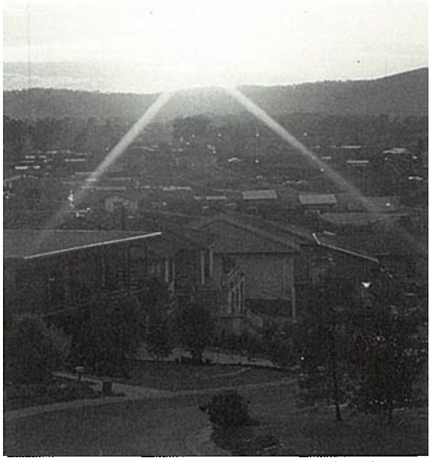
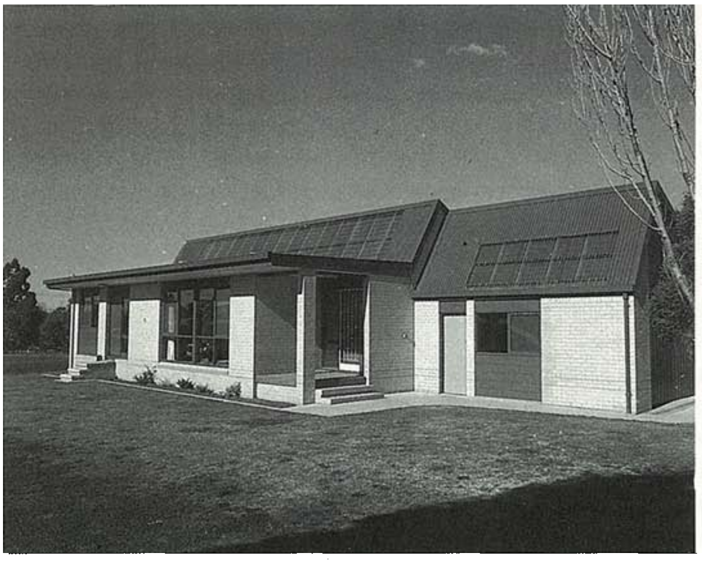


Lessons from a solar house



Solar houses come in all sorts of shapes and sizes; some use exotic technology, some are of basic design. But all of them try, by drawing on the sun's energy supply, to save on the amount of conventional energy needed.

The CSIRO solar house (left) has the same floor plan as a standard Jennings home, the 'Berkshire' (right). It has bigger windows, and a garage added on the western wall.

Scientists from CSIRO wanted to quantify the possible savings in a solar home that resembled, as closely as possible, a common Melbourne dwelling. So, since November 1978, a solar house they designed has been operating at CSIRO's Highett, Melbourne, site. It was described in *Ecos* 19.

The house has a design similar to that of the popular Jennings 'Berkshire', of which dozens can be found around Melbourne suburbs. However, to reduce energy consumption, 'active' and 'passive' solar systems have been built into the CSIRO version. The steeply raked roof, with its in-built collectors, gives it away immediately as a solar house, but it has the same floor-plan as the others.

How much energy was saved? With the co-operation of 29 owners of conventional Berkshire houses, a comparison of each home's energy consumption and comfort was made with those of the solar version. Results showed that the solar house used, on average, only one-quarter as much energy as the others, yet it was warmer in winter and cooler in summer. The biggest savings were in space heating, although the solar water-heaters also provided a good contribution.

In southern Australia, space heating accounts for almost half the domestic energy demand, and is usually provided by oil, natural gas, or electricity. With the solar house, built by the Divisions of Energy Technology and Building Research, the plan was to substitute solar energy, with any deficiency made up by an electric fan heater (of 2·4 kW)

In the event, the auxiliary electric heater proved more than adequate. Typically, less than 1 kW was all that was required to maintain the house comfortably warm from 7 a.m. to 11 p.m., even during the coldest spells.

The solar hot-water system, with 4·5 sq. m of collector sited on the garage roof, reduced the amount of electricity required for the water-heating system by about 40%.

How did the design accomplish its energy savings?

Naturally, good insulation of walls and ceiling prevents heat losses from the building during winter and unwanted heat gain in summer. Rockwool batts 100 mm thick were installed in the cavity of the brick-veneer walls, and others 75 mm thick in the ceiling, together with double-sided reflective foil below the roof cladding.

Careful attention to the building's orientation and window placement and the use of a high-thermal-capacity floor (concrete slab) provide 'passive' use of solar energy.

The floor acts as a heat sink, which evens out temperature fluctuations in both summer and winter. In summer, the low night temperatures are carried through to the day, and in winter the sun-warmed slab stays warm into the evening.

The main axis of the house runs east–west, and windows on the north wall were made large (some 40% of the wall is glazed). Winter sun shines onto the quarry tiles covering the concrete-slab floor and heats the slab. The living areas, with the highest heating needs, are on the north, and bedrooms are on the south.

To avoid overheating of the building in summer, eaves shade off the sun during the hottest parts of the summer day. In addition, a garage protects the western end of the building from the hot afternoon sun.

'Active' design

The 'active' features of the house are the more interesting. Space heating is provided by 19 sq. m of solar air-heater, from which heat is stored in a half-metre-deep bed of crushed rock located under the floor and in direct contact with it.

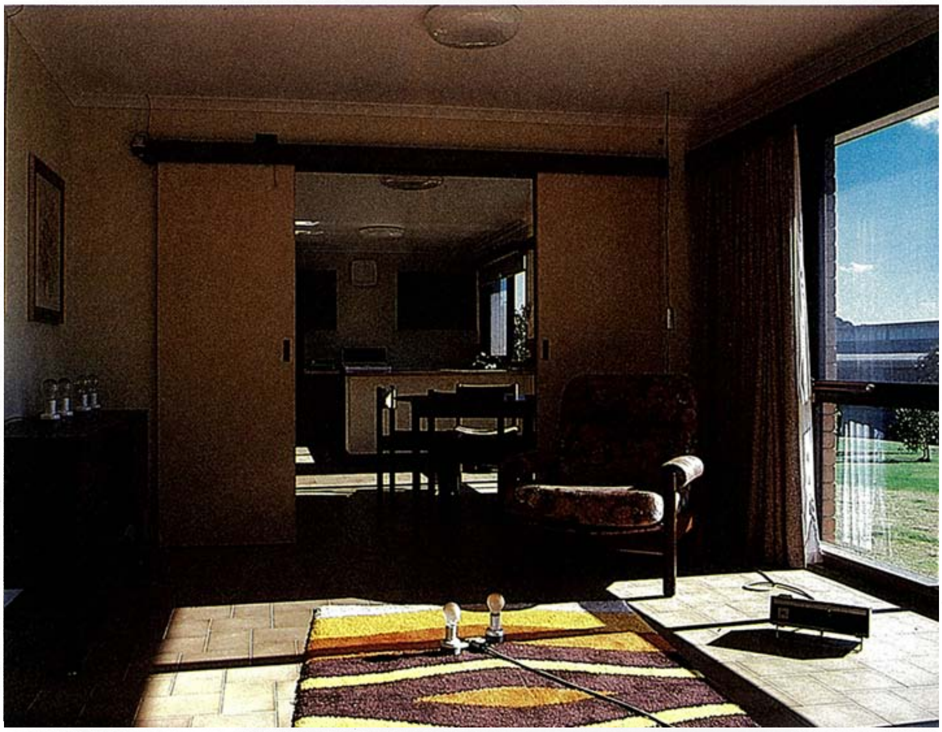
Made to a CSIRO design, the collector comprises two sheets of aluminium cladding, rivetted face to face so as to form air ducts between them. The assembly — painted black, insulated at the back, and protected with a clear acrylic sheet on its face — fits flush with the roof. A fan circulates heated air from the collector, through the rockbed under the floor, and back. (The system is now being used in a number of other solar installations.)

The portion of the rockbed under the living area is heated first. When its covering slab reaches a set temperature (in mid winter, 27 °C), excess heat is diverted to the remaining portion, under the sleeping area.

Heat from the rockbed is conducted through the concrete floor and transferred to the room by radiation and natural convection. This provides more even heating than a forced-air circulation system, but because carpet reduces heat transfer, only an occasional scatter rug is used in the lounge. The bedrooms are carpeted, however.

Studies have shown that floor heating produces the same sensation of warmth as air-circulation systems operating about 1 °C hotter. So, while comfort remains the same, the temperature gap between indoors and outdoors can be smaller, resulting in a lower heat loss and a saving in total energy consumption.

During the night, solar collectors throw off heat to space, and advantage can be taken of this during summer. Using natural 'heat siphoning', the system runs in reverse: heat rises from the rockbed and is passed to the collectors, lowering the temperature of the slab. (The fan could be used to speed up the heat flow, but at an extra cost in energy.)



The quarry-tile floor absorbs sunshine to provide warmth passively. The small electric fan heater on the floor is the sole source of auxiliary heating. Light globes mimic the heat generated by occupants.

To reduce draughts, and heat loss, the doors fit closely, and fixed ventilators are located only in the kitchen, laundry, bathroom, and toilet. Consequently, an air infiltration rate of 0·5 changes per hour was measured, which compares with a figure of at least 1·0 for standard-design homes.

All in all, the CSIRO solar house was designed specifically to suit southern Australian conditions, and to be constructed by local builders using local materials. Jennings Industries Ltd built the house using their normal tradespeople and building techniques.

Not all of the techniques used in the building will be economically worth while at present, but they serve as a demonstration of what can be done, and have enabled scientists to test and monitor long-term performance.

A microcomputer operated the house as if it were occupied.

A microcomputer kept tabs on the performance of the solar house. It also operated the house as if it were occupied by a typical family.

After 3 years of operation, the performance of the house has been evaluated. This would not have been possible without a microcomputer that kept tabs on all the systems and their performance. The 'micro' operated the house as if it were occupied by a family with two school-age children.

It turned power outlets off and on, opened and closed doors, windows, and curtains, and turned taps on and off to simulate washing, cooking, and showering. Light globes were operated to supply the heat otherwise generated by occupants.

All this activity was programmed to match the behaviour of a typical Melbourne family whose living pattern, appliance usage, and desired degree of heating all affect the energy consumed.

The computer also recorded the readings of sensors located at more than 240 locations throughout the house.

Temperature measurements were the most numerous — about 220, from within the rockbeds, the house, and the solar systems. Other sensors detected whether doors, windows, and curtains were open or closed, whether rain was falling on the external walls, and the operating state of the air- and water-heating systems.

Information on electricity meter readings, solar radiation levels, and water flow rates was also logged into the computer.

Mr Mike Wooldridge led the project, and his idea was to operate the house for 3 years in the following manner. For the first winter, in 1979, the 'occupants' were kept very regular in their habits, using appliances and hot water in the same manner every day.

The pattern of use was changed in 1980 to a random one, although the average was the same as before. In the third year, the active systems weren't operated, and the house made do with its passive system.

The instrumentation was handled by Mr Laurie Welch, who also analysed the data and arranged for energy-consumption data to come from 29 other Berkshire homes. This involved the owners reading their gas and electricity meters every month. A small sensor that registered the average temperature over a month was also placed in their homes.

Findings

Mr Welch has now completed his analysis of the 3 years of data and his findings show that substantial energy savings can be achieved through the passive use of solar energy. Indeed, for this particular house, the additional savings resulting from the active solar space-heating system would be difficult to justify on economic grounds.

However, perhaps the most important general conclusion to emerge is that the solar house used much less energy than comparable conventional houses.

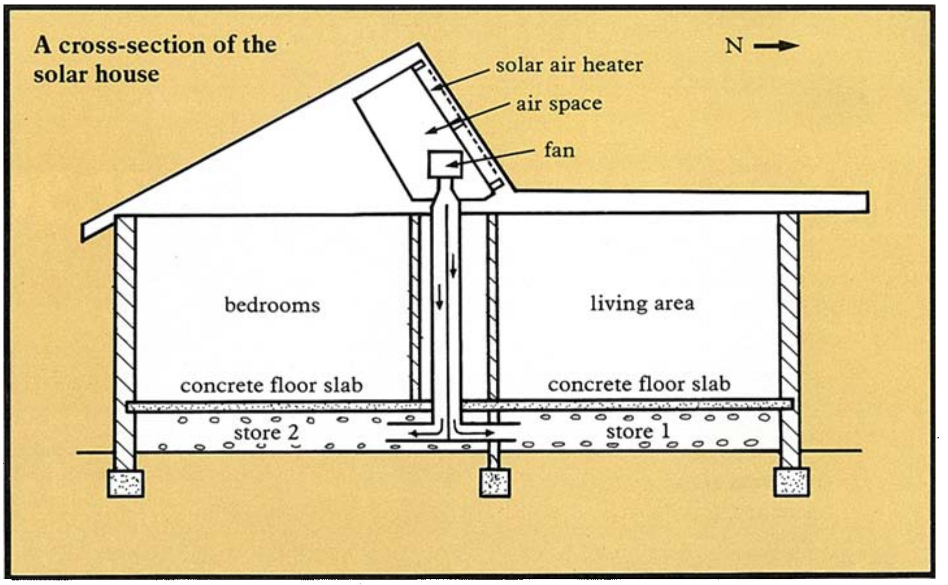
The graph (top left) on page 6 shows, for a typical year, 1979, the energy used per month for each of the houses. Standard Berkshire houses used an average of about four times as much energy as the solar version. Some of the houses used seven times as much.

To be specific, during August 1979, the average standard home used 11·4 gigajoules of energy, whereas the solar one used only 2·8 GJ. As the pie chart shows, the largest slice (70%) of the home-dwellers' monthly energy bill went on space heating.

Nearly all the variation in energy-consumption patterns in the standard houses was due to different space-heating requirements. Water heating usually required about 1·4 GJ per month, and lighting and appliances consumed a fairly uniform 0·8 GJ per month.

In most of the houses, a single natural gas space heater located in the lounge provided heating. The differences between houses in energy consumed therefore mainly reflect the families' different perceptions of comfort — how high the heater was turned up, and for how long in the day it was used. Of course, other factors play a minor part: amount of ventilation, orientation of the house, amount of insulation, and so on.

The graph (top right) on page 6 shows the way in which comfort is related to energy consumption. It is plotted using the average house temperature recorded by a special 'temperature integrator' placed in the lounge room of each home during August 1979.

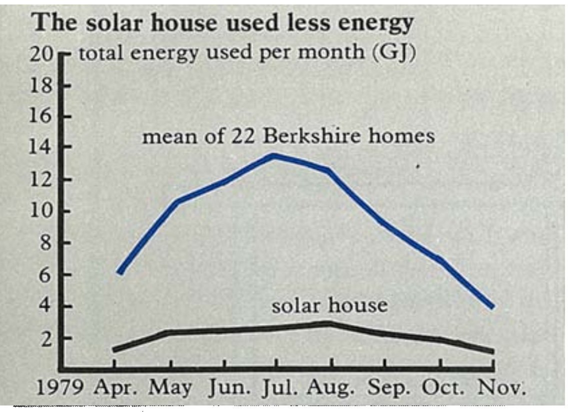


Heat collected from the solar air heater on the roof is stored in rockbeds beneath the floor.

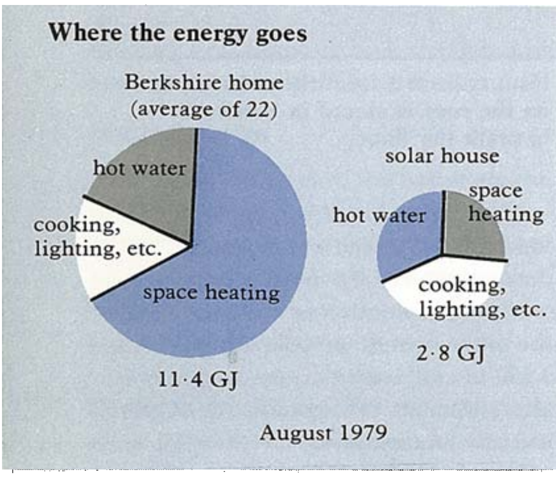
The point plotted for the solar house indicates a degree of winter comfort (21 °C) that would satisfy most people, yet its energy consumption is way below that of the other homes. On cold days, less than 1 kW of supplementary heating was usually sufficient to maintain the required internal temperature.

Measurements taken in the solar house show uniform temperatures within the rooms — the ceiling temperatures are close to the floor temperatures — as expected from use of a floor-heating system.

The solar house is built on beds of crushed rock. The pipes that bring in and take away heat can also be seen. The photo was taken during construction.



The solar house used, on average, one-quarter as much energy as comparable homes.



The charts show total energy use in August 1979, and the break-up between different uses. In normal homes, some 70% of the winter fuel bill goes towards space heating.

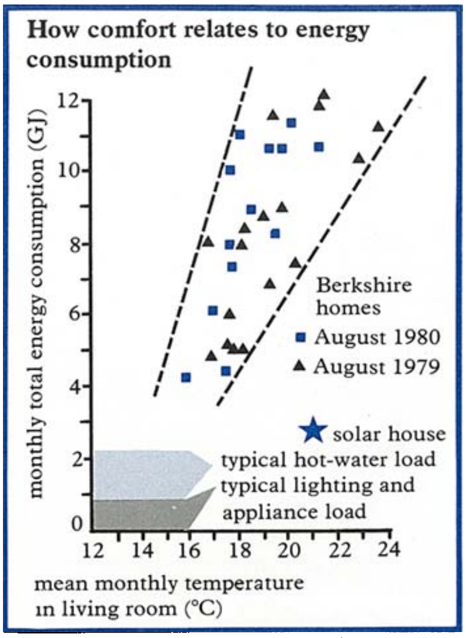
In summer, the solar house again had a satisfactory comfort level. A record of temperatures experienced indoors and outdoors during a 10-day period appears in the third graph, on the right. On four successive days the outside temperature reached 38°C or more, but the corresponding temperature in the lounge room did not exceed 29°C.

The computer automatically opened and closed windows and curtains to reduce unwanted heat gains during the day. Its dedication to this task would surpass that of a human occupant. However, its anticipation of how the day would heat up would be weaker, and so similar internal temperatures would probably result.

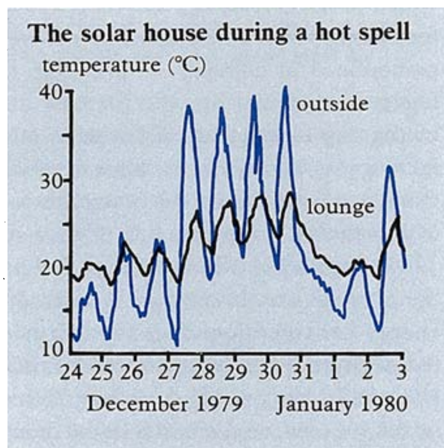
Passive *v.* active

A comparison of total energy consumed between the three years 1979, 1980, and 1981 is revealing. Climatically, the three years were similar, and the energy used by all the survey houses combined varied by less than 1% from year to year.

For the solar house, too, there was only a slight difference. The pattern of occupancy and appliance usage changed be-



Of the homes surveyed, the warmest ones tended to use the greatest amount of energy. However, the solar house was warmer than most, yet it used far less energy than any of them.



On four successive days the outside temperature reached 38°C or more, but indoors it stayed below 29°C.

tween 1979 and 1980–81, when regular patterns were replaced by random ones; this improved realism, but didn't change the results significantly.

The difference in total energy usage between 1979 and 1980, when the active systems were operated, and 1981, the year of passive operation only, is small. This isn't surprising, since the energy used for space heating has been reduced to a small percentage (13%) of the house's annual energy usage. A closer look at the data shows that energy used for heating during the period of passive operation (5·2 GJ) was double that required during the corresponding period of active operation (2·6 GJ). (In terms of energy saved the difference was reduced by the 1·0 GJ required to run the 300-W fan, which circulated air through the solar collector and the rockbed.)

During a typical heating season, 50 GJ of solar radiation will fall on the solar collector, about ten times the energy used for space heating in the passive mode. However, much of this radiation is available at the time when passive gains are greatest (and therefore not needed immediately): during this time the active system stores energy in the rockbed for use during periods of low, or zero, radiation.

About the time of the winter solstice, solar radiation can be very low and this creates a high heat drain from the rockbed. After the solstice, radiation levels increase and energy can again be collected and stored. The thermal mass of the rockbed is an important factor in the response of the heating system, and the quicker the temperature within the bed can be raised then the sooner heat will be available to the house.

The researchers believe that a reduction in the rockbed thickness would result in a slight increase in the savings for heating. However, the savings possible here are minimal, and more important is the need for lower-cost sub-floor thermal storage.

In summary, the project has demonstrated how a well-insulated house, designed to take advantage of passive solar gains, can substantially reduce the energy required for space heating. The potential for further savings through the use of an active solar heating system is small and currently difficult to justify economically.

However, active systems are appropriate in some cases — for example, when higher internal temperatures are required. As well, they permit flexibility in siting of the home, floor plan, window size and location, and type of floor and its coverings. Finally, they reduce problems with privacy and security (and many people aren't diligent enough to keep opening and closing windows and curtains simply to optimize comfort).

Andrew Bell

More about the topic

Active space heating — passive space heating, an energy comparison for the CSIRO's low-energy-consumption house. L. W. Welch. *Papers, Solar World Congress, International Solar Energy Society, Perth, August 1983.*

An examination of household energy data collected for comparison with the CSIRO low-energy house. L. W. Welch, C. J-P. Delage, and M. J. Wooldridge. *CSIRO Division of Energy Technology Technical Report* TR 1, 1982.