Warm sun, cool house
Solar-powered evaporative cooling

Martin Chape describes how he put an old evaporative cooler to good use, automating the system in the process.

LAST year I promised myself that I was going to try and use the excess heat that my solar hot water system generates to cool my home. It was my intention to do this by extracting the heat from the hot water tank, either directly or with a heat exchanger replacing the redundant electric heating element, and use either an absorption or adsorption cooling process.

However, after one or two unsuccessful experiments, I put this idea aside for a while and instead decided on a much easier build: an evaporative cooler using solar PV to power it directly.

My plan was to source a discarded evaporative cooler rooftop box and replace the AC-powered fan and pump with 24 volt DC versions to be powered by a solar PV/battery system. I would also add a control system for monitoring and controlling the system remotely. Evaporative coolers are simple devices that draw air through wet absorbent pads. This cools the air through evaporation, and has the advantage of using a lot less energy than a refrigerated air conditioner. The main issue with using a second-hand unit is the cost of replacement pads, as they degrade over time and may become mouldy if unused for a while.

↑ The converted evaporative cooler is powered by two of the solar panels.

Step 1: sourcing the cooler rooftop box

I figured there ought to be plenty of those evaporative cooler rooftop boxes discarded after they wear out, break down or folks switch to other forms of air conditioning. I put the word out and within days my nephews had dropped off the parts for a Bonaire Brivis they'd found on the side of the road!

However, I ended up deciding to use a Bonaire Celair instead, which I bought for $50, as the Celair has thicker pads than the Brivis and the cost of pad replacement is lower.

Step 2: replacing the fan

I decided to source a fan used in the automotive industry, an 18 inch (457 mm) 24 volt DC fan, commonly used to cool the radiators of the big haul pack mining trucks.

The Celair's removable fan mount made modifying it easy. However, the original fan was larger (19 inches), so I got a plastics company to make me a spacer to close the gap at the outer edge of the blades.

Step 3: replacing the pump

I first considered using a bilge pump but found these are not warrantied to run continuously for the number of hours the system would need. Pond pumps were the next obvious contender as these can run 24/7 as long they're kept cool underwater. After mistakenly buying an AC (rather than DC) pump from a pond shop, I ended up sourcing a submersible 24 volt DC pump from China that would manage 20 litres per minute (the flow rate that Bonaire advised for the original pump, and that many of these pumps run at).

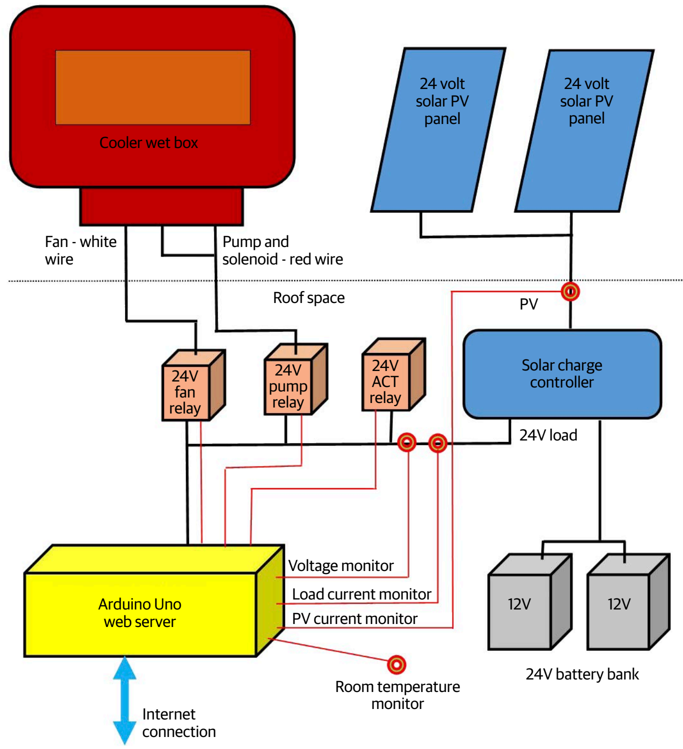
When it arrived I was particularly pleased as it included a speed controller which meant I could vary the flow rate, which would allow me to tweak the system for best performance. I wired it through a float switch so it cannot run unless the water chamber is full, to prevent any damage to the pump.

Step 4: solar/battery system design

The cooler load is 12.5 amps, so I chose two 250 watt 24 volt PV panels, each of which can deliver around 8 amps (their rated load current); wired in parallel, they can deliver a maximum of 16 amps when the sun is out.

The solar cooler uses an MPPT (maximum power point tracking) charge controller which can direct PV current to the batteries, the cooler or split between both. If you turn the cooler on while the PV panels are charging the batteries, the MPPT controller directs 12.5 amps to the cooler and the balance of 3.5 amps to continue to charge the batteries. If the cooler is off, then it sends all current down to the batteries. When there is no sun, the MPPT controller isolates the PV and sends all current to flow to the load terminals from the batteries.

I factored in enough battery capacity (55 amp-hours) to be able to run the cooler in the evening as the PV current drops off and even after dark for an hour or so. The batteries are protected by the MPPT controller; it shuts down the load terminals if a pre-determined battery voltage is reached indicating the batteries are running down.



→ The complete system schematic.

Step 5: sourcing solar panels

I have to thank Reg at wholesaler YHI Power in WA for supporting me by providing a pair of 24 volt, 250 watt PV panels at an excellent price. The cost of solar PV has dropped dramatically in recent years and the efficiency has also improved, which makes projects such as this much more feasible. For example, two years ago I paid $490 for a 24 volt, 200 watt PV panel capable of delivering a short-circuit current of just over 5 amps. Today, these 250 watt PV panels cost just $200 each and they are able to supply a short-circuit current of greater than 8 amps.

Each panel is wired back to a single-pole isolation switch inside the roofspace using solar MC4 connectors and 4 mm² cabling. Even the MC4 connectors are cheap these days, but for that some quality has been sacrificed. I had difficulty snapping some sockets and plugs together and ended up having to file them and replace the rubber O-rings.

Step 6: sourcing batteries

The 12 volt, 55 amp-hour batteries I chose came from the same local importer as the solar PV. I was again given a good price of $100 each as they were end-of-line stock. The batteries are low-maintenance sealed lead-acid deep-cycle units. I connected the two batteries in series to give 24 volts, and mounted them in plastic battery boxes from Boating Fishing Camping.

Step 7: sourcing the charge controller

Any solar setup that includes batteries needs some way of controlling the charge into the batteries so that they are not overcharged, which will damage them and shorten their lifespan, especially with sealed units. Charge controllers are also often called regulators.

As previously noted, I used a 30 amp MPPT controller, sourced from China through eBay. Including shipping, the price was under $50.

Step 8: the cooler control system

For the cooler monitor and control system I decided to use an Arduino Duemilanove microcomputer that I had in my junk box.

You can purchase Arduino micros from $12 to $45 in Australia depending where you shop, and for $5 in bulk from China. You don't need to use the Duemilanove; there are other Arduino boards, such as the Uno and its big brother the Mega [you can also buy an Arduino with on-board ethernet called the EtherTen from www.freetronics.com—Ed].

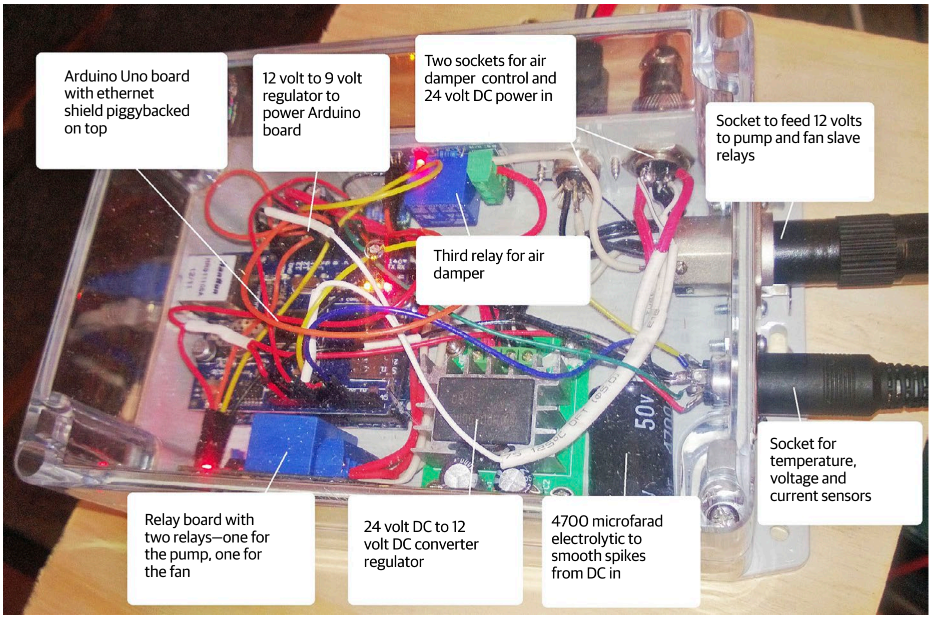
I had played with the Arduino before but all I'd made it do was flash an LED on and off. For this project, I wanted it to be able to monitor the temperature in the room(s) being cooled, provide that information across the internet and be able to turn the system on/off as well.

This part of the project entailed a steep learning curve. But, buoyed by the fact that I'd done some C++ programming early in my engineering career and that I was pretty fluent in HTML, I charged ahead. I should also thank Bill at www.artifactory.org.au who provided advice and encouragement.

I piggybacked an Ethernet board (around $8) on the Arduino board to enable internet connectivity so that I could use a smartphone to monitor the temperature in the house from anywhere, and switch the cooler on before I got home if needed. I set up the Arduino as a web server that serves a single web page to control the system. I used a web page rather than an app, as an app would have required different versions for Android, iOS and Windows.

It took me three tries but I eventually successfully created a web page with three buttons to control the system. 'Cool' turns on fan plus pump, 'Fan' turns on only the fan, and 'Off' turns everything off. The display shows the room temperature in the house, battery bank voltage and PV charge current. The web page works on my Windows 8 Nokia Lumia 920 handset but it may require tweaking for other OS phones, and will likely morph as the project runs on.

Arduino is open source. To get started go



↑ The Arduino controller box showing the various components.

Installation

Although my roof is getting quite crowded, I managed to find a couple of spots for the two solar panels close to the cooler wet box where they would not be shaded during the day. I built brackets to hold the ends of the panels up over the hip line of the roof.

I mounted the Celair wet box on a Polyaire plastic Drop-X box that goes through the corrugated iron roof. The Drop-X box comes complete with its own mount and flashing.

I fed the PV cables through the corrugated iron roof using cheap and simple plumbers' pipe collars.

Inside the roof

As yet, I haven't worked out how I will keep the electronics in the roof cool or even what needs to be kept cool. Most likely the Arduino box will need a fan as it must be enclosed to keep dust out. I am also thinking of gluing some polystyrene insulation to the corrugated iron to prevent direct radiated heat. The Arduino controller box and the battery bank are set down lower on the ceiling joists in the hope it will be cooler there in summer.

[Ed: Martin contacted us just before publication to say he is having problems with overheating of the Netduino on hot days. He is considering moving it out of the roof or changing to use a standard remote control. He says it's still been a useful learning experience with the Netduino.]

The Arduino box is a little crowded because I had to fit two voltage regulators. One drops the 24 volts DC from the battery bank down to 12 volts DC to run the slave relays; the small Arduino relays can't run the high current of the fan and pump. The other is a 12 volt to 9 volt regulator; although the Arduino board can run on voltages from 6 to 12 volts, it tends to overheat its internal regulator if run on voltages over 9 volts.

I had intended to use a popular fabric sock from Polyaire for distribution of the cooled air inside the roof space but ended up paying $165 to my favourite local sheet metalwork company, Air Quip, to make me a custom drop box with two 300mm spigots to connect to air ducting. I also insulated the box with polystyrene sheeting purchased from Clark Rubber. A movable flap inside the box directs air to my study or the bedroom and is controlled by a small Belimo actuator motor. Eventually, this will be controlled from the web page on the smartphone.

The solar PV is wired through an isolator switch to the MPPT charge controller mounted on a wooden board. Also included is a row of spade fuses, an ammeter to show the PV charge current and a voltmeter showing the battery bank voltage.

The box is designed so that it can be unplugged and brought downstairs to work on or reprogram the software. But I have also run a USB cable down into my study so that I can re-flash the code without having to climb into the roof.

to the Arduino website (www.arduino.cc) and download the software. The editor allows you to write code, then compile and bootload your program to the Arduino. To replicate this project you can go to www.bit.ly/SolarCooling and cut and paste the code for the Arduino sketch.

System under test

The system has been tested on the ground. It is now in/on the roof and has the first 300mm air duct connected to an air diffuser in my study. I have run the unit for test periods of several hours and found I had to put on warm clothes as it does work effectively! I am waiting for summer heat to conduct further tests.

Future improvements

I'm planning improvements including spark arrestor screens on the cooler's cellulose pads, a smoke detector inside the wet box to allow the Arduino to turn the pump on and the fan off should sparks from an outside fire ignite the cellulose pads, and a connection to a rainwater tank to try filtering and recycling the water. I am also looking into using rain or bore water to run the cooler.

Now that I am more Arduino-savvy, I also intend to build a new microcomputer control for my solar hot water system and another for my garden reticulation system.

I hope sharing this project inspires some to run out and replicate or improve on this idea. I believe this project helps deal with the waste stream of old coolers and that it may even help reduce the daytime peak electricity load generated by the air conditioners we don't seem to be able to do without these days. Perhaps companies like Bonaire, who have expressed an interest, may even one day offer a commercial version of this system. ✱

Find out more at Martin Chape's website: www.sustainabilitysolutions.net.au.

Safety first

This project has made me do a few other things around the house in relation to safety as my frequent need to climb on and in my roof space increases risk. I have attached some steps to the outside of the corrugated iron roof, installed pull-down loft steps to my manhole cover and added timber sheeting on the ceiling joists inside the roof space to mitigate the chance of me falling through. I can't stress enough the need for safety when you carry out this sort of project.

Solar cooling options

Solar cooling refers to any type of cooling system that uses solar energy, either directly or indirectly.

The simplest system uses an age-old technique based on the chimney effect. This system involves the use of a tower-like construct as part of the building. As the tower is warmed by the sun, the air in it rises up and out, pulling in air from inside the home. The air removed from the home is replaced by air from outside that is drawn through some form of cooling, such as a cool cellar or moist pads as used in an evaporative air conditioner.

Another approach is to include desiccants as part of an evaporative cooling system. The air to be cooled flows over the desiccant, which reduces the humidity of the air. The air is then cooled using conventional evaporation, which is more effective as the air has already been de-humidified. The desiccant is regenerated using solar heat; the absorbed moisture is driven off and it is then ready for reuse.

Active adsorption and absorption cooling systems use solar heat to drive an absorption cycle, much like the flame in a gas fridge causes the fridge to cool its contents. There are many designs and derivations of this approach.

You can also use PV panels for cooling. The electricity from the panels is used to operate air conditioners of various types, including evaporative or refrigerative units (such as common reverse-cycle air conditioners). This can be done either indirectly or directly.

In an indirect system, the output of the PVs feeds the mains grid and the air conditioner is set to run at the same time as maximum generation is occurring. Alternatively, the PVs can charge a battery bank which is used to run the air conditioner.

In a direct system, the PVs are connected to the air conditioner itself. They may drive the fan and pump in an evaporative system or the entire refrigeration cycle in a refrigerative air conditioner.

A number of these units are now available overseas such as the Kingtec Solar units (www.kingtecsolar.com). There is also a system available in Australia that comes as an air conditioner and PV package, the SolarAir. However, we have not verified its performance or the company's claims. The supplier is Aussie Solar World, www.aussiesolarworld.com.au.

The area of solar cooling is quite broad and would require a whole article to explain in detail, but there are some useful web resources that will give a basic grounding in solar cooling systems:

Australian Solar Cooling Interest Group: www.ausscig.org
Wikipedia solar cooling page: en.wikipedia.org/wiki/Solar_cooling
Solar cooling using ejectors (ANU): www.bit.ly/ANU-SCE
AIRAH solar cooling page: www.bit.ly/AIRAH-SC

↑ Echuca Hospital's solar cooling system uses 400 m² of evacuated tube collectors to heat water for the absorption chiller to generate cooling.