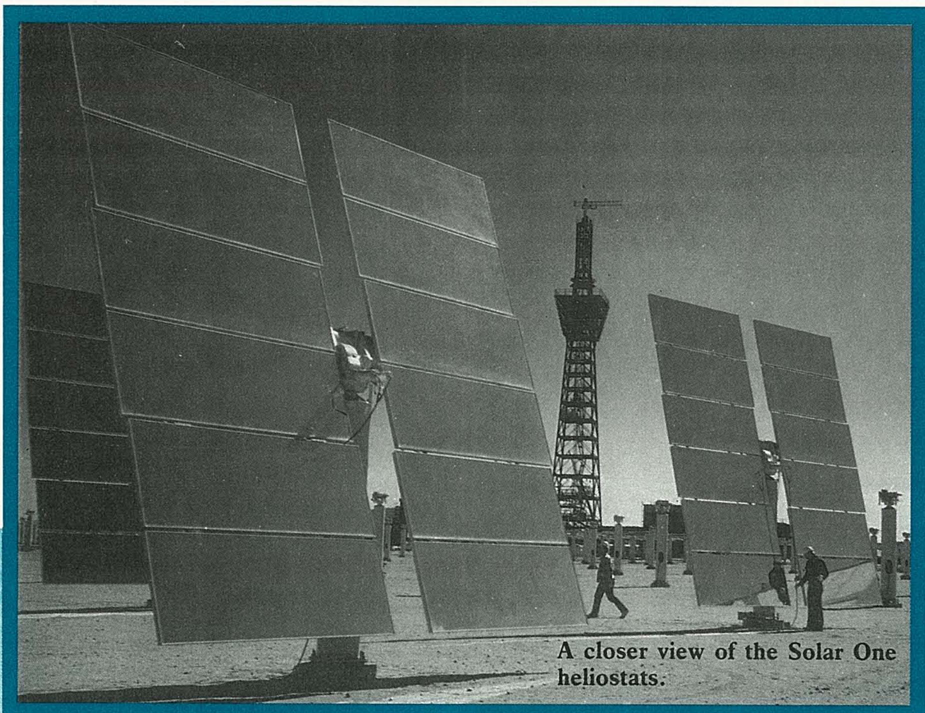
'Solar farms' for the outback?

The Northern Territory has largely relied on oil for power generation. Most centres have their own small generating diesel-plants; larger power-generating and distribution systems exist only in areas around Darwin and Alice Springs, which is about to change over to natural gas.



A closer view of the Solar One heliostats.

Populations are small and scattered, and the industrial energy market is very limited apart from an alumina refinery at Gove and mining operations at Jabiru, Warrego, Nabarlek, and Groote Eylandt. The absence of a large energy market and the presence of a number of small separate electricity generation and distribution systems result in relatively poor average energy economics.

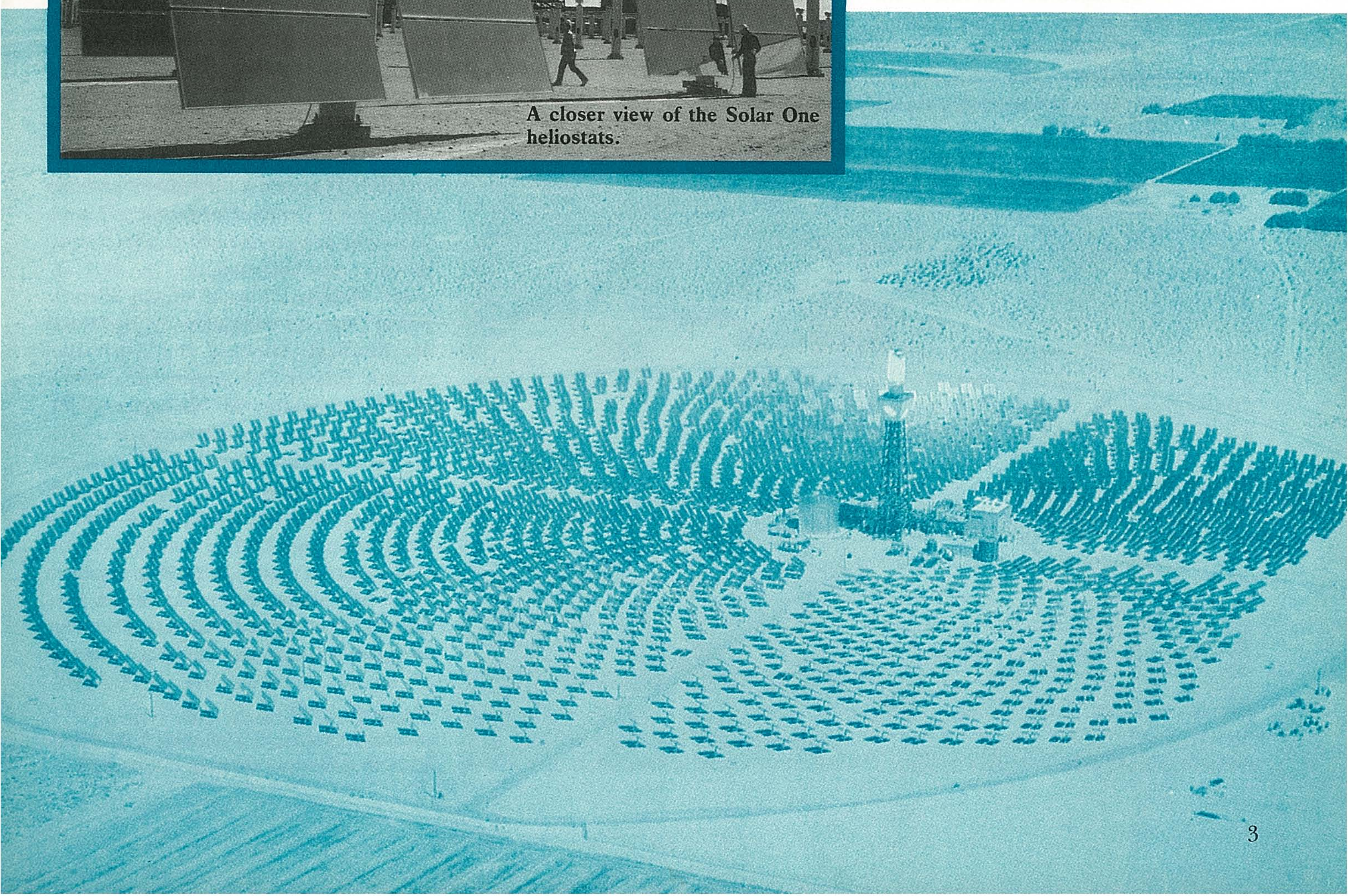
Alternative sources of power in the Territory are under constant scrutiny. Darwin will soon ship coal from interstate and nuclear power is a future possibility; but these sources are not likely to have an impact on centres of lower demand — places like Papunya and Galiwinku, with currently installed capacities of 893 kW and 1410 kW respectively.

One of the obvious alternative methods of electricity generation in this sunburnt land is solar power. Prototype solar thermal power-generating units with megawatt capacities are already operating in a number of countries, including the United States, France, Spain, Italy, and Japan.

Power towers

A solar thermal power supply uses the sun's energy to heat a fluid that drives a

Solar One, the United States' first 'power-tower' plant, at Barstow, California.



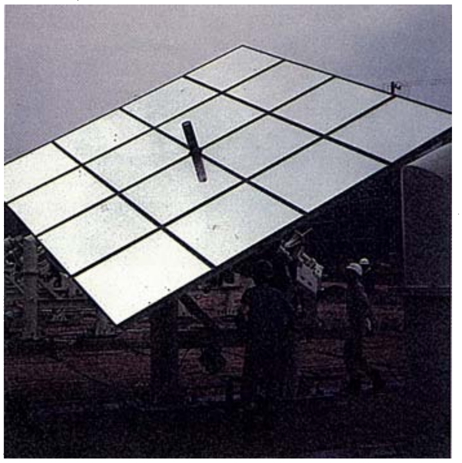
conventional generator for the production of electricity. These systems include 'power towers' (central receiver systems) and 'solar farms' (distributed collector systems).

A power tower consists of an array of mirrors around a central tower: the mirrors focus the sun's heat onto a central boiler, which contains a heat-collecting fluid, on top of the tower. The fluid is most often water or molten salt, each having different heat-collecting, transfer, and storage capacities. It is heated to a temperature around 500°C, and the system uses heat exchange to boil water, producing steam that drives a conventional turbine.

Solar farms consist of many collectors, usually parabolic dish or trough reflectors, that individually heat the circulating fluid, usually thermal oil. Piping systems then transfer the heated fluid to a boiler, which powers a turbine generator.

In 1980/81, under a joint Australia and Japan energy research and development exchange agreement, the Australian Atomic Energy Commission (AAEC) and Japan's Electric Power Development Company carried out a study of the potential for solar thermal electric power generation in the Northern Territory. The engineering designs considered were based on existing central receiver and plane-parabolic (distributed collector) systems used in a demonstration plant at Nio, Skikoku, Japan.

Each of the Nio systems has the capacity to produce 1 MW of electricity. Such megawatt-scale stations would satisfy the present energy requirements of many small outback communities in Australia. Katherine, Tennant Creek, and Alice Springs have higher installed capacities — 11·5 MW, 9·4 MW, and 36·8 MW respectively. They are potential sites for a 1-MW-scale station to supplement the conventional power supply.



One of the heliostats in the Nio 'power-tower' system.

The Kuwaiti solar farm.

The heated fluid powers a turbine generator.

The reflecting components of solar thermal power stations are called heliostats. In the Nio power tower, heliostat mirrors are made of low-iron glass 5 mm thick. The 807 heliostats have a total mirror area of 12 912 sq. m and are distributed over an area of 2·54 ha around the central receiver tower.

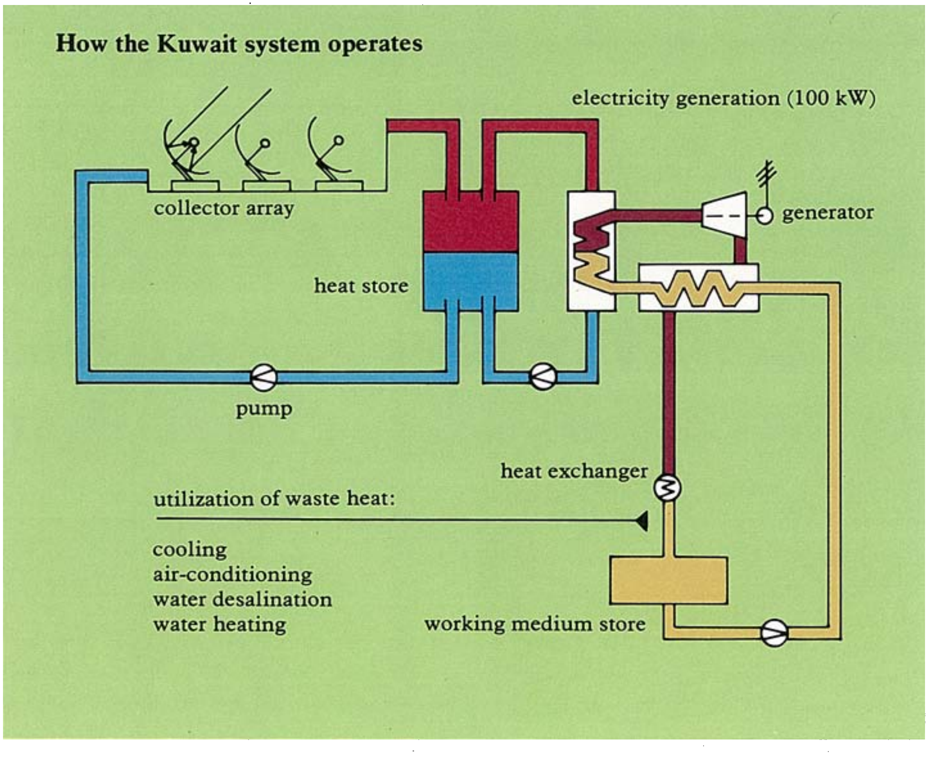
The mirrors for the plane-parabolic system are made of a sandwich of ordinary plate glass 0·7 mm thick, with a silvered reflecting surface, backed by 5 mm of float glass. The 2480 heliostats, with a total mirror area of 11 160 sq. m, are arranged in parallel rows covering 5·38 ha. Although less successful than the 'power tower' system, the scheme of energy concentration is unique — the plane heliostats that track the sun reflect direct radiation towards parabolic troughs that are not tracking.

Solar *v.* diesel

Of five potential sites — Darwin, Katherine, Alice Springs, Tennant Creek, and Batchelor–Rum Jungle — the researchers chose Katherine for their study. They found no significant technical problems in applying either of the Japanese technologies in the construction of plants there. In fact, the design performance of each system appeared markedly better than at Nio because of Katherine's sunnier location. It is nearer the equator and less often under cloud. The January–March monsoon season presented the biggest problem weather-wise.

Mr Masaomi Matsui of the Electric Power Development Company, Japan, and Mr Michael Allen of the Australian Atomic Energy Commission produced a cost estimate for the Katherine plant, based on actual construction costs at Nio, corrected for Australian conditions. They included an allowance for a diesel standby generator and support and service facilities.

Comparing their figures with the costs of a 1-MW diesel unit at Katherine, they found that diesel can generate electricity at one-quarter the cost of either solar sys-



The Kuwaiti parabolic-dish system provides heat for desalination and other uses as well as generating electricity.

The two solar thermal electric plants at Nio, Japan; each is capable of a 1-MW electricity output. The insets show the 'power tower' of the central receiving system and a set of plane-parabolic reflectors.

tem: the Katherine power tower would operate at a unit cost of $1.34 per kW-hour of electricity produced, the collector field at a cost of $1.31; and the conventional diesel plant would cost only 31 cents per kW-hour.

Why is solar electricity so much more expensive? Many of the contributing causes were associated with the remote location — high construction costs, and staffing and operating costs that were higher for the less-familiar solar station than for the diesel.

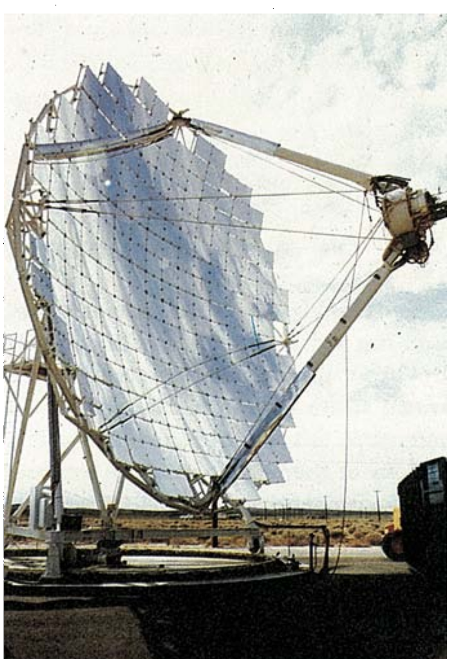
However, the report suggested that a number of significant cost reductions can be expected in the future — from further technological advances, from mass production of components, and from increased plant size — for example, from 1-MW to 10-MW stations.

In the west . . .

But the demand for solar thermal electricity in Australia will most likely be in areas requiring even less than 1 MW. One such plant is already operating in Meekathara, W.A., designed and built through the joint agency of the State Energy Commission of Western Australia (SECWA) and the West German government. Australia's National Energy Research Development and Demonstration Program (NERDDP) and the Solar Energy Research Institute of Western Australia (SERIWA) also contributed to the project.

This plant uses 30 parabolic troughs, with a total reflecting area of 920 sq. m, that track the sun throughout the day. The troughs concentrate the sun's heat onto receivers containing thermal oil, the heat-collecting fluid. After it is heated to 290°C, it passes to a thermal storage system, from which energy is drawn to raise steam that drives a screw expansion engine coupled to a conventional generator.

The 100-kW unit supplements an existing diesel station. Altogether, solar collectors provide about half of the plant's power, the other half being derived from heat recovered from the diesel exhaust. The system — expected to save 100 000 litres of diesel oil a year, valued at more than $40 000 — provides about 14% of the power required for the local population of 600.



A parabolic dish developed by Ford Aerospace in California with an engine under test at the dish's focus.

In another joint venture, SECWA and Ansaldo, an Italian company, have recently completed a 35-kW solar thermal power station at Ballajura, W.A.

. . . and in the east

An experimental parabolic-dish power station has been established by the Australian National University and the New South Wales government at White Cliffs, N.S.W. This installation, currently comprising 14 modular dishes each 5 m in diameter, is designed to produce 25 kW of electricity and 140 kW of low-temperature heat. The array of dishes will keep operating at wind velocities of up to 80 km per hour, above which the array 'parks' automatically with dishes pointed upwards. Normally the dishes park facing south, to reduce dust collection and dew precipitation.

A number of significant cost reductions can be expected in the future.

Parabolic-dish technology is also being developed by, among others, Messerschmitt–Bölkow–Blohm in Germany and the National Aeronautics and Space Administration's Jet Propulsion Laboratory in the United States.

At the CSIRO Division of Energy Chemistry in Sydney, Mr Ivan Mayer has recently begun research to produce another variant of the system. His approach has a unique feature — the solar radiation is deposited on the inner surface of the receiver after passing through a transparent window. This eliminates damaging thermal stress cycling of the receiver walls, and minimizes heat losses.

Mr Mayer has investigated methods for constructing light-weight low-cost parabolic collectors from reflective polymer film. These flimsy objects would be protected from wind forces by an air-supported enclosure of transparent plastic film — a mirror inside a giant bubble.

Farms for factories

A number of solar farms overseas already provide power for industry. One station supplies about half the energy requirements of a knitwear factory in Shenandoah, Georgia, U.S.A., including 400 kW of electricity and 3 MW of heat for garment-pressing, building-cooling, and hot

STEPS around the world

Globally, more than 20 prototype solar thermal electric power stations (STEPS) are operating or near completion, ranging in capacity from 10 MW (electrical) down to a few kilowatts.

Spain, Italy, France, Japan, Russia, and the United States are all experimenting with power towers, some of them using molten salt rather than water as the heat-transfer fluid.

The world's largest power tower — Solar One, in the Mojave Desert near Barstow, California — is already routinely producing electrical power for the southern California electrical transmission system. It can supply at least 10 MW electrical to the transmission system for 4 hours on the winter solstice and 7·8 hours on the summer solstice.

A field of 1818 heliostats with a total reflective area of 71 447 sq. m encircles a central tower, deflecting direct sunlight to an absorber on top of a 77-metre-high tower. Here, circulating water boils into dry superheated steam at 516°C. The steam can directly drive a turbine or can be diverted to a thermal storage system, a combination of thermal oil, rock, and sand.

Solar One can be controlled manually, semi-automatically, or automatically by a computer-based master control system. In its first 2 years of operation, it generated 2 million kW-hours electricity, most of which was delivered directly to the electrical transmission system. Thermal storage provided steam overnight for more than 13 hours for an average capacity of 1 MW gross.

A proposed Solar 100, a 100-MW central receiver plant located near Solar One and also connected to the southern California transmission system, uses Solar One's technology with a few modifications. For example, the use of molten salt will increase the plant's capability for storing thermal energy, and the collector field will be oriented around two receiver towers that share a common power block.

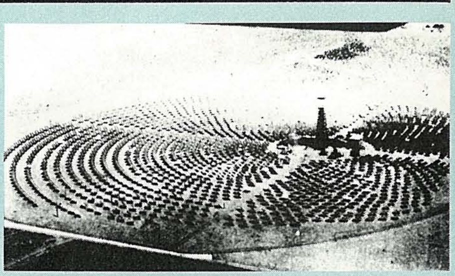
The Paris-based International Energy Agency financed the world's first molten-salt-cooled solar plant in Almeria, Spain. In their design of the heat-transfer system, the German engineers selected salt as the working fluid because its excellent heat-transfer properties and high boiling point allow heat transport at high temperatures and low process pressures. The salt also acts as a heat-storage medium.

Outside Australia, solar farms have been built in Spain, France, Mali, Kuwait, Mexico, Japan, and the United States. Most have parabolic-dish or trough collectors and use thermal oil as the heat transfer medium.

In Kuwait, Messerschmitt–Bölkow–Blohm and the Kuwait Institute for Scientific Research built a 100-kW (electrical)/500-kW (thermal) solar farm that forms the basis of a food, water, and power system providing electrical and thermal energy for greenhouses, desalination and distillation plants, irrigation, and water pumping.

The station consists of 56 point-focusing parabolic dishes; a heat-transfer oil (diphyl) is the heat-collecting fluid and toluene is the turbine working fluid. The plant is self-sustaining and satisfies the power needs of an adjacent agricultural settlement.

In addition, thermal energy from the station powers a desalination system



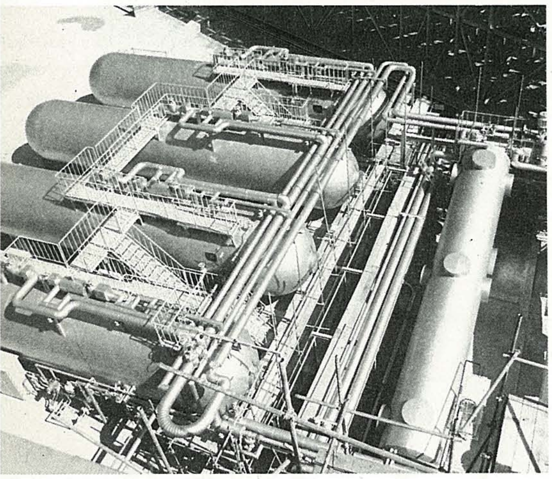
treating 45 000 litres per day. Brine from this is used in a solar pond, which contains very salty water that can accumulate and store heat from the sun; this in turn provides more energy for desalination.

Some plants produce industrial process heat only — no electricity. One solar farm in Las Barrancas, Mexico, was modified before completion so that it would produce process heat rather than generate electricity. Examples of factories supplied with solar heat energy include a chemical plant, a tractor factory, an oil refinery, a latex plant, a soup factory, and a brewery. Most of these plants use parabolic-trough collectors.

Research into improved designs and materials is continuing in countries with prototype plants. The United States has made significant progress in developing parabolic-dish systems for electrical applications during the past few years.

Progress in the design of power conversion units — comprising thermal receiver, heat engine, and generator — is increasing the efficiency with which solar thermal plants convert solar energy to electricity. More efficient engines reduce the collector area required.

New dish technology, including the use of foam glass and aluminized plastic film as reflectors, will improve the heat-collecting and focusing capacities of the parabolic collecting surfaces.



The high-pressure heat storage tanks of the plane-parabolic plant at Nio.

water. The 114 parabolic-dish collectors, each 7 m in diameter, heat a silicone fluid to 400°C; this in turn generates superheated steam for the turbine–alternator unit.

Many of the plants operating overseas have a lower energy output than expected because the amount of direct radiation was over-estimated in the design of the plant. High-temperature solar thermal systems can use only direct sunlight, not diffuse, and at the start of the feasibility study at Katherine the Bureau of Meteorology had no records of the amount available. Indeed, long-term records of direct solar radiation in Australia are held for only one location, in Victoria; for others, the direct radiation can be estimated with less accuracy from other solar radiation measurements.

As an extension of the Katherine feasibility study, the Division of Energy Chemistry (following the 1981 transfer of parts of the AAEC to CSIRO), together with the Bureau of Meteorolgy, established sets of measuring and recording equipment at three locations in the Northern Territory with NERDDP support. These have operated since 1981, and Mr Mayer, the leader of the project, would like to see a network of such stations established around Australia.

Solar thermal power stations could eventually replace or supplement diesel-generated electricity in the Northern Territory and elsewhere, when their component costs fall and the cost of diesel fuel rises. However, not only fossil fuel but solar cell systems will compete with them.

Photovoltaic cells, which convert solar energy directly to electricity, are becoming cheaper and more efficient, but solar thermal systems have some advantages. As well as electricity, these can provide heat for industrial processing, building heating or cooling, and water heating, with a resulting high net efficiency. Also they cope better during the hours when the sun doesn't shine, because heat is less expensive to store than electricity. To cope with lengthy sunless periods, however, a back-up fuel-burning energy source will always be needed for either solar power system.

Researchers at Ford Aerospace, California, U.S.A., are developing a modular solar thermal electric power plant using parabolic concentrators. From their analyses of the performance and cost of the system for small community, industrial, and agricultural applications, they concluded that is has the potential to generate electricity at a cost below that projected for fuel-burning plants in 1995.

During a recent visit to Australia, Dr Sara Busch and Dr Michael Brenner, of the Electronic Space Systems Corporation, Massachusetts, U.S.A., described a solar power system developed by their company, which can use the dishes at night for receiving television programs relayed from geostationary earth satellites.

Mary Lou Considine

More about the topic

Measurement and modelling of direct beam solar radiation for high-temperature solar thermal applications. I.F. Mayer. *Papers, Solar World Congress, Perth, August 1983.*

'Australia/Japan Collaborative Study: a Study of the Feasibility of Solar Thermal Electric Power Stations in the Northern Territory.' (Australian Atomic Energy Commission: Sydney 1981.)

The Japan/Australia STEPS study. M. Matsui and M.R. Allen. *Proceedings of Solar Energy for the Outback Conference, Alice Springs, September 1981.*