Solar Air Heating & Cooling Systems ~ How effective are they?

by Ian Jackson*

There are now plenty of variations in the marketplace of solar air heating and cooling systems. It may seem to be a simple task to stand back and say '*Yes that could be good for me'*. But how good can they *really* be? Are they going to save me thousands of dollars in fuel bills? Sometimes claims are subjective and will only reflect peak performance and not realistic or average conditions. It is safe to say that sun powered systems of heating and cooling *do* work, but the benefits must be applied through the twin filters of local climate and building performance to truly gauge their effectiveness.

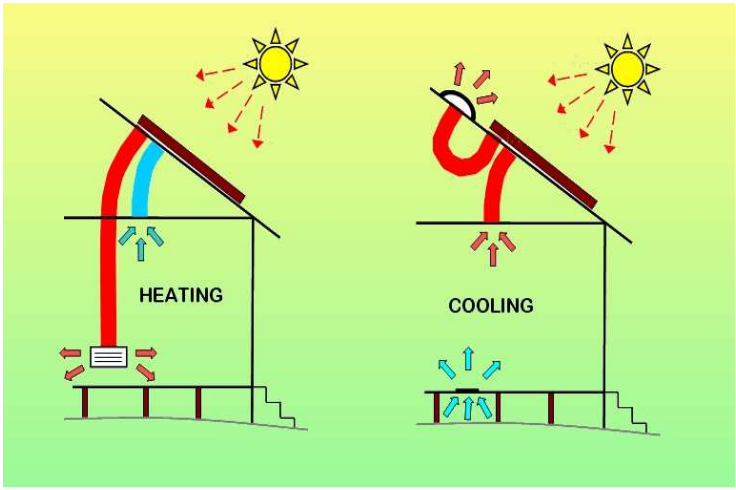
How do they heat?

The heating systems will use a fan to extract air from a room, pass it through a form of solar collector box exposed to sunlight on a roof or wall, and then return the air to the room at a higher temperature. They are at their most effective on cold, sunny mornings, but can also contribute to the total warming of a house on a winters day. It is possible to pre-heat a room to a more comfortable level by the time occupants return home from work without the burden of heating bills.

How do they cool?

Passive cooling systems utilise either of two strategies. Typically there is a nearby reservoir of cooler air, perhaps sub-floor or a heavily shaded garden area close to the room to be cooled. By using an exhaust fan at ceiling height to vent hot air from a room to the outside world, it will create a low pressure within the room, which then automatically draws in cooler air from a naturally cooler area nearby, thus cooling a living space for little cost. This concept is often integrated with the aforementioned heating systems by having a motorised duct control redirecting the output of a solar collector from a room to the atmosphere.

Another popular strategy affects the ceiling space above a room. In summer a room may become uncomfortably hot because the ceiling space above has soared to 65º or more and some of this trapped heat is leeching into the living space below. Forcibly extracting the extreme hot air from the ceiling space to the atmosphere by an active fan system can also reduce the temperature in the living space below.



These air displacement systems may be powered from AC mains or from a modest sized solar panel, or perhaps a combination of both. The fundamentals remain the same. Such systems are not a complete substitute for a domestic heater or air conditioner, but their presence is quite capable of shaving a sizable percentage from an otherwise large fuel bill.

Location and Climate

The heating effect is needed most in colder climates, but mean temperature and cloud cover patterns vary greatly with location. Much of the Australian continent will experience months of cold, frosty, subzero mornings with near cloudless days. This is where the concept is at its best. When the cold temperatures are supplemented by heavy cloud and rain, the heating effect of a solar collector may be negligible. It comes down to how much solar radiation can be captured. Visualise a car parked out in the open with the windows up tight. If conditions are such that the interior of that car is going to warm up naturally, then these are the conditions where a solar collector can heat your home. On a sunny morning a single 1 x 2 metre solar collector can add 22-25º of heat to the air that is being circulated. This will approach the heating effect of a 1.5kw fan heater inside the room. Quite enough to make a large room quite comfortable by the time a family returns at the end of the day from work or school.

Certainly it can offset several hours worth of fossil fuel heating. There will always be extreme sun-free days where heavy cloud let only small amounts of light reach the home. Such days will struggle to add more than one or two degrees to the ambient room temperature.

Insulation and heat loss

Retaining the heat in the home is the paramount aim. If kilowatts of heat energy are pumped into a room and 30% goes straight out again through uninsulated ceiling space, gaps around down lights and doors and windows that don't seal properly, then just adding more heat is not the first action to take. To use a maritime analogy; If a boat has sprung a leak, then using a bigger bucket to empty the boat is not a long term solution. Fixing the leak is better. Of course in the home thicker ceiling and wall insulation is an obvious point of attack, but look more closely at the convection effects around windows and curtains. Infrared scans outside of a building can reveal much about where and how home heat can leach away. If a solar heat collector system is to be fitted, then ensure that the ductwork to and from the target rooms are properly insulated and not just expanded foil. Just eight metres of uninsulated ductwork can loose up to half of the heat that you should be recovering from the collector.

A flat roof can be problematic if it has not been insulated properly the first time round, but at least the duct runs from a solar heater can be shorter. If sufficient ceiling height exists, there is a good case for building a false ceiling into a room 100mm below the original one and loading the cavity with insulation batts. Certainly it would be cheaper and less disruptive than replacing a roof.

Room size & flow rates

Sometimes the advice is bad and the installer gets it wrong. Perhaps a single solar collector is connected to a large open plan living area and the owner complains that it helps very little. A solar heater system can only elevate temperature of a fixed air volume for a limited daylight period. If an owner contemplates fitting a solar collector for a given price, then adding a second collector to double the heating effect may only add 25% of the total system cost. It is important to read the specifications of a system and apply them properly to your home.

Solar heat exchange systems will have a circulating fan. A common error is to associate system efficiency to the volume of air that comes out. Remember that the heat is coming from a single source. By having a lower air flow rate, the heating effect of that air will be much higher. A slower fan setting can reduce electrical energy consumption and fan noise, while providing the same total heating effect to the target space.

Collector orientation

Discuss the location of the solar heat collector with the installer. Orientation is important. Just putting a collector on the roof somewhere is not good enough. In some ways it must match the lifestyle of the individuals concerned. If the occupants are home most of the day, then it makes sense to have the collector face the morning sun and generate the maximum heat at the coolest part of the day. If everyone typically leaves the house until the afternoon or evening, then orient the panels for the highest midday sun, ensuring maximum all-day heating for a warmer home at the end of the day. Look at the tree shadows and roof line. Be aware that any shadows passing over a heat collector will stop them from working. If there is very little sun going to reach your 'ideal' location, then the money may have been better spent on thicker home insulation instead.

Thermostat control.
Even though the heater and coolers are regarded as 'passive' systems, thermostatic control is also important. This is particularly evident where the circulating fan uses an AC power source and could run all day regardless of weather. If nobody is around to turn the system off at night, then a heating system could be cooling your home when the sun goes down. Some systems use a DC Solar Panel to generate the power for the circulating fan on the basis that if there is no power coming out of the solar panel, then the heat collector will remain dormant.
This is only approximately true as a solar collector won't heat up and cool down instantly with the sun. There are lag times to the heating and cooling, but the adjacent photo-voltaic solar panel will react immediately to first sunlight and can circulate cold air about the house. A better way is to have a system that senses the collector temperature, so that the fan will only operate when a preset heat level has been reached. This helps at both ends of the day.

Some systems don't use a solar collector unit at all, but simply pump warm ceiling space air into the living space below, effectively using the whole roof as a solar collector. The concept is fine, but largely the roof materials govern effectiveness. The thermal mass and reflectivity of tiles versus steel sheet differ greatly. Also, the presence (or absence) of under-roof insulation will have a marked effect upon heat capture.
Two additional aspects to consider with ceiling cavity heating are dust ingress and fire safety. If the ceiling space is naturally dusty, then very quickly, the living space below will also become dusty. There is also a worrying fire risk, which comes from the possibility of a ceiling fire. Just suppose a fire erupts in a ceiling at night (say from a faulty downlight in another part of the house). The fan thermostat may say '*great, plenty of useable hot air up here*' then proceed to fill the living space with toxic smoke. For this reason any ceiling space heater should have an integral smoke detector to further protect occupants against fire events.

Passive cooling systems
The previously described technique of withdrawing warm air from ceiling height is an excellent way of taking the edge off a hot room in the summer. Thought must be given to where the air comes from which replaces the departing hot air. The addition of floor vents within a room to withdraw the cooler air from under a timber floor is worth considering. Drawing cool air from long lengths of buried PVC pipes is becoming increasingly popular, though the required space and implementation cost means that this option is not for everyone. The most important aspect of heat venting systems is to ensure that a thermostat is in place to automatically stop the fan and seal the vent when temperatures fall. Many locations have hot days and cool nights where the warm room air will want to be retained after dark and not chimney through the extraction system. A dedicated heat extractor manufactured by Solar Source in Victoria has a servo motor controlled butterfly valve to ensure that the system only vents hot air at appropriate times and the vent is fully sealed when the fan is inactive.

Mains powered fan versus Solar power fan

The thought of powering the fans entirely by the sun in a passive heat or cooling system is appealing in its simplicity, but slightly flawed. So should the circulating fan be powered by a 30 watt solar panel or by an AC power pack connected to the mains? There are some technical and practical issues to having a fan system powered entirely by the sun. Firstly at night the system will go completely dead, with no power to illuminate the controls. At dawn and dusk the controls must deal with marginal power levels, which may cause erratic operation if the system is not equipped with a backup battery. The biggest issue is that fan operation will vary wildly with speed as passing clouds and shadows affect the solar panel. These shifts of a fan speeding up and slowing down all day can often be heard within the living space and can become quite distracting to the occupants.

It is important to get some perspective on the energy levels involved. The heat being transferred by a solar air heater is in the order of *two hundred times* the energy expended by the circulating fan. Ultimately whether the 30-40 watts supplying the fan is coming from the grid or a solar panel is not a big issue. The ideal approach is to have a dual-supply system so that reliable power to the controls and steady air flow is guaranteed by the mains, but some or all of this supply energy is supplemented by a solar panel when the sun is shining.

Isn't this all too complicated for the average home?

This is something of a loaded question. Certainly some of the dynamics involved are complex, but if the installation is sound and controls are smart enough, this should be hidden from the home occupants. It should just quietly do its job by reducing power bills. It is a matter of perspective. Like a car or a television set, it is either simple or complex depending upon whether it is being used by the consumer or serviced by a technician.

This article is intended to prepare homeowners with the many issues that underpin effectiveness of passive heating and cooling, so that they may examine the alternatives from an informed position.

*The author of this article is an electronics engineer who has had involvment in developing a wide range of solar control systems.