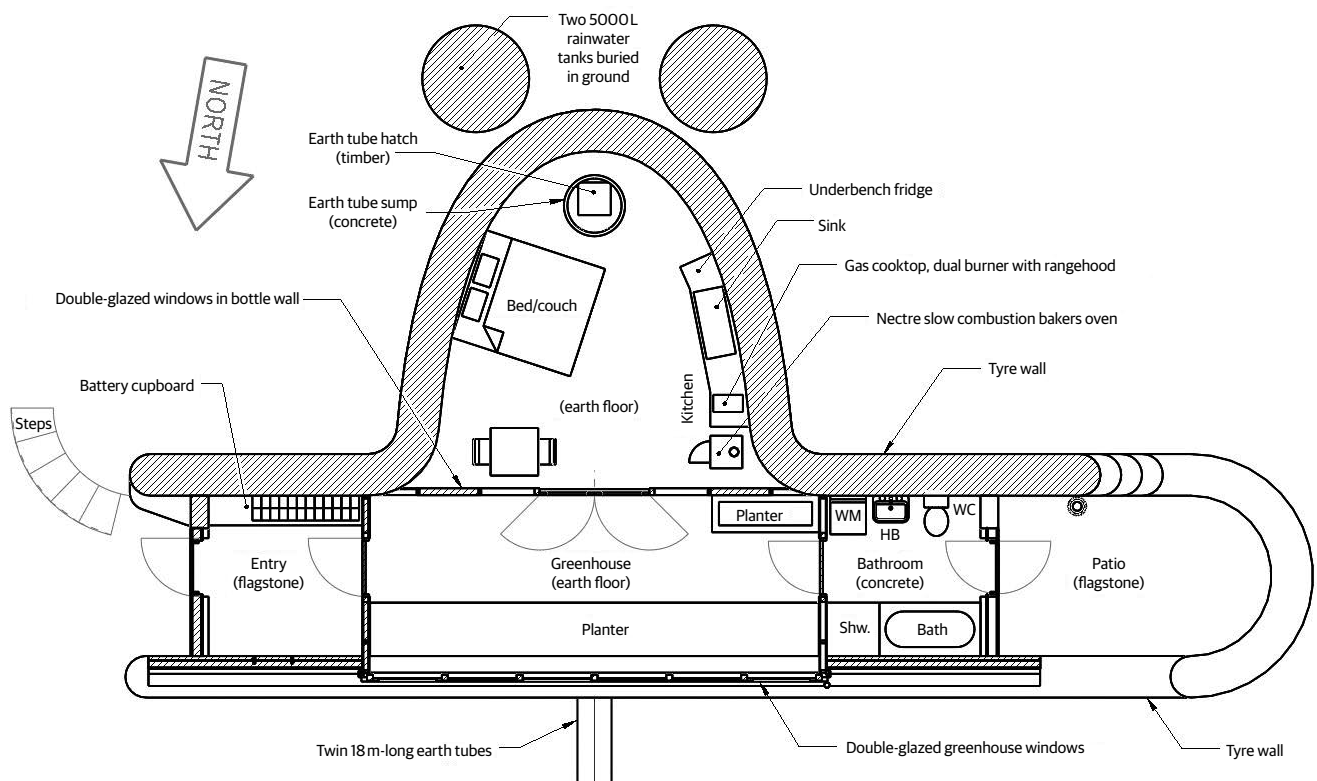
such as—was it comfortable, were they concerned about running out of power or water, did they have to change their behaviour and what would be needed to get them to commit to their own off-grid eco-change?

It's also wired up to collect data. It has temperature sensors buried in the roof, in the berm, under the main floor and under the greenhouse floor to provide a better understanding of how heat flows through tyre walls and earth-bermed structures in general. These will also let me check the energy rating.

Adelaide climate tweaks

There were some design changes I made to

adapt the earthship design to the Adelaide Hills in climate zone 6 (mild temperate), a very different climate zone to Taos, New Mexico, where the earthship design evolved. Taos has extremely cold winters (-20°C) and, compared to Adelaide, mild summers (35°C maximum), with summer nights usually below 20°C. In Adelaide we often suffer from very warm nights when it's impossible to use cool night-time air to cool our homes by opening windows. We also have overcast winters, whereas in Taos they are blessed with abundant winter sunshine, essential to passive solar functioning in the otherwise bitterly cold conditions. The winter sunshine



↑ The earthship's layout is quite simple, with very little wasted space.

also means they can use relatively small PV arrays and battery banks.

To allow for this, I increased the area of north-facing roof so that I could fit a larger solar PV system as well as a solar hot water service (24 evacuated tubes, close-coupled with the roof-mounted tank). With a 24 V, 600 Ah battery bank and 65% DOD, this gives almost three days of autonomy for my predicted usage of 3 kWh per day. The roof also incorporates two double-glazed operable skylights to regulate hot air venting out the greenhouse roof (similar to Reynolds' roof vent boxes, but more elegant to my mind). I may install internal blinds to block summer sun, but I am anticipating that it will be important that the greenhouse heats up sufficiently to cause a natural thermal convection cycle to draw air through the earth tubes for natural cooling.

Many earthships feature angled glazing which minimise heat loss and maximise heat gain. Double glazing is quite expensive (I paid about \$220/m² for argon-filled 5/10/5 double-glazed units, installed) and angling it to maximise winter solar gain means you need less glass for the same winter performance, thus saving money. However, angled glazing could lead to excessive heat gain in Adelaide's

harsh summer sun as well as complexity in construction: it may void the warranty as it can tend to sag and be more prone to breakage.

My approach was to try a bit of everything: I have a small area of angled glazing (the skylights) which can be easily shaded if necessary. These let winter sunlight deep into the main room to warm the thermal mass floor and walls. I have also made provision for a shade structure, with roof beams extending past the glazing to be used to train deciduous vines on high-tensile wires.

What is an earthship?

The invention of US architect Michael Reynolds, an earthship includes passive heating and cooling, natural and recycled or reused construction materials, off-grid renewable energy, rainwater collection, on-site wastewater treatment/recycling using biological methods, and food production, generally using wastewater.

The overall aim is to create a highly self-sufficient home that provides its own services so that it is not reliant on the polluting infrastructure that conventional homes rely upon. It should passively provide comfortable indoor temperatures and aim to

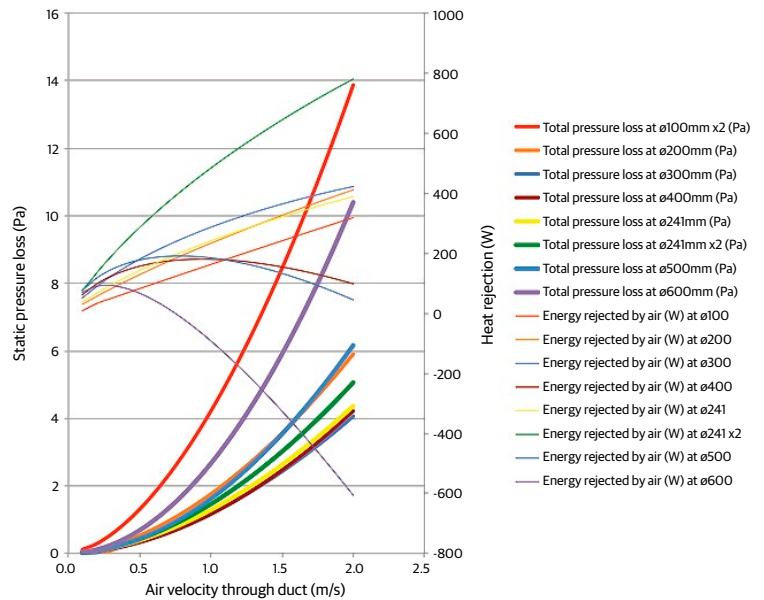
Earth tube cooling

I had the good fortune to meet Alex Swanson, a natural ventilation engineer, who was keen to get involved with the design of the earth tubes. I did some basic energy modelling to estimate the summer cooling load and Alex calculated the earth tube parameters to provide adequate cooling. He investigated a range of diameters of PVC earth tubes, ending up with a design for two 240 mm-diameter tubes each 18 metres long, buried at a depth of one to two metres at the deepest point, and

use low embodied energy materials.

Furthermore it aims to be affordable. Reynolds claims that an earthship costs about the same as a conventional home to build yet the savings on electricity, water and sewage bills over the earthship's lifetime are substantial. Owners need a savings plan to replace system components such as batteries, but this should be more economical than paying for the same services from the grid. Another key principle is that it uses simple construction methods which enable the owner (plus friends and family) to get involved in the construction of their home.

Pressure loss and heat rejected versus duct air velocity
(ambient air 35°C, internal air 26°C)



→ This graph models various tube diameters and the heat rejected by earth tubes. The thin lines show the amount of cooling (large positive values are good) and the thick lines show the drag or friction caused by the pipe diameters and air flow rate.

both feeding into the main room.

A typical Earthship Biotope earth tube is made of 250 mm diameter corrugated galvanised steel and is about 7 m long, with just one per room. My design changes were aimed at addressing Adelaide's very hot summers and overcoming some problems I anticipated with other materials. Although PVC pipe is not a very eco material and not a good conductor of heat, it should have a long

life, its smooth walls will be easy to clean and other Australian systems have reported good performance with PVC pipe. [Ed note: Earth tube systems must be designed to prevent mould growth and moisture buildup. They should also be easy to clean if needed. For more information on basic earth tube design requirements see www.bit.ly/1Ny9YDd and www.thenaturalhome.com/earthtube.php.]

The longer length of tube is important to

enable sufficient surface area and time for heat exchange to occur. The rate at which the air is drawn through the tube is also critical: too fast and the air doesn't have time to cool down; too slow and you don't get enough cool air into your building. The longer the pipe the greater the drag, so small diameter pipes may 'jam' (stop the airflow) if they are too long.

I have also incorporated a small sump where the earth tubes enter the building. This may serve as a mini cellar for storing wine and perishables but can also house an earthenware pot filled with water for evaporative cooling, ideal for the dry (low humidity) Adelaide summers. The sump has a water outlet for filling the pot and an electricity outlet to power a fan to enable air to be sucked into the earthship if it is cooler at night. The fan might also be useful if the greenhouse fails to perform its natural convection cycle overnight.

Other building changes

As the earthship is going to be a B&B, I decided to provide backup heating for prolonged overcast winter weather. A small wood stove in the kitchen provides both heating and cooking. It also provides backup for the solar hot water system via a water jacket (wetback/boiler).

All timber is termite-resistant as this seemed the most practical way to deal with the termite issue, something they don't have in Taos.



← The tyre pounding process starts by ensuring the tyre is fairly level. You add a layer of cardboard (beer carton is a good size) in the bottom of the tyre and half fill it with earth, which can be sandy, clayey, gravelly or recycled concrete rubble as the tyre provides the structural integrity. You then compact the first layer of fill using a tamping device such as a sledge hammer. Stomping with your boots also works for this layer! You then gradually add two or three more layers of fill to make it easier to compact fill under the rim of the tyre, a process that requires an angled, sideways swing of the sledge hammer, well aimed to just miss the tyre rim. This levels the top (it doesn't have to be perfect). Finally the tyre is adjusted sideways (in/out of the wall) to ensure it has the right 'batter' (slope/angle) to resist the tipping forces of the berm, or in some cases the tyre wall might be built plumb. We corrected the (anti) batter of one of my walls with a gentle yet persuasive nudge from a backhoe bucket!

Exposed timber also had to be bushfire resistant. The site was assessed as being BAL 19, so it was important that the design respond to the bushfire threat. A green roof over the main room has a 150mm thick gravel layer which will be planted with fire-resistant, succulent ground covers. The greenhouse roof is corrugated iron, and lime or cement-based renders cover the rest of the earthship; tests by EcoFlex Pty Ltd, a NSW-based civil engineering company, demonstrate that so long as tyres (used as a wall material, see below) are protected by render they are not a bushfire hazard. The main weak points are the double-glazed windows on the greenhouse. I am going to protect these with butterfly sprinklers (also designed to wet down the corrugated iron roof) powered by the earthship's tank water supply and electric pump. This is electric to avoid the need to deal with explosive fuel in a bushfire and is more suitable for automation.

Tyres as a wall material

Approximately 800 tyres were reused in the construction of the earthship and another 300 for the fire-fighting rainwater tank. Reusing tyres as a wall construction material has many advantages: they are free and they enable you to use another low-cost material—earth—to make your walls. Also, they are typically shipped off to Asia (millions per year from Australia alone) and burnt in waste-to-



↑ Xiang and Agua creating the cob wall sculpture.

energy plants, releasing toxic particles into the atmosphere, so I think it is a better solution for this problematic waste material. The question of leaching or off-gassing of toxins from the tyres is often raised, but my research indicates that the risk from an earthship is low, as the tyres are isolated from water, air and extreme heat (see more about this online).

I contacted my local council and the EPA to check whether they had any issues with the use of tyres. There are rules in South Australia about how many tyres you can handle per annum (500) and there are guidelines about how to store them to avoid issues with rats and mosquitoes breeding in them and how to manage the fire hazard. I also found that, as I had council approval for my project, I could have had a limited licence, at a cost of \$800, to 'dispose' of a certain number of tyres in the construction of the earthship.

As I had already substantially completed my tyre wall, however, this is something for next time. Many tyre retailers were willing to pay about \$1 per tyre for me to take the tyres, so long as the EPA approval was in place.

Finding the right-sized tyres at times proved challenging. You can use just about any car tyre for an earthship wall but it's easiest if all the tyres are a similar size. I tried to get the retailers to put aside the sizes I was after, but I often ended up having to dismantle huge piles of tyres to get at the ones I wanted.

In the end, I tracked down where most used tyres were being taken—a facility that shredded thousands of tyres every day to be packed into shipping containers bound for Asian waste-to-energy plants—and found this to be a brilliant source; they would put aside a huge, neatly stacked pile of my favourite-sized tyres for me to load into my ute/trailer. So good!

Tyres are such a versatile building material. Usually we just used them whole, putting some scrap cardboard (another reused material) in the bottom to prevent the earth from falling out the hole, but occasionally we cut them using a reciprocating saw to make half tyres, useful for the end of a wall. We also tried cutting out the upper side wall—tyre pounding is much easier with the side wall removed—but even though it only takes less than a minute to cut out the side wall, we felt that a whole tyre results in a better rubber-to-rubber connection between courses of tyres and therefore a more 'bomber' (earthship-speak for superior!) result.

The majority of fill for the tyres came from



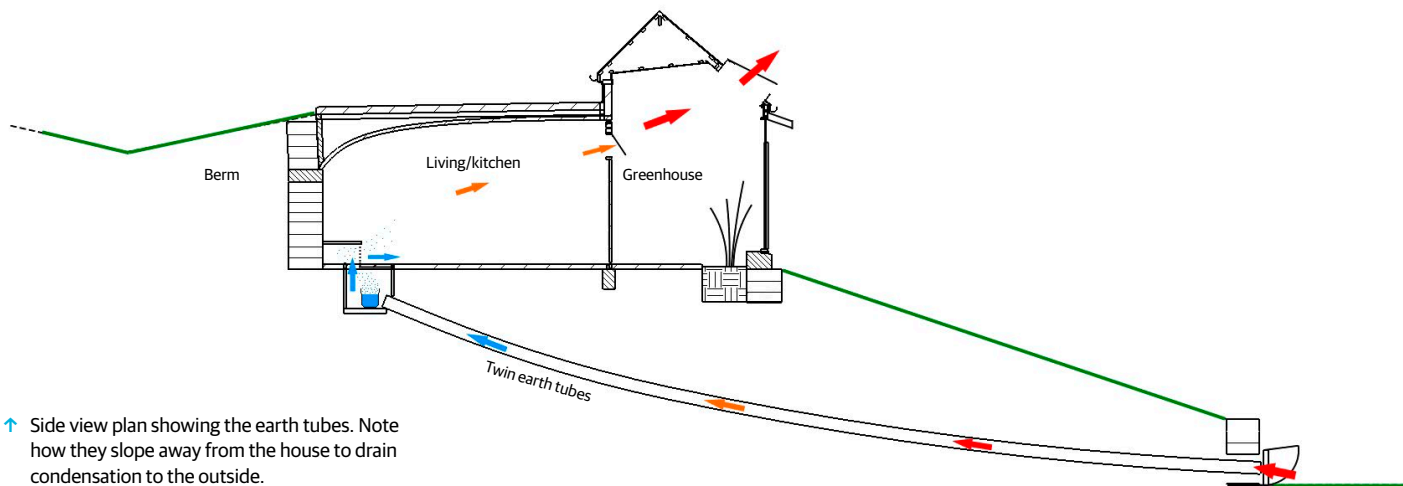
↑ Growing in the greenhouse is an array of amazing fruits and vegetables: bananas, kale, tomatoes, lemongrass, rosemary, mint, passionfruit, broccoli, lettuce, basil, eggplant, guava, chives and more!

the initial excavation of the site. Very high in clay content, this was also used for adobe render and cob. We sourced some additional fill for backfilling the tyre wall via a 'clean fill wanted' sign at the end of the driveway.

A shortage of bottles and cans!

An unusual challenge building an earthship in South Australia was sourcing beverage containers for the bottle and can walls that are typical of earthships. In South Australia, beverage containers have a 10 cent deposit so they can be hard to come by. All the wonderful people who came to help build the earthship did an excellent job 'making' empty beverage containers, but we fell short of what we needed and had to buy empty cans! The recyclers weren't licensed to sell us cans (they thought we were mad), but in the end we found one who was willing to do this.

We tried various methods to cut the bottles including bottle cutters, flaming string and thermal shock, but found that the Earthship Biotope method of a wet tile saw was the quickest and most reliable, although the downside was the noise, mess from glass shards and danger. We cut off the neck of the bottle to the right dimension to suit the bottle wall, washed the bottle and, when dry, used duct tape to join the bottoms of two bottles together, sometimes mixing colours to get an interesting new colour. Many of the bottle



↑ Side view plan showing the earth tubes. Note how they slope away from the house to drain condensation to the outside.

necks were recycled in the concrete bathroom floor as aggregate, replacing much of the gravel we would have otherwise used, but some were recycled, reluctantly accepted by the bottle recycler because we had not thought to separate the different colours of glass.

Many hands, many friends

The earthship was built in a series of workshops of about 20 weeks total duration. Most of the workshop participants had little building experience, which is quite typical of those involved in earthship construction, as it involves simple, easily learnt (though labour-intensive) construction methods, such as tyre pounding and rendering. The builders came from all over Australia and the world: from Canada, New Zealand, Taiwan, Italy, America, France, UK, Germany, Singapore and more.

Many camped on site. This led to wonderful friendships and information exchange on the construction site and around the campfire. Although there was a substantial carbon footprint arising from all the interstate and international travel, balancing that was a growth in ecological awareness, new skills and ideas about living sustainably, which shouldn't be discounted.

It was occasionally a bit stressful taking care of all these people, but in fact they were very self-sufficient and looked after themselves wonderfully well. I took out a public liability insurance policy which somewhat eased my anxiety, but thankfully there were no serious injuries on the construction site.

Sometimes over-enthusiasm and lack of experience meant a lower quality of

workmanship and we had to redo things, but this didn't happen very often. We re-did part of a tyre wall and also one bottle wall to ensure they passed muster, but the amazing instructors, whom I hired with the funds raised from the workshops, taught the participants well. Some of the participants were even tradies, who were an absolute blessing, rocking up with a ute-load of tools and a brain-full of know-how.

The final accounting

Currently the building is at lock-up stage with many of the internal finishes complete. There is still the bathroom to complete and a kitchen to build. This last stage is going slowly, as I'm only able to dedicate about a day a week to it, but it has been a great opportunity to spend time with my dad who is a great problem-solver and amateur builder. He often helps me on weekends, hanging doors, installing the extra-low-voltage DC lights, sanding, painting, etc.

Everyone asks how much it has cost. I estimate the final cost will be approximately \$150,000, including the solar panels and batteries, rainwater tanks (three 5000L poly tanks and one 40,000L tyre tank), greywater system, septic system, pump—things that grid-connected houses don't need to factor into the budget. Of that, around \$16,000 was for the renewable energy system of 1kW PV array, 600 Ah 24V sealed lead-acid battery bank and 3kW SP-Pro inverter.

That equates to about \$2000 per square metre, which is fairly typical of a bespoke house design, although it should be noted

that most of the labour for tyre pounding and rendering was free, via workshops. The cost is comparable to what Reynolds quotes for this Global Model Earthship design (US\$200/sq ft). With the benefit of hindsight I'm sure I could reduce the cost. *

Martin recently launched Earthship Eco Homes (www.earthshipcohomes.com.au), a sustainable design consultancy aimed at helping people with their earthship-inspired projects. He also lectures in sustainable design and product design in the School of Art, Architecture and Design at the University of South Australia. Earthship Ironbank B&B will be open for business early in 2016 and there will be ongoing open days and workshops. See www.earthshipironbank.com.au for details.

ReNew 122 covered Martin's research and initial design approach, with some of that information available online. See renew.org.au/wp-content/uploads/2012/12/Earthships-downunder.pdf.

See www.renew.org.au for more articles on Martin's PhD research and the approvals process for the earthship.