Outlook

Prospects for solar air-conditioning

The most noticeable thing about solar energy is that we get more of it in the summer than we do at this time of year. Many Australian sunburnt skins will attest the fact next summer, as more than 1000 watts per square metre come pouring down on them from a clear blue sky. As well as the sunburn cream, all those watts conspire to bring out the fans, air-conditioners, swimming pools, and other accoutrements that go towards beating summer heat.

A solar air-conditioner therefore sounds exciting. Just when it is needed most—on a cloudless, muggy, shimmering hot day—the most solar energy is around to run an air-conditioner. Fighting fire with fire!

To date, solar energy has been used primarily for heating water. In this system, solar heaters feed a storage tank capable of holding 2–3 days' supply to tide it over periods of cold cloudy weather. Yet, despite large expensive storage tanks, inevitably at some time during winter it will prove inadequate and some booster heating will be needed.

And then, of course, during summer, the same system gives forth copious—often embarrassingly large—quantities of heat. What should we do with it? Dr Don Close and Mr Robert Dunkle, of the CSIRO Division of Mechanical Engineering at Highett, Melbourne, are two of the increasing number of solar energy researchers who think the answer lies in using that excess heat to drive a refrigerating air-conditioner.

It's not a way-out idea, or science fiction fantasy. Solar air-conditioners are now commercially available in Australia. About $2000 will buy you a small-size domestic unit operating from hot water provided by solar collectors. The units are manufactured by the Yazaki Corporation, a Japanese company known for its conventional absorption air-conditioners. The first solar units only came off the production line in October 1976, although experimental ones had operated for some years before that.

Collectors, of course, are extra, and a major drawback is that they will cost more than the air-conditioner. You'll need something around 50 sq m of collector (at about $100 a sq m) to drive the thing. But prices of collectors are expected to fall when mass production comes in.

Even now, though, the price is not prohibitive for certain applications. At remote mining sites in northern Australia conventional fuel is expensive, temperatures are high, and sunshine is abundant.

The first Yazaki solar air-conditioner in Australia will probably begin operation at such a site. As part of a major 2-year research project sponsored by the Australian Mineral Industries Research Association, the BHP Research Laboratories have set about testing the solar units on location. By the time this article is in print, they should be fully operational.

One prospective site, on the coast, experiences high temperatures and high humidities. Another is inland, where only high temperatures prevail. The installations will form part of an experiment to test their effectiveness in real-life situations. Researchers will collect data on their performance under different weather conditions and at different seasons, and compare the efficiency of the Yazaki collectors with that of other available collectors.

One of these is a high-temperature unit developed by the BHP Research Laboratories in Melbourne. It embodies a boiling tube—moulded into a thin steel pressing, covered with a double layer of glass, and partly evacuated. This should make it possible to obtain water temperatures near 100°C—conditions that favour more-efficient operation of the air-conditioner.

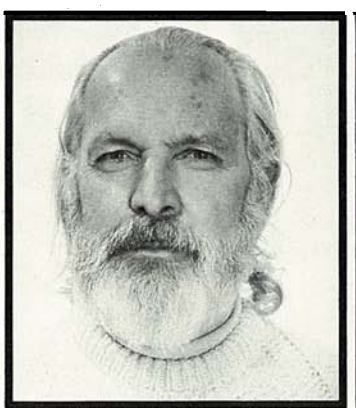
How to cool by heating

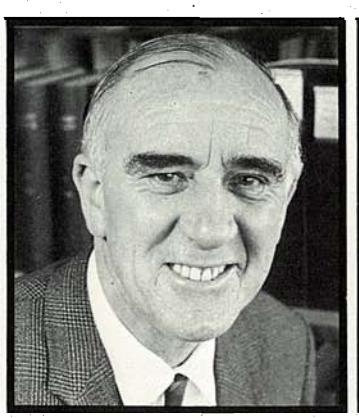
We normally associate solar energy with its capacity to heat. How is it possible to harness solar energy to cool?

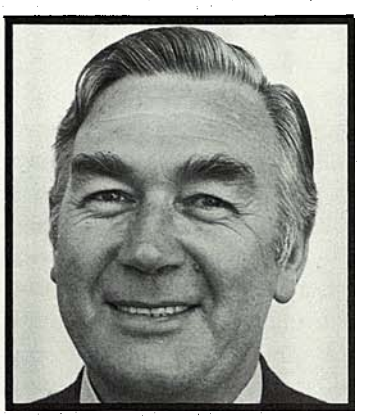
The principle of the solar air-conditioner differs from that of the common compressor-type refrigerators, but is quite similar to that of some gas-fired absorption chillers already in widespread use, which employ lithium bromide solution as a refrigerant. In the solar air-conditioner, hot water takes the place of the gas burner.

Lithium bromide, a non-toxic substance, is highly hygroscopic—that is, it strongly attracts water. The solar air-conditioner puts this property to use: a thick concentrated solution of the sub-


Dr Don Close.


Mr Robert Dunkle.


Mr Keith Robeson.


Mr Wal Read.

stance absorbs water vapour from an air-free volume, creating a partial vacuum into which water is released. When the added water rapidly evaporates under the low pressure, it produces a powerful cooling effect.

The lithium bromide keeps absorbing this water vapour until the chemical is diluted, whereupon it passes to another section of the unit. Here solar heat drives off the water as vapour, leaving concentrated lithium bromide solution ready for returning to its absorbing function. Meanwhile, the unit condenses the steam back to water, to be re-used for evaporation and cooling (see the diagram). The cycle can be altered to permit heating instead of cooling.

Since 1974, the Japanese have built a number of experimental houses with roofs covered with collectors that operated lithium bromide air-conditioners. They have all worked well.

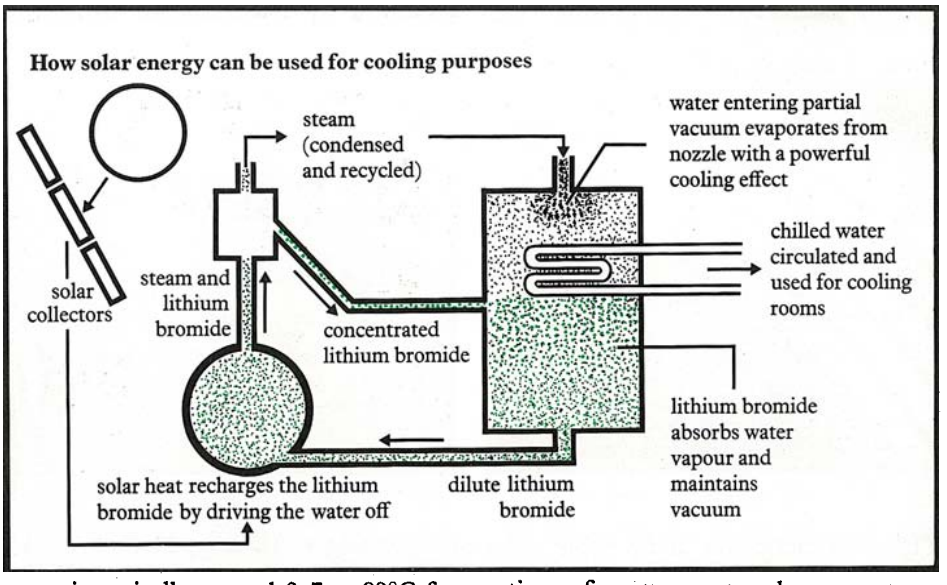
Collectors, of course, are extra, and a major drawback is that they will cost more than the air-conditioner.

The first solar house in Australia—built at Brisbane more than a decade ago—also used lithium bromide units. However, its driving power was simulated solar energy—the output of one solar collector was magnified electrically to simulate the output of dozens of collectors.

Yazaki solar air-conditioners are available in sizes ranging from 4·5 to 35 kW cooling power. These ratings apply for water from the collectors arriving at 88°C. Higher temperatures will give higher ratings, since the efficiency of the units increases with temperature. The lithium bromide principle requires that the water be at least 75°C.

This is quite a lot higher than the temperature at which normal collectors designed for hot-water systems operate (about 60°C). Push their operating temperature higher and their efficiency falls off as larger amounts of heat are re-radiated and convected away. Special collectors must therefore be used in conjunction with solar air-conditioners, a factor increasing cost.

The efficiency of solar units is about the same as that of their conventional counterparts. The 'coefficient of performance', a measure of thermal effectiveness, is typically around 0·7 at 88°C for the solar units, not much lower than for fuel-fired units. Compressor-type air-conditioners exhibit a figure of around 3 for small domestic units, but this falls to about 0·6 if we take into account the efficiency of electricity generation and transmission.



Evaporative cooling

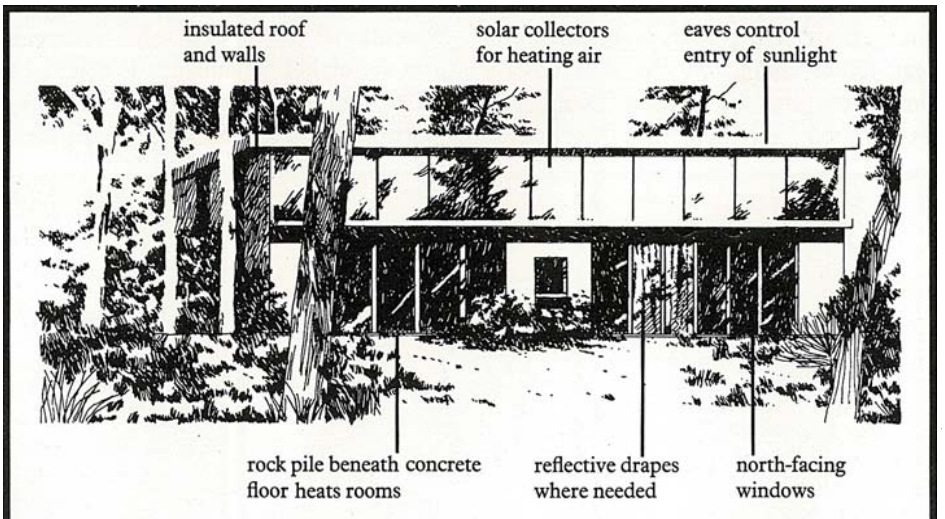
While lithium bromide units are the only solar air-conditioners available commercially, many new avenues for solar cooling are being researched. They include systems that operate like domestic gas refrigerators (using absorption of heat by ammonia and water); others use solar cells to generate electricity that then cools at a thermocouple junction.

But wait a moment. Before we get embroiled in these exotic devices, what about the simple evaporative cooling method of many domestic air-conditioners and of the Coolgardie safe? Indeed, although the evaporative cooler derives its 'coolth' from latent heat of evaporation of water, not solar energy, a number of solar air-conditioning systems make use of the method. To adjust to this usage, 'solar' air-conditioning needs to be defined as a system in which most of the energy supplied is 'free'.

The big drawback with evaporative coolers is that they add water vapour to the air, making it more humid. This doesn't matter much at inland sites where the humidity is low, but in coastal areas, where the humidity is high, the units don't cool very well and simply make the air too muggy for comfort.

Nevertheless, evaporative cooling is cheap to run, and over the last few years the Division of Mechanical Engineering has developed two interesting systems that take advantage of it without raising the absolute humidity. In the first, two beds of gravel act as heat-exchangers for the air to be cooled. The unit is located under the house, where evaporatively cooled air passes through and cools the two beds alternately.

The cooled bed in turn removes heat



A house proposed by Mr Dunkle uses air—not water—to transfer heat.

Solar heating systems compared

	air-based system	water-based system
1. corrosion damage	low risk	high risk
2. leaks	unimportant if small	any leaks serious
3. freezing damage	low risk	high risk
4. piping cost	high	low
5. power needed for circulation	relatively high	low
6. integration into structure	use existing building practice	more complex practice needed
7. cost	cheap materials, low-quality construction adequate	expensive materials, high-quality construction necessary

from fresh air drawn through it, which is then piped to the room to be conditioned. After about 5 minutes, when this bed has heated up somewhat, the fresh-air supply is switched to the other bed, which has been cooling. The units, called RBR coolers (for 'Rock-bed Regenerative'), are commercially available and have been in widespread use for several years.

A more recent development using a similar principle is the PHE cooler ('Plate Heat-exchanger'). In this device, thin plastic plates separate an evaporatively cooled air stream from the air to be conditioned, and heat exchange occurs continuously between the two air streams. The PHE coolers have been under test at the Division for a number of years, and should be manufactured commercially soon.

Both these units will work satisfactorily in all areas except those of highest humidity, where water evaporates only with difficulty.

Combining evaporative cooling with solar energy permits even better control of air conditions, achieving either lower temperatures or, if needed, dehumidification. In each case, greater comfort ensues.

Taking the air

Dr Close and Mr Dunkle have recently proposed a system in which solar energy is used to drive the water from a bed of solid water-absorbent material such as silica gel or activated alumina. The treated bed can dehumidify room air, which is then cooled by being passed over a heat-exchanger in contact with evaporatively cooled air. The team is also looking at variations on this arrangement.

Their system differs from all other solar coolers in that air is used throughout as the fluid for transporting heat. So the solar collectors too have air running through them, rather than water.

In the closest approach to this—proposed more than 20 years ago—a tower of water-absorbent glycol solution did the same job as the present system's silica-gel bed. But Dr Close and Mr Dunkle point out that their cooler, being totally air-operated, needs far fewer parts. It doesn't use liquid-to-air heat-exchangers and other components, and so should cost less.

Moreover, they cite additional reasons for sticking to a totally air-based system. The aim of the exercise is, after all, to condition air, and so starting with collectors circulating hot air, rather than hot water, seems to make sense. Against this, though, they acknowledge that water heaters have reached a more advanced stage of development than have air systems. Indeed, solar hot-water systems stand as the most successful utilization of solar energy to date. Further comparisons between air and water systems are set out in the table.

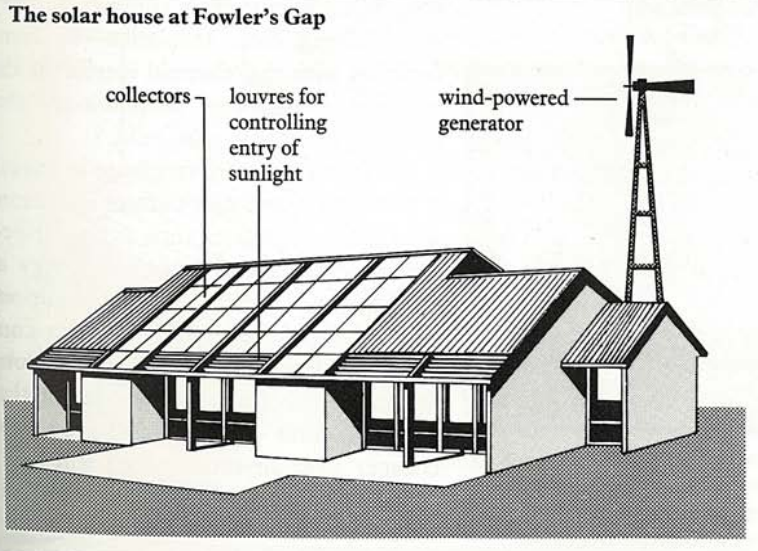
Of course air-conditioning implies the ability to heat in winter as well as cool in summer. Certainly it's not too difficult to put a solar heater on the roof and pipe the warmth into the room below. The real problem with solar heating is that most places don't have much sunshine in winter—when it's cold and you need the warmth most.

Their system differs from other solar coolers in that air is used throughout as the fluid for transporting heat.

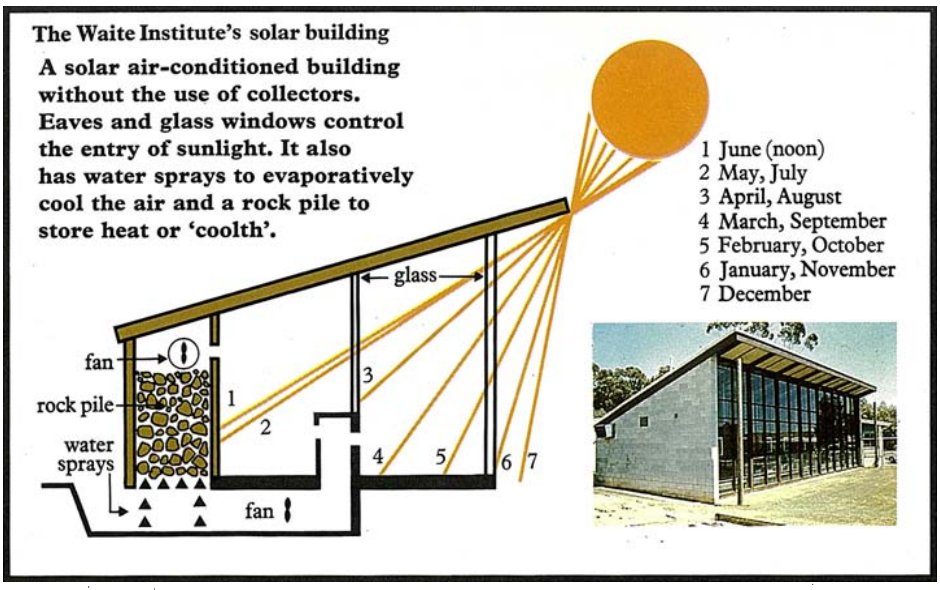
Research teams have sought the answer by designing energy storage tanks that hold enough heat (collected on sunny days) to provide heating throughout a succession of dull days.

One of the earliest of such systems is

The solar house at Fowler's Gap



The solar house at Fowler's Gap, N.S.W., nearing completion. Its interior temperature is controlled by hot or cold water flowing through concrete pipes coiled in the concrete-slab floor.



Successful solar houses must be designed and built with solar air-conditioning in mind.

an air-conditioning unit added to the group of laboratories and offices at Highett. Dr Close and Mr Dunkle designed it in collaboration with their colleague, Mr Keith Robeson. Hot air from the experimental installation's solar collectors mounted on the roof is passed through a huge tank of gravel, which it heats on the way. The gravel acts as both storage and exchanger for the heat, so room air is circulated through it when extra heat is needed. Booster heating is available.

In a similar way, the system stores 'coolth' in summer by passing evaporatively cooled air through the gravel.

The installation was built 12 years ago and, apart from minor modifications, has worked continuously since then. The building has always been comfortably conditioned during office hours at a saving of 80% on the fuel bill.

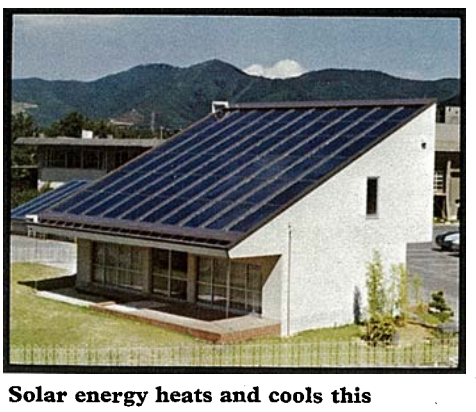
Cold comfort

But, as Mr Robeson is anxious to point out, the installation also teaches an important lesson about solar air-conditioning. Although the collector area of 56 sq m was half that of the area conditioned and although the storage tank is a massive 32 cu m, at some time during every Melbourne winter full booster capacity is needed for a few days. Note too that the building is only conditioned during office hours, not at night or at week-ends. Against this, bear in mind that the conditioned area was uninsulated and on the south side of the building.

For a home requiring conditioning around the clock, the inescapable conclusion (at least for Melbourne conditions) is that it's not economically possible to turn a house into a completely solar one, entirely self-sufficient in energy, simply by adding collectors. The existing heating equipment will still be needed.

Indeed, the head of the solar energy research team at the Division, Mr Wal Read, says that adding solar collectors to existing buildings is very expensive, and he believes it is not economic at the moment to do so. Yet he is sure that solar air-conditioning, in one form or another, will become commonplace in the future.

This solar house in Odeillo, France, has a concrete wall behind a double-glazed facade.



Solar energy heats and cools this experimental house in Japan. Collectors covering its roof absorb energy and drive a lithium bromide air-conditioner.

The reason why it will undoubtedly take on is simply that successful solar houses must be designed and built with solar air-conditioning in mind. Such a house needs to be correctly sited, effectively insulated, and so designed that collectors are aesthetically integrated into the building structure.

House of the future?

Prototype solar houses already exist. The one at Brisbane was built and evaluated by the University of Queensland in the 1960s. The insectary at the Waite Institute in Adelaide has solar air-conditioning. The University of New South Wales has only recently built a totally wind- and solar-powered house at Fowler's Gap in the west of that State, and others have been built overseas.

Just from their outward appearances, it is obvious that they differ markedly in design from conventional houses.

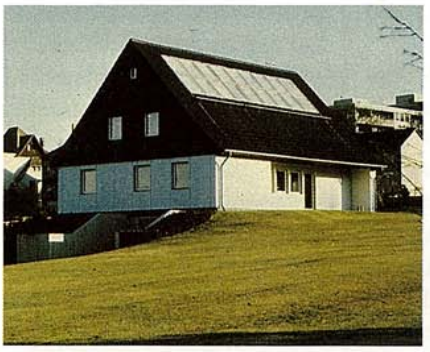
Their radical appearance stems from the fact that they all aim at 'passive' air-conditioning to assist the 'active' work of the collector-driven devices.

A passive system doesn't need any special collectors or machinery. Instead, the building is arranged so that it will receive the maximum warmth possible in winter. Windows, eaves, and drapes are strategically placed so that they will let through sunlight then. Conversely, they will screen it off in summer, to keep the building cool. Insulation—in combination with the 'thermal inertia' of the building fabric and foundations—also helps keep temperatures mild.

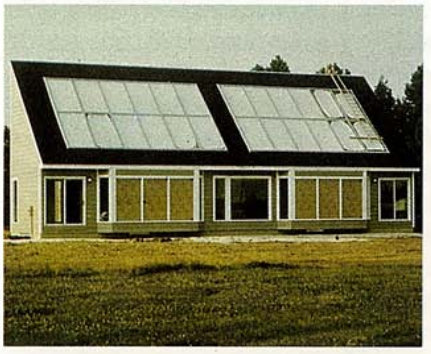
In Australia we are fortunate in having a relatively temperate climate compared with that in countries such as the United States, which spend half their energy in heating and cooling. Mild conditions allow the passive solar systems to contribute a large proportion of the total energy needs. The lower the deficit that active systems have to make up, the cheaper solar air-conditioning will be.

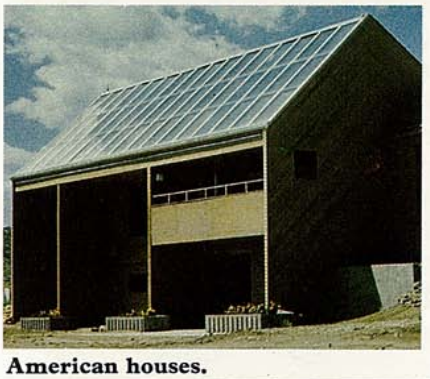
As an example, the Waite Institute building has almost totally passive 'conditioning': sunshine through the

Solar air-conditioning is most effective in houses designed especially for it.



West German house.





American houses.

windows provides necessary heating; a rock pile along the back wall, which is evaporatively cooled at night, provides cooling.

Most systems will be hybrids, as demonstrated by the model proposed by Mr Dunkle. He suggests taking the heat from solar collectors to a gravel bed beneath the house, which is built on a concrete slab. Heat then moves from this bed to the building interior, by conduction and radiation, supplementing sunlight shining through the windows.

At the Fowler's Gap house, building temperature is controlled both by passive means and by plastic pipes set in the concrete slab foundation, which carry either hot or cold water.

Under one roof

One new approach to economic solar air-conditioning lies in integrating solar collectors with the roof. Mr Read, who is pursuing this line of research, points out that you don't really need a roof at all if it is covered by collectors. A com-combined roof–collector would undoubtedly save in construction costs, and probably be more efficient as well.

The era of solar air-conditioning has only just begun, but Mr Read believes its future prospects are good, given continued increases in fuel prices and sufficient research effort. Even though only 4% of our total energy usage is consumed domestically, he considers that solar air-conditioning will appear first in houses, for that is where the interest and demand are greatest and where design can be most easily arranged to make use of passive energy collection. Industrial users require much higher temperatures than solar energy can provide at present, and pay less for their fuel, per unit, than domestic users.

Meanwhile, what do you do until you can shift into your new solar air-conditioned home? 'Make your present house into a "passive" solar energy collector' is probably the best answer: install insulation, provide eaves over the windows, and plant some deciduous trees in front of them.

More about the topic

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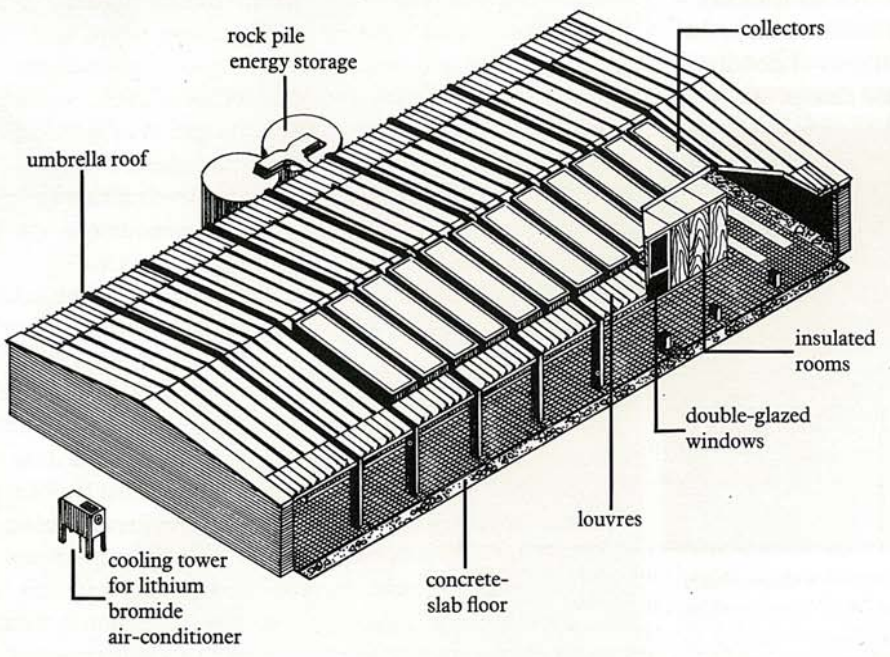
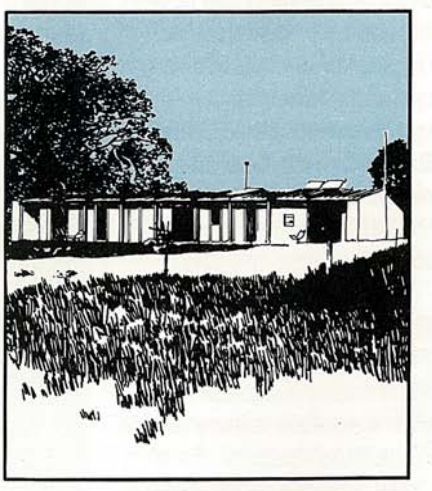
Brisbane solar house





The Brisbane solar house, built in 1966 by the University of Queensland, was the first in Australia.
An umbrella roof protects room modules underneath.