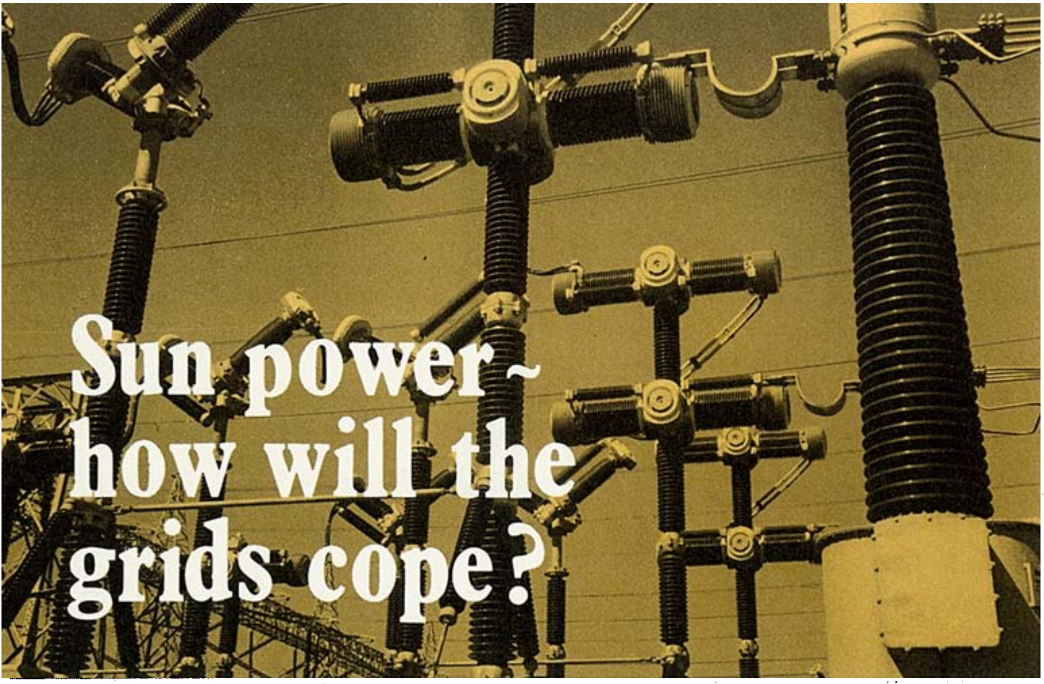


Sun power ~ how will the grids cope?

The lucky country, the sunburnt country: Australia is better placed than most nations to exploit the most abundant of all energy sources, the sun. For some years solar collectors have been on sale to householders keen to use less electricity to heat water, and more and more people are installing them. The question now arises, how would State electricity supply systems be affected if really large numbers of homes used solar water heaters?

This question has been tackled recently as part of a predictive exercise for an Australian panel of the Australian National Committee of the Conférence Internationale des Grands Réseaux Eléctriques (CIGRE). CIGRE is an international organization involved in the study of large electric power systems.

The Australian panel, convened by Mr F. Brady, chairman of the Electricity Commission of New South Wales, is studying the effects of external influences on the future of electricity supply systems. The detailed investigation of solar water heating was carried out by three engineers: Dr Peter Cooper of the CSIRO Division of Mechanical Engineering and Messrs John Welford and Bob Lehman, of the Electricity Trust of South Australia.

This is the first Australian study to predict the impact of solar heaters on both consumers and electricity supply authorities, rather than on consumers alone. Since the community pays the costs of supply, it's no esoteric point.

A domestic solar water heater uses supplementary electric heating to keep the water temperature up on cold, overcast days, and the engineers wanted to find out how big this demand for supplementary energy might become and at what times of day it might occur. They were particularly interested to know whether solar heaters might place appreciable extra demands on electricity supplies at times of peak load.

One way to tackle these questions would be to conduct field trials with several different solar heaters in a variety of households, using their hot water at various times of day and in differing climates. Unfortunately it would take a long time to collect enough information to provide reliable averages, and so many variables need to be taken into account that such an exercise would be technically difficult and expensive.

What's more, this approach would exclude the newest technology. It would be interesting to evaluate solar collectors with the latest selective surfaces, for example, but they are only beginning to get off the test rig and onto people's roofs.

To overcome these problems, the study team used a computer-based mathematical model of domestic solar water heaters to examine the performance of the various systems. This method makes it a relatively simple matter to find out the effect of altering one or more variables: the relevant figures are adjusted and the computer performs the calculation anew.

The accuracy of any predictions made with such a mathematical model depends on the reliability both of the figures used and of the model itself. The CSIRO Division of Mechanical Engineering was uniquely placed to assist here, having already developed a suitable mathematical model while helping to establish standards for the Standards Association of Australia. The Division had also accumulated essential statistics on the performance of solar units.

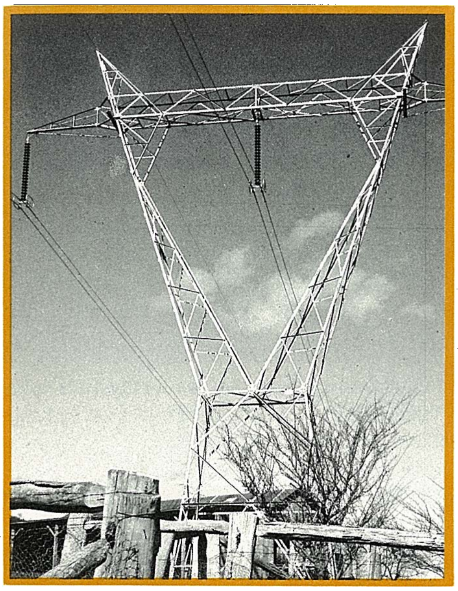
The calculations were complex. Solar collectors of different areas and absorber surfaces were compared, in combination with storage tanks of various volumes. Continuous and off-peak supplementary electricity powered the 'back-up' elements. Also, both the timing and level of water consumption were varied in the calculations. From the interaction of so many variables came a mass of information that should give food for thought not only to electricity supply authorities but also to manufacturers and consumers.

Peaks of demand

To a supply authority, the ideal community would be one that used the same amount of electricity all day and all night. Electricity generation would be relatively cheap because power stations would run continuously. In practice there are 'peaks' of demand, particularly in the early evening.

The graph on page 27 shows a typical supply pattern: the line represents the electricity consumed by an imaginary community of about half a million consumers on a winter's day in southern Australia. In general, 'base' loads in Australia are supplied by the most efficient coal-burning plant running continuously, except in Tasmania, which meets virtually all its needs with hydro-electric power. The peaks are met by operating other power stations for only part of the day. Except where hydro-electric power is available, it usually costs more to generate peak electricity than base-load electricity and involves less-efficient plant, near the end of its life or burning more expensive fuel such as oil.

To help even out the load, many electricity authorities in Australia offer special cheaper tariffs for electricity supplied only during off-peak times, generally from about 11 p.m. to about 7 a.m. In many households water is heated overnight by an electric element using the off-peak supply; if the tank is big enough and adequately lagged, hot water will be available all day although the element is switched off for at least 16 hours continuously. Off-peak domestic water heating plays an important role in reducing the disparity between day and night electricity loads.

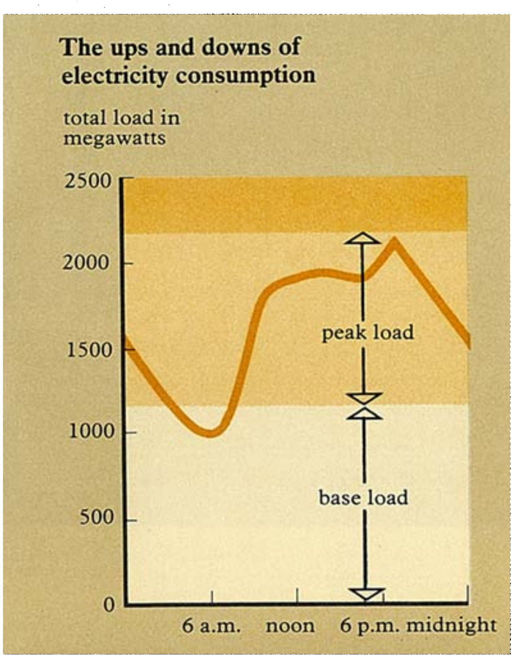


Solar heaters obtain much of their energy from the sun. Will it be of any great consequence which electricity supply, continuous or off-peak, they draw upon for 'back-up'? The CIGRE report says yes. If households converted their water heating from off-peak all-electric to solar with continuous electrical back-up, the grid would face an additional demand at the very times of day when it was least welcome.

This would happen because most hot water is used during the periods of peak demand for power. Installing all-electric water heaters using the continuous power supply would, of course, raise the peaks yet higher.

If, instead, people installed off-peak heaters, either solar or all-electric, their load could easily be accommodated in the 'trough' of daily demand. The authorities would face one special cost: the installation and maintaining of separate switching and metering gear for the off-peak supply. Off-peak electricity tariffs are generally designed to fully recover this cost as well as cover the cost of producing the base-load electricity used.

The demand for electricity fluctuates during the day. This graph shows a typical load pattern in a community of half a million consumers in southern Victoria in winter.



As the annual electricity consumption of a solar-boosted heater is about half that of the equivalent all-electric off-peak heater, the report concludes that supply authorities will not effect a full recovery of costs if solar-boosted electric off-peak heaters are supplied at the same rate as conventional off-peak heaters.

Most solar water heaters in Australia have continuous electrical back-up.

At present the majority of solar water heaters in Australia have continuous electrical back-up.

These considerations apply particularly to electricity supply systems whose greatest load comes during winter. Some systems — in the United States, for example — are 'summer-peaking'. The summer demand comes from air-conditioning and refrigeration.

In recent years South Australia and Western Australia have seen their summer loads grow to rival the winter demand, but winter consumption may rise again as electricity supplants oil for room heating. If a system does become summer-peaking, solar water heaters with continuous back-up are less likely to pose supply problems, because the sun provides most of the heat needed in summer and there is little call on back-up power in the most critical periods.

The CIGRE studies indicate that in Melbourne the solar collector will provide 75% of a typical household's requirements during summer, but only 25% in winter — not enough on its own to provide really hot water on most days.

New designs

The report has some interesting things to say about the design of solar water heaters. In essence, a heater has two parts: a collector to intercept and absorb sunlight and a hot-water storage tank. The two are connected by pipes that carry cold water from the tank to the collector to be heated, then back to the tank.

The engineers mathematically 'modelled' the performances of both a conventional solar collector and one with a selective surface — that is, one that absorbs a high proportion of the solar energy falling on it but radiates little heat. To explore the limit of what is currently possible, the study team used the performance characteristics of one of the most efficient types of domestic collector. This incorporates a chrome black surface under a single cover of glass with a low iron content that allows more light through than ordinary glass. The chrome black surface has been investigated by the CSIRO Division of Mineral Chemistry, and was described in *Ecos* 17.

Collectors with chrome black surfaces are now appearing on the market, but without the high-transmittance glass, which is so far available only from overseas. To illustrate the superiority of the selective surface, let us look at one of the graphs compiled from the mathematical modelling exercise. The graph on page 28 averages the collectors' performances over a whole year in Melbourne for a typical hot-water demand of a household of three or four people. The upper curve applies to a selective collector, and the lower to a non-selective one. The greater efficiency of the selective collector is striking.

Trouble in store

The report came to some pertinent conclusions about storage tanks. The tank used with a solar collector usually holds approximately 300 litres, and has an electric element about half-way up. When the element is on, it heats only the water above it, so its position determines the volume of hot water available in cold weather.

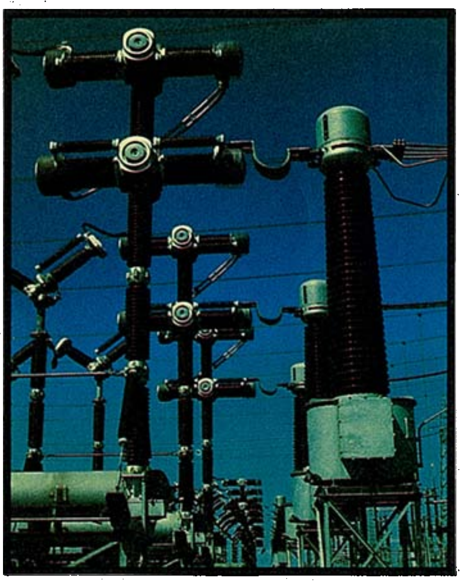
A tank of this size meets the needs of a household of three or four people if the electrical back-up is continuous, but if the heater runs on off-peak power, the 'boosted' volume must be large enough and the thermostat setting high enough both to meet the household's needs and to stay acceptably hot for at least 16 hours. The engineers fed Melbourne's sunshine and temperature figures into the computer and found that off-peak solar units needed a boosted volume of about 200 litres with the thermostat set at 75°C to be really reliable for a three- to four-person family. A similar-sized tank would be needed for such households in other parts of Australia, too.

Because the element is off for at least two-thirds of the day, an off-peak unit needs a larger thermal storage than a unit with continuous back-up. For the computer exercise the engineers assumed that the tanks were insulated with the equivalent of a layer of wool or fibreglass about 10 cm thick, but they comment in their report that commercial models usually have poorer insulation than this. The wastage can be compounded by heat loss from pipes, especially if the unit is poorly designed. In general, about 30% of the energy supplied to existing storage-type water heaters is lost from the tank and pipes.

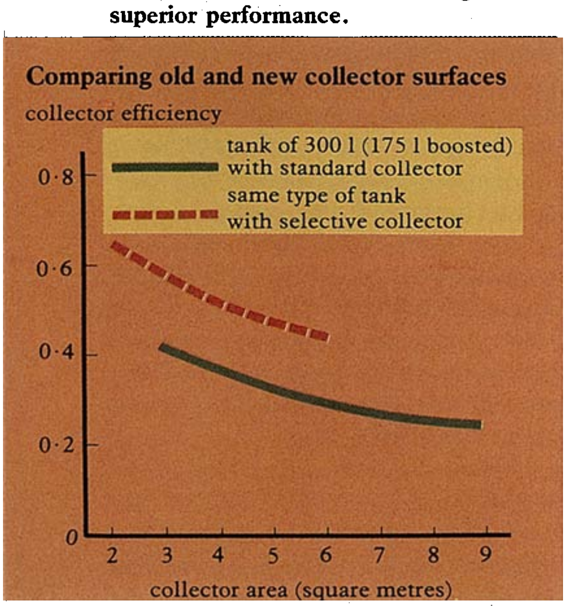
An opposite problem can beset unwary owners of solar heaters in hot weather. If the household does not draw off much hot water, the temperature in the tank can rise embarrassingly high. In an all-electric system there is a thermostat to stop the water getting too hot, but you cannot switch off the sun.

In extreme cases the water can even boil. Not only might the heater unit be damaged, but high temperatures also do more insidious harm by accelerating corrosion of the tank, especially in places like Perth and Adelaide, where the mains water contains relatively large amounts of minerals.

The switchyard at Liddell, one of six base-load power stations in New South Wales.



The newest selective collectors give superior performance.



Home economics

The study team took advantage of the computer model to look at the economics of solar heating from the consumer's viewpoint. This is a complex subject, partly because tariffs vary around Australia, and partly because the calculations must involve assumptions about the future. For this reason all conclusions must be tentative, but the report is able to say that it pays to install solar heating in some regions where electricity tariffs are high. In the future, as improved solar units come on the market and are manufactured in greater quantities, solar heating will possibly become cheaper than all-electric over much of the country.

At present, in much of southern Australia a solar off-peak heater is economically slightly less attractive than an all-electric one. The solar unit is more expensive to buy but cheaper to run, and over the assumed life of the units, about 15 years, the costs more or less even out. To obtain the greatest economy from a solar heater, a household must carefully match the capacity of the unit (the area of the collector, the size of the tank, and so on) to the consumption of hot water in the home.

Selective collectors seem to promise markedly better value for money than non-selective ones, but they have not been available long enough to confirm the characteristics assumed for them. Can a chrome black collector maintain its efficiency for 15 years? Will a selective collector with high-transmittance glass cost more than the study assumed? The economic calculations hinge on the capital costs of the units and the typical electricity costs used.

If the cost assumptions are correct, then many solar heaters would give better value with larger collectors. The usual size is about 4 sq m, but where tariffs are high enough to make solar water heating attractive it would be more economical to use a collector of 5–6 sq m. If no off-peak tariff is available the collector should be larger still, perhaps 8 sq m. These figures apply to non-selective surfaces; selective ones are more efficient and more expensive, and their optimum sizes are therefore smaller.

Solar water heating shows a great deal

Hazelwood power station, in the LaTrobe Valley, Victoria, burns brown coal to help meet the base load.

Society must plan carefully for the gradual shift in the balance of power between the pylon and the sun.

of promise for the future, but there is considerable scope for improvements in design. It will be interesting to see how manufacturers respond to the challenges offered both by the newest collector technology and by the report's comments on solar-heater design. Meanwhile researchers will go on hunting for yet-better materials.

The lucky country is not lucky enough to escape the world-wide rise in fuel costs, nor sufficiently sunburnt to ignore the findings of this CIGRE report. Society must plan carefully for the gradual shift in the balance of power between the pylon and the sun.

John Seymour

More about the topic

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