Outlook

Can we tap the power in the wind

We hear quite a lot these days about solar energy studies, but not so much about wind power, another alternative energy source. This may not seem surprising, since we all know that Australia is a sunny country but we don't necessarily think of it as a windy one. Nevertheless, it's interesting to think about whether we can contemplate obtaining a useful proportion of our electrical power needs by using wind power.

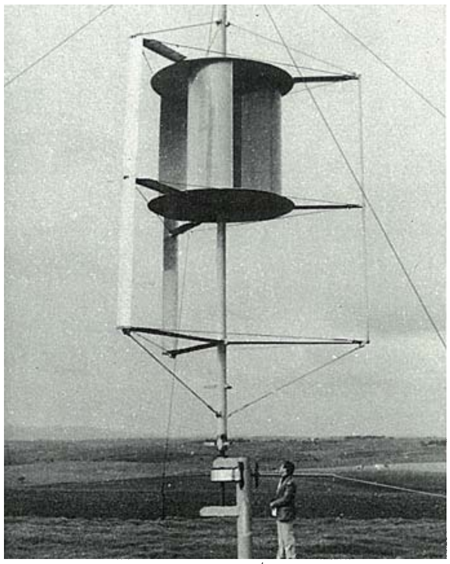
Dr Mark Diesendorf, a physicist with the CSIRO Division of Mathematics and Statistics, has been studying this question, and according to his theoretical calculations it may well be possible to make use of this natural resource.

It's a sad fact, but there is so little detailed long-term information about winds in Australia that it is very hard to discuss the subject sensibly. (We don't, for instance, have an isovent map of the country — that's a map of wind speeds equivalent to one of rainfall isohyets.) However, the windiest part is the strip of coastline along the Great Australian Bight that abuts onto the 'roaring forties', so this must be the most promising place to look.

Tasmania's western coast could also be a suitable place for using wind power, but the State already obtains as much electricity as it needs from hydroelectric power stations. Elsewhere the prospects don't seem too good.

The only comprehensive survey of the potential for wind power for any part of this continent was carried out by Mr Les Mullet for the Electricity Trust of South Australia between 1954 and 1956. He measured the hourly mean wind speeds 9 metres above the ground at eight stations in South Australia, and backed these measurements up with standard monthly meteorological measurements taken at 3 metres height at a further 20 stations. These measurements allowed him to define the general wind patterns in the State's coastal zone.

The wind speed close to the ground is slowed down by surface drag, so Mr



Not all wind generators look like large aircraft propellers. This one in South Australia spins on a vertical axis.

Mullet's readings would have understated the winds available to a windmill located on top of a high tower. Adjusting the figures from the best of his stations (those that were located on the coast or on hilltops) to a height of 50 metres gives mean annual wind speeds ranging from 8 to 11 metres per second. These are high by Australian or international standards. They are comparable with wind speeds found at many of the best sites in Sweden and Denmark — two countries that are regarded as particularly windy, which are spending several million dollars apiece on investigating the value of wind power.

Wind has the advantage of being a renewable resource. The major disadvantage is its fitfulness. It cannot be relied on to provide power at times of peak demand. Therefore, if it's going to be used effectively in large quantities, wind-generated electricity must be fed in to a large grid, or stored — both solutions present technical difficulties. What's more, the strength of the wind varies from season to season. If it becomes necessary to store the energy collected from one season to another, constructing the storage may become prohibitively expensive.

Providing short-term storage of a few days may be adequate to cover day-to-day fluctuations in the wind supply and the

Sweden will be spending U.S.$21 million on developing wind generating systems in the 3 years from 1978 to 1981.

Dr Mark Diesendorf.

demand for electricity, but this is currently a matter for debate.

British argument

Of interest in this regard is an argument that has been going on for more than a year in Britain in the pages of the prestigious journal 'Nature'. Some months ago, Professor Sir Martin Ryle at Cambridge University published a paper suggesting that wind power could make a substantial and economical contribution to Britain's electricity supply. It could do so both by substituting for energy derived from what will shortly become increasingly scarce supplies of oil and natural gas, and by supplying some of the base load currently expected to be provided from coal or nuclear power stations.

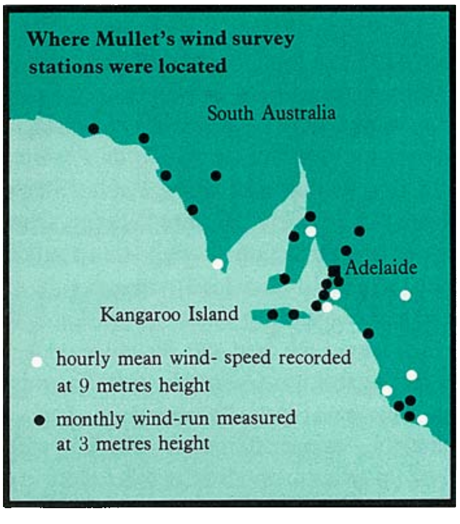
Professor Ryle pointed out that a major portion of the energy used at peak times of the year and of the day goes on space heating in commercial buildings and homes. At present a good deal of this heat is provided by burning oil or natural gas. But, as these fuels become scarcer, people may have to turn more and more to electricity for space heating.

Dramatically expanding the nation's current coal output could in theory provide the fuel to generate the additional electrical power, but in practice other demands will be made on this coal — it will be needed as feed-stock for the chemical industry and for conversion into liquid fuel for air and surface transport. Professor Ryle therefore looked into providing energy for space heating from nuclear power, and compared providing electricity by this means with producing it from alternative energy sources.

Under British conditions solar power couldn't really compete without long-term storage from season to season. This resource would provide relatively little energy in winter when it is most needed. Wind power, however, looked very promising if the fitfulness of its production could be smoothed out by providing a way of storing the trapped energy for only 150 hours.

Professor Ryle suggested that the heat needed for space heating could be stored as hot water. In other words, each house or block of flats should be provided with a large well-insulated water tank that will be heated by electricity generated from the wind whenever it's available. A thermal storage capacity of 150 hours would smooth out both the daily fluctuations of supply and demand, and also those resulting from cold spells, which may last several days.

According to Professor Ryle's calculations, installing the necessary wind generators and storage arrangements would not only cost less than building the equivalent generating capacity as nuclear power stations, but would also cost less to run. So far his thesis that ensuring a reliable heating supply requires storage of a few days rather than weeks has survived several onslaughts, including one from Britain's national electricity supplier, the Central Electricity Generating Board. In support of Professor Ryle, Dr Diesendorf and a CSIRO colleague,



L. F. Mullet's study of the coastal zones of South Australia was the only regional survey of the potential for wind power that has been carried out in this country.

Professor Ryle's estimated costs of producing 1 gigajoule of electricity per year

	capital cost ($)	running cost ($)	total cost over 20 years ($)
nuclear without storage	174	3·6	246
nuclear with 150 hours storage	90	2·1	132
solar panels with 150 hours storage	85	0·5	95
wind with 150 hours storage	49	0·8	65

Figures for the costs of producing 1 gigajoule of electricity per year from nuclear, solar, and wind power (in U.S.$ at 1975 prices). Wind power appears to undercut the others.

Dr Mark Westcott, have recently published a letter to 'Nature' indicating that many of the Board's criticisms can be overcome. For Australia, few calculations of the type being debated have even been done.

What's the potential?

Putting aside for the moment the problems of feeding electricity into the grid and storing it, what sort of potential for generating electricity could the windy coastline of the Great Australian Bight theoretically have? Australia's particular difficulty is that, although this region may have the best potential, most people who would use the electricity generated don't live there. What's more the costs of installing power lines to transmit electricity from the Nullarbor Plain to where it's needed are enormous. There would also be considerable power losses during transmissions over such huge distances.

For these reasons, Dr Diesendorf has restricted his calculations to suitable areas that are within 50 km of existing or proposed State grids. On the eastern side of the Bight these restrictions still leave a continuous strip that stretches from the Victorian border to beyond Ceduna — a span of about 2000 km.

Most scientists looking into the use of wind power on a large scale currently seem to agree that the best results will be gained using wind generators with a capacity to produce about 1–2 megawatts (MW). According to Dr Diesendorf's calculations a single line of 2–MW wind generators located along 1200 km of the coastline on the eastern side of the Bight at intervals of half a kilometre should provide 8·4 terawatt hours (TWh) per year (1 terawatt is one million megawatts).

By comparison, the entire electricity output of the Electricity Trust of South Australia's existing plant during the financial year 1976–77 was 5·26 TWh. So the amount of electricity theoretically available from that 1200 km strip is much more than South Australia alone could use. (Even this 5·26 TWh of electricity could not, of course, be entirely replaced with wind power, since even with short-term storage of a week or more incorporated into the system the fluctuations in the supply would be too big or too expensive to control.)

Putting in a second row of windmills far enough inland to avoid shielding from the first row would in theory provide a similar amount of electricity. Although the wind speed inland will be lower, it turns out that the length of the strip of suitable land available is greater.

Dr Diesendorf further calculates that the section of the Western Australian coast stretching 350 km from Cape Naturaliste to Albany, which again is both windy and located near the Western Australian grid, could also make a sizeable contribution. On his estimates, 700 units, each of 2 MW and located half a kilometre apart along this 350-km coastline, should provide about 1·7 TWh per year. (The energy production fed into that State's grid in the year 1976–77 was 4·05 TWh.)

Thus in all, he calculates, Australia's wind power potential from a double line of windmills along the 1200 km of South Australia coast and the 350 km of Western Australian coast could perhaps be as high as 20 TWh per annum.

But can it be used?

How much of this power potential could be used is an open question — even if people are prepared to put up with the sight of one or two lines of 80-metre-high windmills located 500 metres apart.

As Dr Diesendorf admits, realizing even a small part of this potential won't be possible without considerably increasing the specification of the existing power grids, or finding effective ways of storing the power generated. In addition, there will be difficulties with feeding the power generated into the grids.

Another major problem to solve if a large amount of energy derived from the wind is

Using excess electricity to pump sea water into reservoirs atop the cliffs along the Great Australian Bight has been suggested as one way to store wind power. Releasing the water through generators would provide electricity when it was needed.

actually going to be used is how to store it so that it will be available at times of peak demand. Professor Bockris, formerly of Flinders University, proposed the idea of the hydrogen economy as an efficient method. However, developing this will take many years. Two less-exotic approaches may offer more immediate solutions.

The first of these is to use any excess power generated when demand for electricity is low to pump water uphill into reservoirs so that it can be used to generate hydroelectricity when it's needed. This is known as pumped hydroelectric storage. The second is to use what are called 'super-flywheels'.

There's nothing new about either of these pieces of technology. The Tumut Three development in the Snowy Scheme is a pumped-storage arrangement. The flywheel is nothing more than a heavy wheel mounted so that it can free-wheel with the minimum of friction, and hence store energy as the momentum in its spin. The Russians used a steel one in conjunction with a wind generator back in 1920. The use of materials other than steel should make it possible to store much larger amounts of energy in the same volume.

Perhaps pumped hydroelectric storage looks like being the only suitable contender in the near future. Yet South Australia seems a particularly bad place to contemplate storing energy by this means, being both flat and arid.

Dr Diesendorf suggests that the problem may be solved by connecting the South Australian grid to Victoria's. Surplus wind power might then be exported to Victoria for immediate use there, or any excess could conceivably be stored in reservoirs located in the Great Dividing Range.

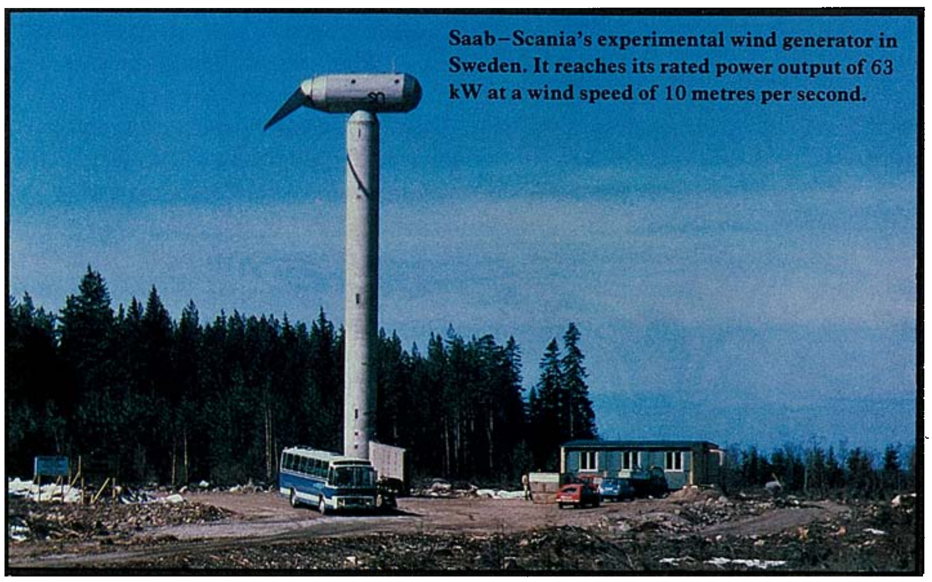
Interestingly, Mr K. A. Howard of the Victorian State Electricity Commission estimated back in 1970 that, leaving environmental considerations aside, the untapped potential for pumped storage in that State far exceeds the amount that could be usefully incorporated in the State's generation system. However, any proposals to put in large numbers of reservoirs in the Great Dividing Range would, no doubt, be objected to on environmental grounds. Incidentally, the idea of connecting the two grids is not new. The two States have discussed it in the past, but not in relation to wind power.

Designing large mills

Even if feeding electricity into the State grids and storing it does prove feasible, what about the windmills themselves? Probably it's fair to say that no major technological breakthroughs are needed. The 2-MW wind generator at Tvind in Denmark, the world's largest, has now been operating for about a year.

Certainly there is still scope for development. Engineers need to learn more about designing such windmills — as NASA's experience with its 100-kilowatt (kW) generator in Ohio has shown. This has a two-bladed turbine located downwind of the tower on which it is mounted. The problem here was that the momentary reduction of force on the turbine as each of the two blades passed the tower caused it to become momentarily unbalanced and destructive resonances caused cracking.

The much larger Danish Tvindmill has three blades, which has reduced this particular problem. It provides space heating and electricity for three local schools. During windy periods it will produce much more than the 200–300 kW they need, so surplus energy will be sold to the local electricity grid. During calm periods the schools will buy back energy at off-peak rates from the grid.



Saab–Scania's experimental wind generator in Sweden. It reaches its rated power output of 63 kW at a wind speed of 10 metres per second.

It's interesting that the local power company will pay about 2 cents per kilowatt hour (kWh) for the surplus electricity generated, yet when the schools buy back off-peak power during windless periods they will have to pay about 4 cents per kWh. The difference may seem inequitable, but the local electricity company regards the extra power purely as fuel oil saved when running its diesel generators.

Right strategy needed

This fact illustrates very well one of the difficulties that arise when large-scale generation of power using the wind is under discussion. To date, electricity suppliers in most countries have thought of wind power as a saver of fossil fuel, but not as a saver of the capital cost of back-up equipment such as diesel motors or gas turbines for providing emergency power at peak times. Without some form of storage of the energy obtained from wind power this thinking may apply, but it's becoming increasingly apparent from studies in North America and Europe that, with storage and suitable strategies for using the stored energy, wind power can make a worth-while contribution to a country's base load requirements as well as to its needs at times of peak demand.

Of course the acid test for wind power, assuming that it is technically feasible, must be whether it can be economic. Unfortunately, comparing its economics with those of other methods of making electrical power is very difficult. However, in Denmark, the Academy of Technical Sciences has estimated that wind-generated electricity without storage would cost about

Denmark's Tvindmill

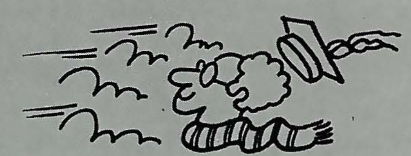
The Tvindmill, the world's largest wind generator, is located at Tvind close to the North Sea coast of Denmark. Building the Tvindmill was a remarkable achievement in the best traditions of self-help. It cost just under $A1 million.

None of this money came from the government, a large private foundation, or a corporation. Instead it came from a fund into which the school-teachers who built it (along with some volunteer labour) agreed to contribute their salaries for 3 years. This huge wind generator stands between a group of three residential schools located on flat land about 10 km from the coast. It was built to provide economical space heating and electricity for the three schools. Its huge blades began to turn for the first time on Easter Sunday, March 26, last year.

It's a massive structure. The blades, which sweep a disc 54 metres in diameter, are supported atop a 53-metre concrete tower. (The 100-kW NASA–ERDA machine in Ohio has a tower 30 metres high that supports a turbine 38 metres in diameter.) Each of the Tvindmill's three hollow blades weighs 5 tonnes, and was hand-made out of fibre-glass, epoxy resin, and PVC. The blades each contain a small parachute that can be used to slow them down in an emergency.

In fact Tvindmill is an extremely sophisticated piece of machinery. Its speed of rotation is variable up to a designed 42 r.p.m., at a wind speed of 15 metres per second. In higher winds the speed of rotation is kept constant by altering the pitch of the blades. At lower wind speeds it can be controlled by adjusting the load on the generator. A microprocessor located in the hub monitors such features as the wind speed, speed of rotation, temperature, and strains within the blades. It passes the information to a mini-computer housed on the ground. Ultimately this mini-computer will provide completely automatic control.

Obviously, a machine like this that can produce up to 2 MW of power will provide a great deal more electricity during windy periods than the 200–300 kW needed by the three schools. Surplus power is therefore being transformed down to 440 volts, rectified to direct current, and inverted to 50-cycle alternating current so that it can be sold to the local electricity grid. During windless periods the schools will buy back power at off-peak rates from the grid. Heat for space heating will be stored by feeding the electricity generated through heating coils in a 3000-cubic-metre reservoir. This reservoir should hold enough thermal energy to cover a windless period of 7 days — which is longer than has ever been recorded in that region.

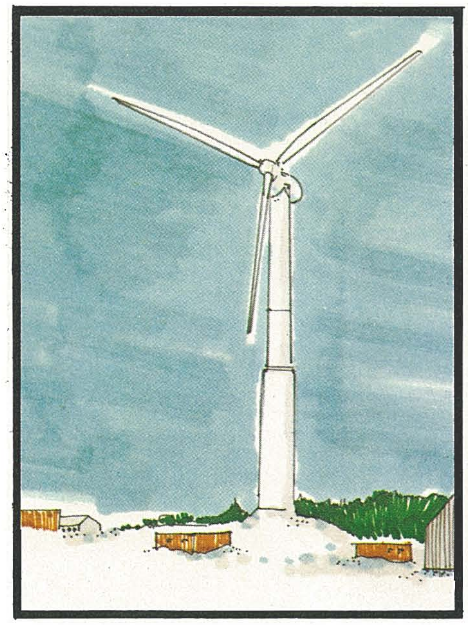


1·3 cents per kWh over the lifetime of the wind generator at 1975 prices. In Canada the estimated cost of electricity from a 200-kW-rated wind generator in the Gulf of St Lawrence is about 1·6 cents per kWh at 1976 prices.

Using 1000 Tvindmill-sized generators each costing $1 million apiece and assuming a working life of 25 years, Dr Diesendorf has estimated that the cost of electricity produced in Australia without storage would be about 2 cents per kWh at 1977 prices (the actual interest rates available when the capital is borrowed to build the wind generators will affect this figure). The State Energy Commission of Western Australia seems to have come up with the same figure independently.

Interest in the west

All the mainland States, except Western Australia, currently generate most of their electrical power from locally mined coal or from natural gas for considerably less than 2 cents per kWh. Perhaps it's not surprising that Western Australia is the State showing the most interest in investigating wind power. Imported oil makes up about 20% of the fuel used to generate electricity there, and the contract price of fuel oil supplied to the State Energy Commission in 1977 was about $77 per tonne, which works out at about 1·9 cents per kWh of electricity



An artist's impression of the 2-megawatt Tvindmill, the world's largest wind generator.

generated. The Commission is therefore particularly interested in reducing its dependence on imported fuel by finding other ways of producing electrical power.

Recently it has called for tenders for a wind generator with a rated capacity of about 50 kWh. It hopes to instal it on a trial basis at windy Cape Leeuwin and feed the electricity generated into the State grid.

At a price of 2 cents per KWh, the power being fed into the grid will certainly not be

Wind has the advantage of being a renewable resource. The major disadvantage is its fitfulness.

Volunteers roll one of the blades of the Tvindmill out of the hangar where it was constructed.

economic under present circumstances in much of Australia. However, in Sweden and Denmark the situation looks very different. Sweden will be spending U.S. $21 million on developing wind generating systems in the 3 years from 1978 to 1981. It spent U.S. $4 million between 1975 and 1978.

In Denmark the government has

appropriated U.S. $4 million to be spent on wind power studies in the 2 years from December 1976, and DEFU, the research organization of the Danish electricity utilities, has committed a further U.S. $500 000. The Academy of Technical Sciences has estimated that electricity fed into the country's grid after being generated by large windmills would actually be economic today because of the imported fuel oil it would save.

The situation in these two Scandinavian countries may be different from that in Australia, but wouldn't it be wise to thoroughly investigate our potential for wind power as a hedge against the day when we too may need it?

More about the topic

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Small windmills studied

While Dr Diesendorf has been investigating ways of using large 1- to 2-megawatt (MW) wind-powered generators, Dr Julian van Leersum of the CSIRO Division of Mechanical Engineering has been taking an interest in small ones. Recently he has taken delivery of a 5-kilowatt (kW) Swiss Elektro wind generator, which he hopes to instal at Port Melbourne.

Australia has of course for years been a world leader in making small wind generators — the famous Dunlite 2-kW machine that graces many an outback property first went on the market more than 40 years ago. This windmill has gained an impressive reputation for its sturdiness and reliability. It has been sold in many countries, and in particular in the United States. A larger 5-kW model is coming on the market.

Small generators like the Dunlite certainly have their place. They have served remote homesteads well by providing electricity and charging the banks of lead–acid accumulators that even out the fluctuating supply. But sadly, Dr van Leersum points out, the Utopian dream that urban householders can make themselves self-sufficient by erecting windmills in their backyards has many problems.

To begin with, large Australian cities do not have enough wind. Even those southern ones located in the westerly wind belt of the 'roaring forties' (like Adelaide, Melbourne, or Hobart) don't have enough because trees and buildings greatly reduce the wind's speed. The only really suitable sites for windmills are those located right on the coast, or particularly exposed ones on top of treeless hills.

It has been estimated (not by Dr van Leersum) that a citizen of Melbourne, to supply a quarter of the amount of electricity currently consumed in the average Victorian home, would have to erect a wind generator with a blade diameter of at least 7 metres. For every house to have such a turbine, each mounted atop a 20-metre tower, would clearly raise enormous safety problems, and each windmill would interfere with the wind reaching others.

What's more it would be surprising if most people would put up with the sight of suburbs looking like a forest of windmills. (In addition, large numbers of rotating metal blades would play havoc with reception of 'footy' on T.V.)

Dr van Leersum is therefore looking at small wind generators in the expectation that they will be used for specialized applications. The Queensland State Electricity Commission, for example, is looking for ways of providing electricity to all consumers at a uniform cost. For some locations remote from the grid, small wind generators may have a part to play.

Dr Van Leersum's 5-kW Elektro wind generator looks like this.

Dr van Leersum is currently following two lines of research. Firstly, he is looking for a simple design procedure for deciding what equipment to instal if somebody wishes to put in a wind generator at a particular site. He hopes to come up with a way for that person to decide just how much energy he can expect to get, what would be the optimum-sized turbine, how much storage as lead–acid accumulators would be required, and what form of back-up as diesel generators would be needed to obtain a reliable electricity supply.

At present, making these decisions is no easy task, and installing the wrong equipment costs a lot of money. Once wind-speed data have been gathered for the particular site concerned, Dr van Leersum thinks that it should be possible to use formulae that will make such decisions much easier.

The other line of research will be to study just how efficient wind-operated machinery really is. In theory it should be possible to convert up to nearly 60% of the power in the wind into electricity. In practice the figure is not likely to exceed 45%. There are good reasons for this. For example, windmills may not react quickly enough to pick up the power from high-frequency gusts. Since the electricity generated varies as the cube of the wind speed, considerable generating potential must be missed.

To begin with, Dr van Leersum will test his 5-kW wind generator against theoretical mathematical models of what its electrical output from particular winds should be. The site at Port Melbourne where he hopes to erect it is a relatively windy one by Melbourne standards. Perhaps at a later date he will be able to draw on the experience of appropriate companies to find ways of improving this wind generator's design.