Renewable Energy for Development

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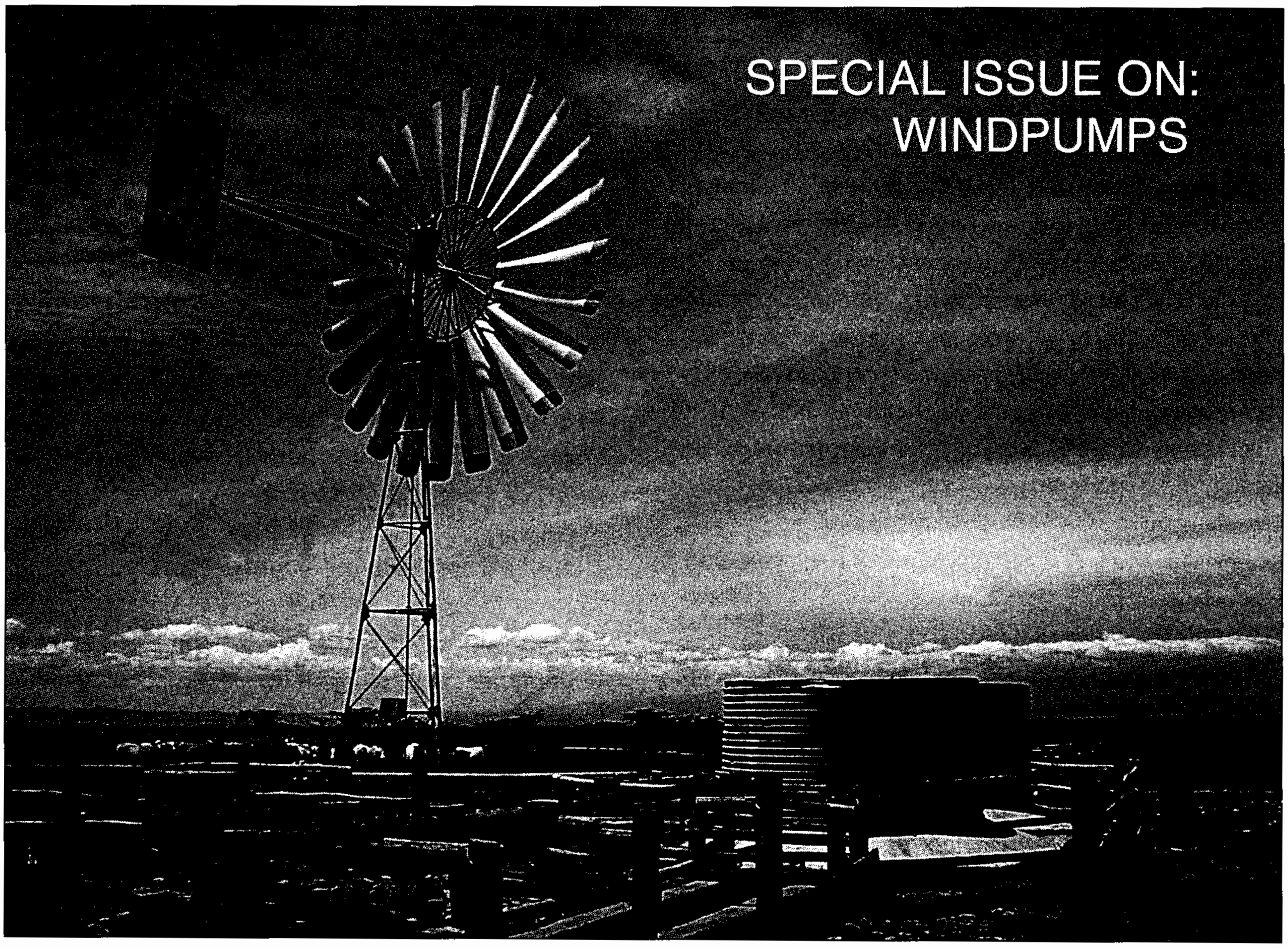


A 7.1 m diameter "Kijito" windpump manufactured by Bobs Harries Engineering Limited, Thika Kenya.

This issue of "Renewable Energy for Development" is dedicated to the topic of windpumps. Windpumps represent a welldeveloped technology which has been applied worldwide. After World War II the use of windpumps, however, started to decline, due to extensive electrification of rural areas and access to low cost fossil fuels. But there are still more than one million windpumps in use, mainly in USA, Australia and Argentina.

During the 1980s, considerable technological development took place to make windpumps less costly, more reliable and easier to maintain. We think that windpumps have a role to play, for water supply to people and cattle, for drainage and for irrigation, especially to develop nonelectrified rural areas in the developing countries. Windpumps represent a mature, environmentally benign, renewable energy technology which is competitive and economic in many places. The text in this special issue is a summary from our new book titled "Windpumps. A Guide for Development Workers", which is pictured on the back cover. The aim of the guidebook is to provide information on the technology, economics, performance, experience and potential of windpumps for water- pumping in developing countries. Other uses of windpower in developing countries are also briefly described in this Newsletter.

Lars Kristoferson, Vice-Director SEI

Why Windpumps?

Windpumps are wind-driven machines for pumping water. The Technical Committee on Wind Energy at the United Nations Conference on New and Renewable Sources of Energy in 1981 foresaw... "wind energy playing a significant role in pumping water for households, animal husbandry, irrigation and drainage in rural areas of developing countries." The committee concluded that the potential for windpumps in the developing world would run into "many millions".

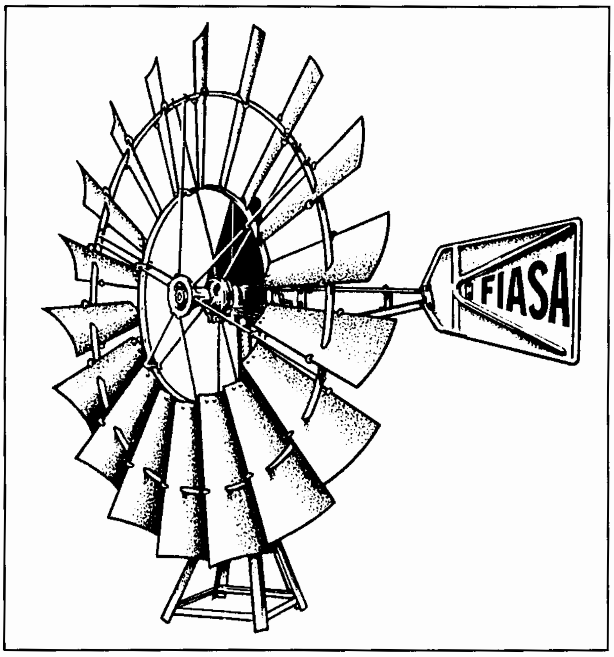
However, in the years since 1981, the dissemination of windpumps in the developing countries has been limited. There are several reasons for this. Most of the aid money for energy went to big-scale centralized energy systems. A lot of the development money allocated for windpumps, went to new windpump designs, a difficult and time consuming process. To make reliable windpumps, quality is essential, but this can be difficult to achieve in a developing country situation. Windpump economy often depends on long-term loans, which can be difficult to obtain in a developing country. Appropriate information about windpumps, available products, their implementation and costs have also been difficult to find.

We still think that windpumps can play an important role in development, and with this newsletter and the book upon which it is based, we intend to overcome at least the information gap, and to provide a new base for windpump introduction.

In the same way that windpumps were catalytic in opening up to economic development the Great Plains of the USA, the Patagonian Plains of Argentina and the outback of Australia, they are proving to be invaluable in the development of the livestock industries in Africa, Asia and Latin America. In Kenya for example, more than 200 windpumps have been manufactured, principally for livestock watering. Other countries with significant livestock herds, such as Botswana, Namibia and Zimbabwe, are finding windpumps to be well suited for meeting livestock water demands.

The vast majority of windpumps in use in the world today (around 500,000 - 750,000) are for livestock and village water supply and to a more limited extent irrigation.

India has embarked on a programme of windpump dissemination with full government support. More than 2,000 windpumps are now in use, mainly for irrigation, but also for water supply and pumping sea water for salt production.



The top of one of the more than 30 000 FIASA Windpumps manufactured in Argentina and exported worldwide.

Though there is the potential to install several million windpumps in the developing world, the numbers installed to date remain limited in comparison. Only a few developing countries manufacture more than 100 windpumps per year.

Principal Benefits of Windpumps

- They are often the most economic method of pumping water in rural areas where the average wind speed in the least windy month is greater than about 3m/s, and no grid power is available.
- They have no fuel requirements, contrary to engine-driven pumps which require expensive fuel that is difficult to obtain in rural areas.
- They represent an environmentally sound technology, though there is some noise, and visual impact.
- They are highly reliable given regular maintenance, and are also less vulnerable to theft or damage than other systems.
- They can last a long time, typically 20 years for a well-made, regularly maintained machine.
- They can be locally manufactured in most developing countries, creating indigenous skills and reducing foreign exchange requirements for costly diesel fuel and equipment.

International Programmes

The Global Windpump Evaluation Programme

In November 1986, the World Bank and the United Nations Development Programme (UNDP) initiated a preparatory phase for a Global Windpump Evaluation Programme (GWEP). The preparatory phase included country studies on the current position of and prospects for windpumping in seven African, four Asian and three Latin American countries. The preparatory phase also included development of test standards and procedures.

The report of the GWEP preparatory phase concluded that the potential for windpumps remains good and recommended a Global Windpump Implementation Programme (GWIP). Despite the need, such a programme has not been created.

The IT Power Windpump Programme

Intermediate Technology (IT) Power is an associate company of the Intermediate Technology Development Group (ITDG) in the UK. The origin of the IT windpump programme is traceable to the British engineer Peter Fraenkel. In 1975 he was working in Ethiopia on the development of low-cost informally-manufactured windpumps of the Cretan-sail type. This village level "do-it-yourself," low cost approach failed to produce reliable windpumps.

In 1977, ITDG began co-operation in the manufacture of windpumps with six institutions in developing countries. By 1979, five out of the six had manufactured and installed working prototypes. In 1981, IT Power sought and was awarded a research contract by the UK Overseas Development Administration (ODA) to finalise the design of the 6 and 7.5 m diameter IT windpumps.

The IT Windpump is of the direct-drive, crank-transmission type that requires no casting and thus is easily fabricated in developing countries. The design, which received significant input from the Kenyan collaborator, is now manufactured commercially by original collaborators in Kenya and Pakistan, as well as in Nigeria and Zimbabwe. More than 300 IT windpumps have now been installed, mainly in Kenya.

In 1990, with assistance from an European Commission grant, IT Power embarked on the development of affordable, high performance, ultra-reliable, small diameter windpumps. The design will be available in rotor sizes from 1.5 to 4 m diameter. The first prototype (3 m diameter) was installed in December 1992.

The CWD Programme

In 1975, at about the same time that the IT windpump programme began, the Steering Committee on Wind Energy for Developing Countries (SWD) was established in Holland, funded by the Netherlands Ministry for Development Co-operation. SWD was a joint activity of the Eindhoven University of Technology, the Twente University of Technology and DHV consultants. The programme changed its name to Consultancy services in Wind energy for Developing countries (CWD) in the mid-1980s.

CWD developed a range of small diameter windpumps with direct-drive transmission ranging from the 2 m diameter CWD 2000 to 5 m CWD 5000.

Concentrating on irrigation applications rather than water supply, CWD co-operated in the development and manufacture of CWD windpumps in several countries, including Cape Verde, Morocco, Mozambique, Nicaragua, Tanzania, Sri Lanka, Sudan, Tunisia and Zambia.

In July 1990 the CWD programme was ended. By that time almost 500 windpumps had been manufactured by Third World organisations and workshops. Most have since ceased production. Reasons cited for withdrawing from the windpump market include reliability and technical problems in manufacture. Economic reasons include having to compete with subsidised fuel for engine-driven pumps.

The Danish "Folkecenter" Wind Programme

The Folkecenter for Renewable Energy has been working on development of technologies for the developing countries since the centre was founded in 1983. The first project was the development of a mechanical windpump in connection with CWD. They installed a CWD 2740 in Mauritania in co-operation with the Lutheran World Foundation, and established a workshop for production of these pumps.

Later on, with the CWD 2740 as a starting point the Folkecenter developed a windpump of 3.6 m rotor diameter. This pump is manufactured in Denmark, but has not yet been implemented in any developing country.

Parallel to the work with the mechanical wind pumps the so-called multi-purpose concept has been developed: i.e. an electricity producing turbine with many possibilities of application, such as: water pumping, grinding of grain, lighting, running of smaller workshop machines, etc. The turbine has been installed in Zambia and two other demonstration plants are in preparation, one in Gambia and one in India.

In June 1990, a comprehensive measuring programme of 7 different Danish windpumps was finished. Six with mechanical and one with electrical transmission systems.

Windpump Production Worldwide

Africa

Kenya has two main manufacturers of windpumps and some other enterprises assembling windpumps informally. There are over 360 windpumps installed, the majority being the Kijito, IT based machine. The Kijito is a large diameter windpump used mainly on deep wells. More than half of Kenya has average annual wind speeds over 3 m/s.

In Mozambique at the Gaza Province Agricultural Department, approximately 50 units per year were manufactured of the Dutch Steering Committee on Wind Energy for Developing Countries (CWD) 2740 design. However, production was interrupted during unrest in the country.

South Africa, where there are about 100,000 windpumps, remains the largest market in Africa. New installations have slowed recently as a result of economic problems and displacement by photovoltaic pumps. In Gezira, about 150 conventional gearbox design windpumps installed in the 1950s have been abandoned (the last one in 1965) as a result of lack of spare parts and increase in village populations.

In Zimbabwe, two companies are manufacturing windpumps - Stewarts & Lloyds and Sheet Metal Kraft (SMK). Stewarts & Lloyds manufacture the UK designed IT windpump (6 m diameter) and Climax windpump designs of 2.6 m diameter upwards (gearbox types). The SMK design is a 3.6 m diameter 18-bladed windpump. Approximately 200 windpumps have been installed and sales are around 30 per annum.

In Botswana and Namibia, where there are large livestock industries, there have been successful windpumping experiences, including manufacturing.

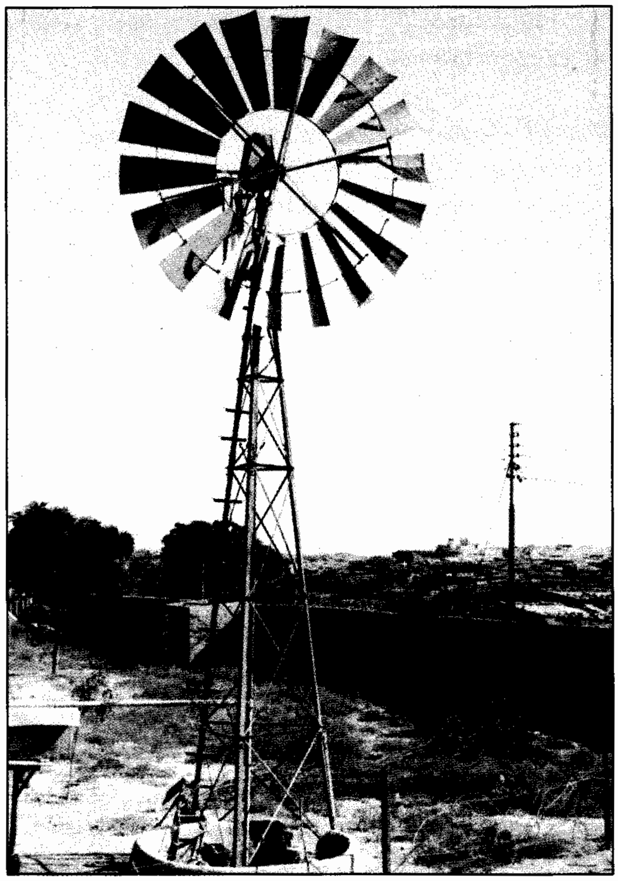
Morocco has a long history of using windpumps. The Centre des Energies Renouvelables (CDER) has been co-operating with CWD on the 5 m diameter Atlas windpump.

Tunisia is reported as having a market of 50 per year and has one local manufacturer (SEN). Larger markets are estimated in Algeria, Egypt and Libya.

Asia

China has a long history of windpump use. In 1959, about 200,000 wooden windpumps were in use in Jiansu province. By 1963 the number in use declined to about 130,000, and in 1992 reached a low of approximately 1,700 in the whole of China. The Chinese Wind Energy Development Centre (CWEDC) is undertaking most development of windpumps, in association with the Chinese Academy of Agricultural Mechanisation Sciences (CAAMS), various academic institutes and the Xinghua Tractor Factory. For use in Inner Mongolia and Gansu, high-lift geared windpumps have been developed with rotor diameters from 2 m (the FD-2) to 6 m (the FD-6).

Mongolia has imported Russian windpumps for the livestock industry but was reportedly dissatisfied with the technology. Small diameter Akrobaatti windpumps from Finland were also demonstrated under a UNDP programme. Given the 100,000 nomadic livestock-herding families in Mongolia, a potential market of several thousand windpumps is assumed for livestock-watering stations.



The Merin 3.7 m windpump from Pakistan.

The first indigenous concerted efforts to apply windpumps in India began in 1952 under the auspices of the Council for Scientific and Industrial Research (CSIR) and later the National Aeronautical Laboratory (NAL). Some 160 Southern Cross windpumps were imported during the late 1950s but most were abandoned after a few years due to lack of trained staff and spare parts. By 1966 some 70 WP-2 locally manufactured machines were fabricated but then production ceased through lack of interest. After the 1973 oil crisis, interest was revived by the Department of

Science and Technology and a national demonstration programme was initiated for the sixth plan (1980-85). 1985 more than 1,700 windpumps had been installed, mainly of the 12-PU-500 model manufactured by research institutes. By the end of 1992 some 3,500 windpumps had been installed and the Government's eighth plan (1990-95) calls for a target of 5,000 windpumps installed with full commercialisation. There are approximately 20 companies manufacturing or assembling windpumps in India. The most active of the windpump manufacturers are NEPC in Madras, BHEL in Rudrapur, the Scientific Instrument Company in Madras and Wind Fab in Coimbatore.

Pakistan has potential for windpumps in the coastal regions, particularly in Sind Province. The local manufacturer, Merin Limited, manufactures the Tawana windpump which is based on the IT Windpump (6 m and 7.5 m diameter). The company has exported its Tawana windpumps to Nigeria and the Middle East. A commercial market of 200 to 300 windpumps per year is estimated.

The Philippines has a high potential for windpumps, principally for water supply. More than 200 conventional gearbox windpumps have been manufactured and installed locally and many are reportedly working successfully after more than ten years operation.

Sri Lanka has had poor experience with windpumps as the locally manufactured WEU I/3 windpump suffered from reliability problems. The Government Water Resource Board terminated its windpump programme in 1987.

Thailand has a windpump industry that has produced more than 2,500 units. Research is being undertaken by the King Mongkuts Institute of Technology.

South America

Argentina is one of the success stories of windpumping in developing countries. Output is around 5,000 per year, representing a significant proportion of global windpump production. The success has been achieved without any government involvement or assistance and few government orders.

The first windpumps were imported from the USA in 1876 and subsequently manufactured by the Lanus Roland Company. Large-scale manufacture of windpumps was started by the Instilar Company in 1937. The subsequent production of this 1930s- design gearbox windpump to satisfy US and Argentinean markets (principally for livestock watering) soon grew and the FIASA windpump is now one of the most widely-sold. There are also at least 10 other manufacturers of windpumps in Argentina. The total number of windpumps is reported to be as high as 600,000. The price of Argentinean windpumps are typically US$500 for a 2.7 m diameter machine and US$800 for a 3.4 m diameter machine excluding works. Wind speeds in Patagonia average 4.5 m/s, and in the wet Pampa region around 2.5 m/s.

Factors influencing the success of windpump dissemination in Argentina can be summarised as:

- high wind speeds (compared to Africa);
- the large livestock industry;
- the initially guaranteed export market (to a US licenser);
- sub-contracted component manufacture involving large numbers of companies and thus many experienced people;
- sub-contracted maintenance and repair, letting manufacturers concentrate on production and marketing;
- the development of teams to undertake major repairs and servicing; and
- good user maintenance.

Bolivia has been producing the Condor 2 m diameter simple windpump based on the Gaviotas design of Colombia. Two other organisations, CIPER and SEMTA, are producing designs based on the TOOL 12-PU-350 and 12-PU-500 designs.

Brazil has 12 manufacturers producing conventional gearbox windpumps with at least 7,000 installed and almost all under 4 m diameter.

Colombia, after Argentina, is South America's most significant windpump market with some 3,000 imported units installed (of which half are abandoned) and a thriving local industry (Las Gaviotas) which has sold 9,000 MV2E 2 m diameter machines with an annual market of over 1,000 units. These machines are limited to low-head pumping and so the company has developed a higher head (up to 50 m) 3.1 m diameter "Guajira" windpump.

Peru is one of the few areas where indigenous appropriate technology type windpumps are used in significant numbers. There are more than 1,000 Miramar 6 m diameter wooden units in use on the Pacific coast. There are eight other windpump manufacturers in Peru, all but one (Matto) of which manufactures windpumps under 4.5 m diameter. Of the metal fabricated machines, the lowest cost unit is the Segovia 2.8 m diameter gearbox type windpump selling at approximately US$800.

Australia

Some 150,000 windpumps are in use in Australia, where production peaked at 10,000 per year in 1965. Since then, numbers have declined due to reducing livestock numbers and new alternatives, including solar pumps. The Australian market is now estimated at around 500 units per year. The Yellowtail, manufactured by WD Moore, is one of the more successful small diameter gearbox windpumps. Southern Cross is the other principal manufacturer.

USA

The USA has also seen a decline in windpump sales as a result of increasing electrification and sales of photovoltaic pumps. Although there are still several active manufacturers (e.g. Aermotor and Dempster) the annual market is now believed to be less than 500 units per year.

Europe

The market for windpumps in Europe is only a hundred or so per year (installed mainly in Greece and Turkey), and only a few manufacturers are left there, notably Abachem (UK), Tozzi and Bardi (Italy) and Poncelet "Oasis" (France). A few manufacturers also exist in eastern Europe.

The previous Soviet Union

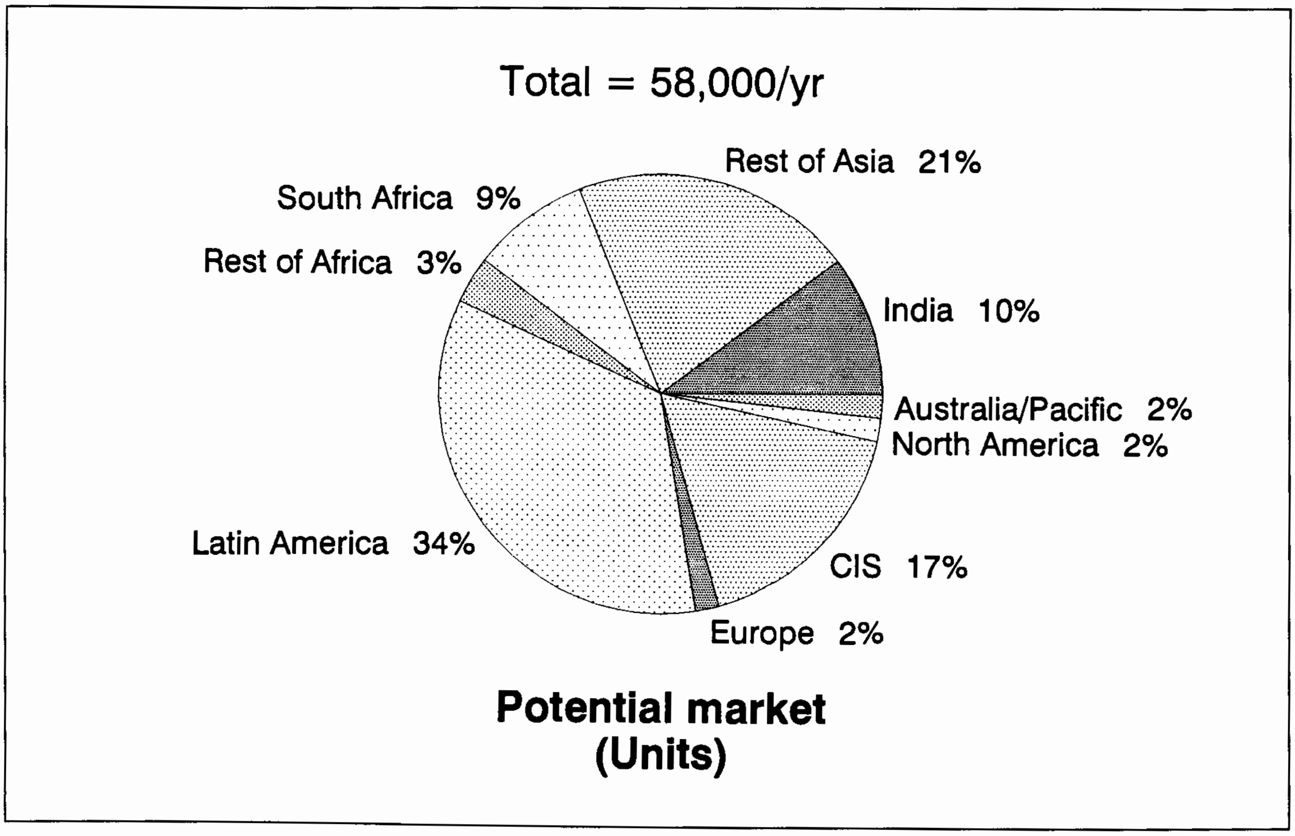
The previous Soviet Union has a vast potential windpump market and indigenous designs (developed by the All Union Institute for the Electrification of Agriculture, VIESH) have been developed and marketed. The principal markets are in Uzbekistan, Turkmenistan, Khazakstan, Kyrgyzstan and Eastern Russia.

A recent assessment by the Wind Power Association of Russia reported a potential market of more than 500,000, due to an increasing need to take water from ground sources rather than polluted surface-water sources.

Summary of the Market Potential

The potential market is an estimate of demand, given reasonable promotion and market development resources. The applications considered to have most potential are livestock watering and village and homestead drinking-water supply. It is expected that the windpump market will grow by, while the number of windpumps will mostly remain constant. This is because there will be a continuing fall in the number of windpumps in Australia, USA and South Africa, but new markets will develop in other countries.

The potential market for windpumps.



The History of Wind Power

The first known reference to a windmill was in the 850s by the Arab historian Tabari. He documented that the Persian craftsman-slave Abu Lulua, from Seistan province on the border of Iran and Afghanistan, boasted in 644 AD that he could construct a mill turned by the wind. There are still about 50 horizontal windmills in the area.

During the time of the crusades (1096-1191), the knowledge of windmills spread across Europe. Later, the expansion of windmills followed the track of colonisation, particularly the establishment of monasteries (Cistercians). Windmills are first recorded in Holland in 1240, Germany in 1222 , Italy in 1237, Greece in 1239, Denmark in 1259, Sweden in 1330, Latvia in 1330, Estonia in 1353, Finland in 1463, Hungary in 1550, Romania in 1585, Brazil in 1576, USA in 1621, Russia in 1622 , Barbados in 1651 and South Africa by the end of the 17th century.

"Wipmolen" windpumps were first used in 1408 in Holland, probably using a scoop-wheel for pumping. By 1600, the wind-driven scoop-wheel was to be seen in the low-lying lands of western Europe. The wind-powered Archimedes screw was introduced in Holland in 1634. The first use of the annular sail, in which all the shutters are assembled radially, was made by Henry Chopping and Richard Rufflein in England 1838, and this concept was exploited for windpumps.

Windpump development shifted from Europe to the United States during the nineteenth century. As settlers moved across the Great Plains of the USA during the 1850s, one of their biggest problems was the provision of water to sustain their large herds of cattle. As well, with the spread of the railroad came the need for water tanks to serve the steam locomotives.

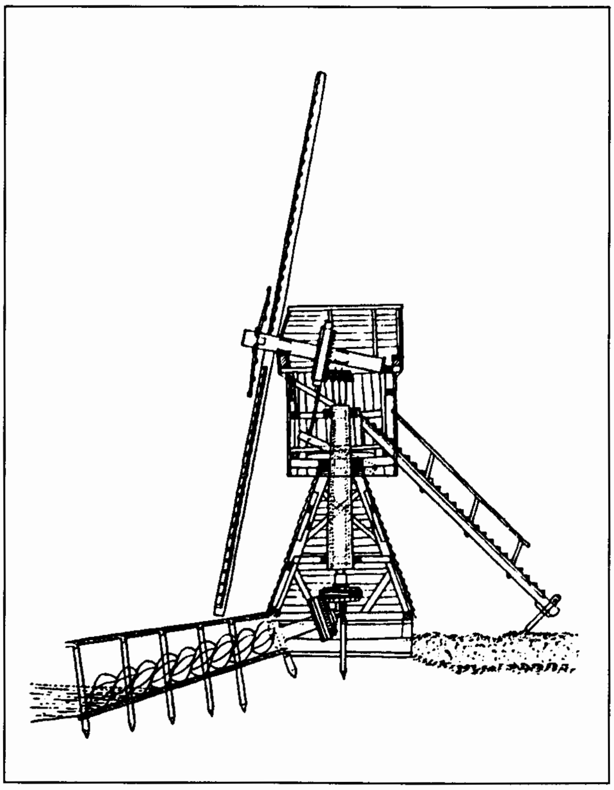
By the end of the 1980s there was a major windpump manufacturing industry in the USA. The first commercially successful self-governing "American Farm Windpump" was invented in 1854 by a New England mechanic named Daniel Halladay. It has a rotor shaped like a flower that folds in on itself as wind speed increases, thus presenting a lesser area to the wind. In 1866, Leonard Wheeler invented a windpump (Eclipse) with two vanes, one that holds the sails towards the wind and a smaller one that pushes the sails out of the wind as wind velocities increase.

Early windpumps were made of wood. By the 1870s a new style of mill made from iron and steel began appearing. But two decades passed before substantial numbers of steel windmills came into general production. During the early 1900s virtually all windpumps were made of steel. Further, self-oiling was introduced and the bearings of the main shaft and the crankshafts were enclosed within special cast-iron reservoirs in an oil bath.

Large-scale production of American windpumps started in the 1870s and reached its peak between the end of the century and World War I. By the turn of the century the Aermotor company alone had produced over 800,000 windpumps.

The American Farm Windpump technology spread throughout the world during the 1890s and manufacture of licensed or similar designs took place in Australia, Argentina, South Africa, the UK, France, Italy, Germany, Sweden and the Soviet Union. The windpump export trade reached its peak before World War I, but exports continue to the present day, mainly to South Africa, India, Australia, New Zealand, Mexico, the West Indies and South America.

US sales remained high into the 1920s. In the 1930s, the great depression, gasoline engines and electrification struck the windpump industry. By the late 1950s and 1960s only a handful of makers remained. As energy prices began soaring in the 1970s and there was a revival of interest in renewable energy sources, investment in windpumps again became attractive. During this renaissance of windmills, a number of interesting innovations emerged.



Wipmolen with Archimedes screw pump in Holland, were first employed in 1604.

Energy from the Wind

To assess the case for a windpump it is important to consider the mean wind speed over a period of time. Perhaps the crudest statistic one is likely to encounter is the annual mean wind speed. This gives a general idea of the viability of a site, but is by no means sufficient. Although variation in annual mean may be fairly small, seasonal variation within the year is likely to be large. A more useful statistic is mean monthly wind speed. This reflects seasonal changes and is the quantity most often used for siting studies. Of particular relevance is the number of consecutive windless or low-wind days in each month. It is important to size the windpump and the storage tank so that there is sufficient water to last over the longest likely lull period.

Wind is extremely variable on a small scale of distance, right down to a few tens of metres. Even though the prevailing wind over a region may be very good, a particular site may not have a reliable amount of wind.

Windpumps are most commonly used on flat plains, and not in hilly country. Coastal areas and lake shores tend to have higher wind speeds than inland areas. Generally, wind speed is greater higher up and weaker near the ground. This effect is most pronounced in the first few tens of metres above the surface. Thus, the higher the windpump tower, the better the mean wind. As power output is proportional to the cube of the wind speed, even a small increase in mean speed will give a sizeable increase in power. Using a higher tower to help overcome the effect of surface roughness is one of the most cost effective ways to increase the effective wind resource.

Extracting Energy from the Wind

The power in the wind at low wind speeds is too diffuse to be practically exploited (for example it is only about 10 W/m^2 at 2.5 m/s). In contrast, the power in winds of above 10-15 m/s becomes so high that it demands excessive levels of structural strength from a machine (for example 15 m/s represents about 2,200 W/m^2). Therefore, most windpumps are designed to function in wind speeds that range from about 5 to 10 m/s over a reasonable period of time.

A windpump requires a certain lowest wind speed in order to initiate rotation. At that wind speed the turning force (or torque) of the rotor is just sufficient to exceed the resistance to movement imposed by the pump. As the wind speed increases, the power available increases steadily until the nominal rated wind speed is reached, after which point measures are taken to limit any further extraction of power. To prevent damage at high wind speeds a windmill is usually "furled" (shut down) at the nominal rated wind speed.

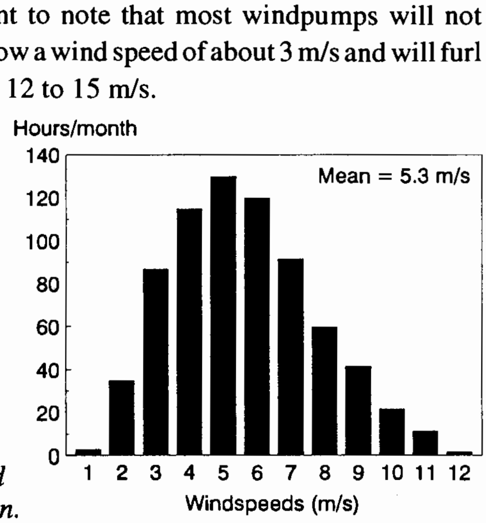
The key part of a windpumping system in terms of ensuring its general robustness and reliability is the power transmission train, which carries the forces generated by the rotor through to the pump.

The mechanical components of a windpump are subjected to an unusually great amount of use during their lifetime. A typical windpump that runs an average of 15 hours per day for 25 years will run approximately 136,000 operating hours and complete about 200 million pump strokes. That a high quality car sometimes only completes about 3,000 to 5,000 operating hours before it is scrapped indicates that the mechanical requirements for a windpump are highly rigorous.

Site Assessment

Some advise for carrying out site assessment is as follows:

- Available meteorological records should be studied. One should consult the meteorological office, local recording stations, airfield, seaports and universities, as well as local knowledge from long-term residents and obtain data on mean speeds, directions, peak speeds and number of calm days.
- Possible sites should be carefully examined, taking into consideration the surrounding topography, positions of buildings, trees and other obstructions. The type of surface cover in different directions, i.e. grass, shrubs, trees, etc. should be noted.
- Wind speed and if possible wind direction should be measured at the site 10 m above ground. These should then be compared to any local meteorological records. Data over at least a three month period is needed, and if possible all year round. It is important to note that most windpumps will not start below a wind speed of about 3 m/s and will furl at about 12 to 15 m/s.



Windspeed distribution.

Types of Windpumps

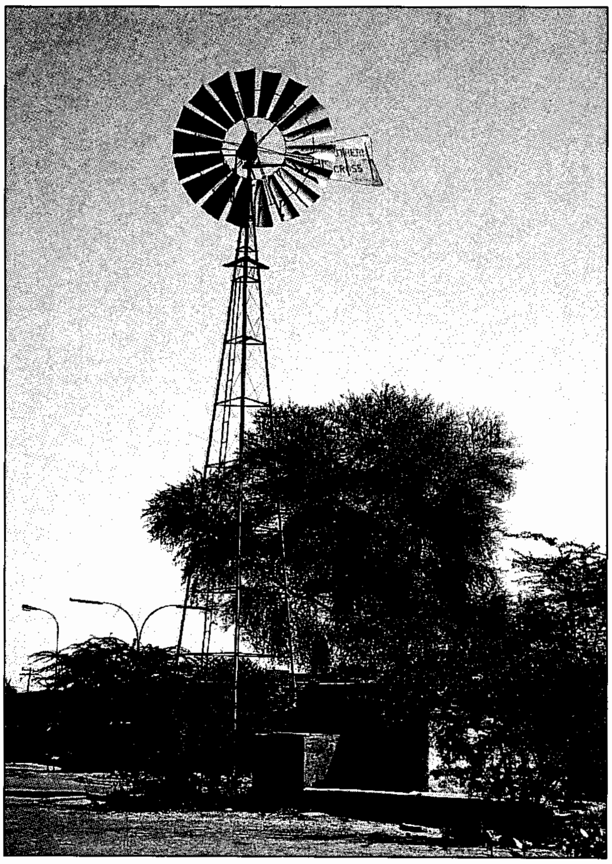
Windpumps may be broadly divided into five categories, depending on their design and method of construction.

Conventional Gear-Driven Windpump

This is the most common type of windpump, which has become well-established through over a century of use worldwide. It is sometimes also called the American Farm Windpump.

The rotor is multi-bladed, and typically has between 12 and 30 blades. However, the most important characteristic of the machine is the gearbox. This reduces the speed of the pump-rod action, while increasing the force with which it pumps. This leads to a far more versatile machine, suitable for shallow or deep-well pumping. It also means a more reliable machine, as there is less wear-and-tear with a slow pump action. The gear wheels usually run in a bath of lubricating oil, which must be topped-up by the user every few months. Otherwise, maintenance is minimal.

To manufacture a gearbox requires facilities to cast metal and cut gears, which adds complexity to the manufacture of gear-driven windpumps compared to those with a simpler transmission system. The windpump is constructed entirely of metal (including the tower) and can only be produced in a well-equipped workshop by machinists with some degree of skill. This means that in general the quality of components and construction is high, as is the reliability. A well-made gear-driven windpump given regular maintenance should have a lifetime exceeding 20 years. Due to the more expensive materials and construction techniques, small gear-driven windpumps are likely to be more costly than a simpler design with the same rotor diameter.



Gear-driven windpump, India.

In general, manufacture of gear-driven windpumps in the developing world is restricted to the more developed parts of Asia (e.g. India) and South America, where foundry facilities and gear-cutting are more common. However, gearboxes are sometimes imported from Europe, Australia or South America due to lack of indigenous manufacture.

Commercial Direct-Drive Windpumps

A direct-drive windpump is usually similar in appearance to the conventional gear-driven design, but does not use a gearbox. Instead the force is transmitted from the rotor to the pump-rod directly by means of a crank or a cam. This means that there is one stroke of the pump-rod for every turn of the rotor.

The crank mechanism is simpler than a gearbox, and can be manufactured with fairly standard workshop facilities. Crank machines are more suited to village-level operation and maintenance, and can provide a sustainable water supply in under-developed regions. Due to the simpler design and construction, the cost has the potential to be less than that for a gear-driven machine.

A wide range of quality of design and manufacture is possible with direct-drive windpumps. In the right circumstances, a well-made machine can be very durable and reliable, using modern design techniques along with materials and engineering of a high standard. Conversely, less rigorous construction techniques and inappropriate design can lead to an unreliable machine with a short lifetime. The lifetime of a typical direct-drive machine is about 10 years.

Direct-drive windpumps are wellsuited to larger, village-scale applications, as the larger rotor diameter means that the rotation speed will be low. However, problems can develop with smaller rotor diameters, as rotation speeds will be higher causing greater wear on the crank and on the pump itself.

Informally-Manufactured Windpumps

In some developing countries there are small groups of artisans assembling limited numbers of windpumps on a casual basis. The designs may be original, or are more likely modified from existing designs to suit locally available components.

Construction materials may include wood (particularly for the tower) and whatever else is at hand, and can be worked with a minimum of facilities. Almost all of these windpumps are direct-drive machines, using a rudimentary crank or cam system.

Clearly, the reliability and performance of these windpumps will be poor in most cases, but the attractions to the user are low costs and easy user maintenance. It is difficult to say how many such pumps are in use, as the village workshops that make them do not usually sell commercially or outside the local vicinity. Some windpumps may even be constructed by the users themselves as one-off items. Again costs will be low, probably at the expense of reliability and performance.

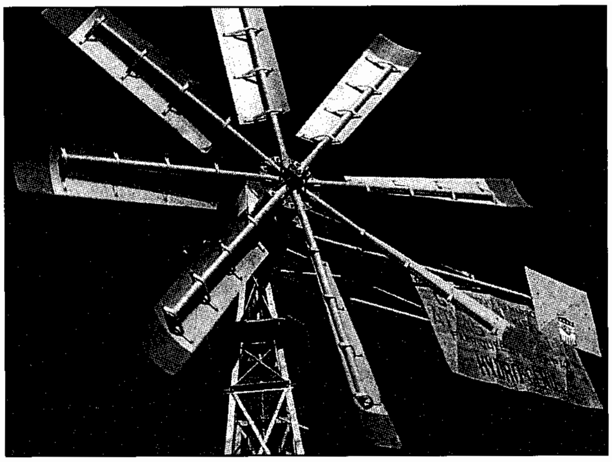
Locally-manufactured pumps can provide a valuable service in remote or impoverished regions where farmers or villagers have virtually no capital to invest in a more expensive commercially-made windpump.

Wind-Electric Pumping

In more developed countries there tends to be a greater number of manufacturers of wind-electric generators than mechanical windpumps and many of them recommend their systems for use with electric motor pumpsets.

Wind-electric systems have several potential advantages. For instance, any surplus electrical power may be stored in batteries and used for other purposes such as running lights or a radio. Another useful feature is that the generator does not have to be located directly over the borehole or well, and can be positioned to capture the best wind regime.

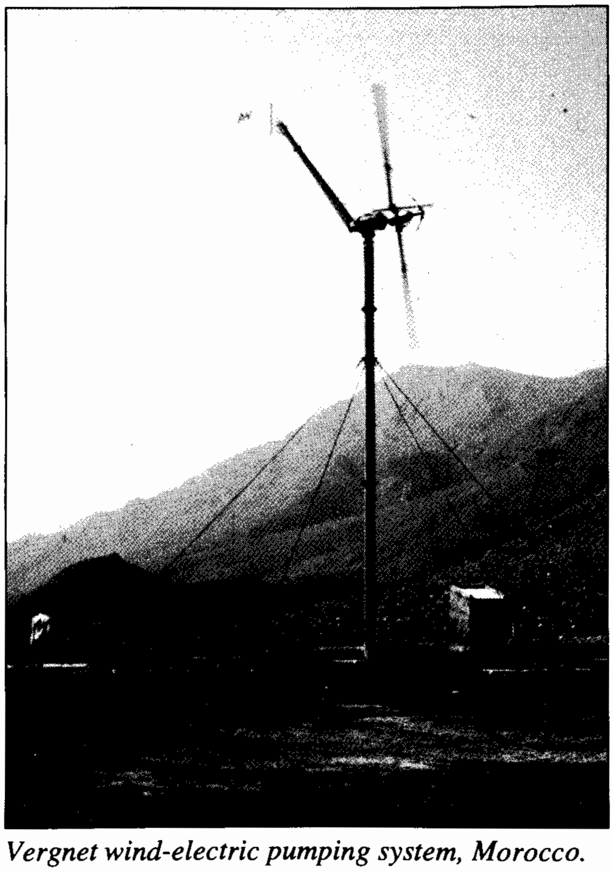
Wind-electric systems can be expensive, and to build a reliable generator requires a fairly high level of technology. Most commercially-available generators are manufactured in Europe and the US, although there are several models manufactured in the developing world. Maintenance is a problem in remote areas where the technology is unfamiliar and spares have to be imported. Therefore, even where they are available, wind-electric systems are seldom suitable for use in most developing-country applications.



Direct drive windpump, Morocco.

Unconventional Designs

There are also a few types of windpump on the market that fall into none of the categories described above. These are mainly windpumps that involve some unusual aspect in their design, aimed at giving a better performance (e.g. variable stroke machines), less expensive construction, or some other specific advantage. However, their rarity can be a disadvantage as spare parts may be hard to find or the mechanisms not properly understood by the user.



Vergnet wind-electric pumping system, Morocco.

Survey of Products

During the winter of 1991/92 all known manufacturers of wind-powered water pumping systems were contacted and asked to provide information on their products. There are thought to be a great many more manufacturers producing windpumps at the time of writing than responded to the survey. One region that is considerably under-represented is South America. The UNDP/World Bank Global Wind Energy Project (GWEP) conducted in 1987 identified 9 manufacturers in Argentina alone, and several others in each of Columbia, Peru and Bolivia.

Over half of the windpumps that featured in the survey fall into the category of the standard gear-driven machines, with direct-drive windpumps making up the bulk of the remainder. There are several wind-electric systems in the list, most of which are of European or US manufacture. A handful of the machines on offer fall into the "unconventional" category, being vertical axis or having a rotary drive.

The geared and direct-drive windpumps almost all have between 12 and 24 blades depending on rotor size. In terms of physical size, the more conventional gear-driven and direct-drive windpumps vary in rotor diameter from 1.6 m for a portable windpump by Cataventos in Brazil, to the 7.5 m direct-drive pump manufactured by Southern Cross of Australia. The normal size range available from a typical manufacturer is between 1.8 and 4.8 m (6 to 16 feet), and a survey in Argentina suggested that machines with rotors around 1.8 to 2.4 m (6 to 8 feet) are by far the most popular.

Maximum-pumping heads vary greatly between pump types, sizes and manufacturers. In general, most manufacturers can supply an appropriate combination for any reasonable head.

In practice, few systems are able to exceed heads of about 150 m. Some of the very smallest machines, or those that do not use reciprocating pumps, may only be capable of lifting water over 10 or so metres.

TRADE NAME:
Address
Rotor diameter (m)
Drive Type
Max pumping head (m)
Cost ($US)

Matrix used in survey of products.

Costs

Windpump prices can vary greatly, even between machines of similar design. Part of the reason for this is that most manufacturers supply only to the local market, and so prices in different countries can become independent of each other to some extent. However, the main price differences are due to the large variation in manufacturing costs and margins from country to country. In developing countries labour costs are fairly low, and most of the total cost is materials. The price of a windpump depends to a large degree on the quantity (and quality) of steel used. Cheaper designs may cut corners on strength, corrosion protection or quality of bearing materials, leading to a less reliable machine. In general the wind-electric systems are the most expensive for a given rotor size.

The mid-range is occupied by gear-driven machines, although there is still quite a spread. The most expensive gear-driven machines are of European or US manufacture. The lower boundary of the gear-driven windpump prices is likely to be set by the cost of building (or importing) a gearbox.

At the lower end of the price range are some of the direct-drive windpumps. Depending on quality and country of origin these reach from within the gear-driven price range, down to just a few hundred dollars (US). Due to the wide range of prices, it is difficult to define a typical price for a windpump of a given size.

In the process of choosing a windpump the potential buyer will be presented at some point with a manufacturer's brochure. The quantity and quality of information provided vary greatly between different manufacturers.

Windpump performance (i.e. how much water it will pump) is the most important factor and the hardest to interpret. One should be suspicious of high output rates where the head and wind speed conditions are not explicitly specified. Some manufacturers quote outputs at unrealistically high wind speeds.

Better brochures give performance in litres per hour or per day for a range of different wind speeds and pumping heads. An informative way to present performance data is as a graph. It is usual to show output versus pumping head, with several lines representing either different wind speeds or different sizes of rotor.

Another important point to check is that the quoted wind speed (m/s) is a mean wind speed and that the output is not for a brief test with constant wind speed.

List of Companies that responded to the IT-SEI questionnaire

Windpump manufacturers and their capabilities

Company	Country	Rotor Diameter (m)	Drive
AbaChem Engineering Ltd.	UK	2 - 6.3	G
Aermotor	USA	1.8 - 4.8	G
Aureka	India	5.5	D
Auto Spare Industries	India	2 - 5	G
Bergey Windpower Co.	USA	3 - 7	E
Bharat Heavy Electricals Ltd	India	5	D
BJ - Steel	Denmark	3.6	D/E
Cataventos	Brazil	3 - 1.6	G
Climax Windmills	South Africa	2.4 - 5.5	G/D/R
Dempster Industries Inc.	USA	1.8 - 4.2	G
Ets. D. Hermaneau	France	2 - 2.5	D
Energomachexport	Russia	1.2 - 3	G
Essex Associates Inc.	USA	1.8 - 4.8	G
Facogsa Srl.	Peru	4.5	D
FIASA FAB	Argentina	1.8 - 4.8	G
Gaviotas	Columbia	2.0	D
Bobs Harries Engineering Ltd.	Kenya	2.0 - 7.4	D
Industrias Jober Ltda.	Columbia	2.5 - 3	G/D
ISERST	Djibouti	2.7	D
KMP Pump Co.	USA	2.4 - 3	D
LMW Windenergy B.V.	The Netherlands	3 - 5	E
MERIN (PVt.) Ltd.	Pakistan	3.6 - 7	G/D
MidWales Productions	UK	1.8 - 4.8	G
NEPC-MICON Ltd	India	3	G
Ets. Poncelet & Cie	France	1.8 - 2.5	D
Pwani Fabricators	Kenya	3.7 - 4.9	G
Sahara Engineering Co.	Sudan	5	D
Serept Energies Nouvelles	Tunisia	5	D
Sheet Metal Kraft	Zimbabwe	3.6	G
South Africa Plant and Eng. Co.	South Africa	2.3	R
Southern Cross	Australia	1.8 - 7.5	G/D
Star Engineers	Sri Lanka	3	D
Stewarts & Lloyds	Zimbabwe	6	D
Thermax Corporation	USA	0.6 - 2	G/E
Tozzi & Bardi	Italy	4 - 6	D
U.SA Economic Development Co.	Thailand	2.4 - 6	
Vergnet Sa.	France	10	E
Wind Fab (Mayee Eng. Ltd.)	India	3	G
Wire Makers Ltd.	New Zealand	2	D
W.D. Moore Ltd.	Australia	1.8 - 4.2	G

Key to drive types: G = gear-driven, D = direct, E = wind-electric, R = rotary

Economics

Installation and operation of any pumping system requires a long-term financial commitment. The consequences of inadequate assessment beforehand can be dear. In most cases, economy is one of the central factors considered. However, it is important to realise that not all the relevant considerations can easily be reduced to monetary terms. The final decision should always be made on a balance of factors.

For a pumping system to be economic in an absolute sense, the value of the benefits must outweigh the costs. This is very difficult to calculate. Although costs can be quite easily quantified, the value of benefits are more subjective. This is particularly true in the case of village water supply, where the main benefit may be access to clean water.

One method of economic analysis is to compare different pump types for a given job. The cost for each can be expressed as a meaningful figure such as a price per unit volume of water, or a cost per family per year.

The chief alternatives to windpumping are diesel and handpumping. Solar photovoltaic pumping can also be a competitive technology in remote regions, and its popularity in the developing world continues to grow. Solar pumps are expensive to buy initially, but require very little supervision or maintenance and, of course, no fuel.

Handpumping is the mainstay of village water supply in the developing world. It is a simple well-established technology that is cheap and generally reliable. However, handpumps cannot deliver large quantities of water, and they require a person to spend valuable time working the pump.

Diesel pumpsets are also common throughout the developing world for larger-scale village pumping and irrigation applications. They are usually oversized for the application, and are used for an hour or two each day.

Another concern is the price and availability of fuel and maintenance services. Fuel prices can vary enormously between and within countries. At some times diesel fuel may simply not be available, or may be of poor quality. Diesel pumps require regular maintenance and are generally not left to operate unattended for any length of time.

Petrol-driven pumpsets are not generally used because of their relatively short life and the problems of obtaining good-quality fuel in remote areas.

Life-Cycle Costs

Life-cycle costing is the sum of all the costs of the system over its lifetime, expressed in today's money. It is the most complete analysis and is the usual method for determining whether an application is economic. Payback period is often used to give a quick and simple indication of whether an application is likely to be economically viable.

General Economic Analysis

Rural village water supply is characterised by a fairly even year-round demand, and relatively small quantities of water. This water supply must be clean enough for drinking, and so it is usually pumped up from groundwater a few tens of metres below the surface. Because of the small quantities of water required, and the high value placed on clean drinking water, windpumping for village supply can be cost-competitive given a good wind site.

Irrigation pumping is characterised by the demand for very large quantities of water, but only at specific times of year. This means that for most of the year the pump is idle or oversized. For this reason irrigation pumping is often harder to justify economically. Irrigation water is generally taken from surface water (e.g. canals or water holes) and storage is neither practical nor necessary in most cases.

Livestock watering has many similar characteristics to village water supply. However, capital costs may be lower, as the water source is less critical, and distribution will not be required. Village supply and irrigation have been used in the examples below because they represent the extreme cases.

Village Water Supply Costing Scenario

The initial costs for the equipment and costs of replacement parts have been taken from current manufacturers' data wherever possible. The initial costs also include the expense of drilling a well or borehole, building a water storage tank and installing all the equipment.

The annually recurring costs include maintenance of the whole system (pump, water-source, storage tank and distribution system), and fuel and operational costs where appropriate.

With a 10 m water depth it is clear that at lower daily volumes, windpumping is the cheaper option. Even at wind speeds of just 2.5 m/s, windpumping is cheaper than diesel for daily volumes up to 10 or 20 m^3, depending on the diesel cost scenario.

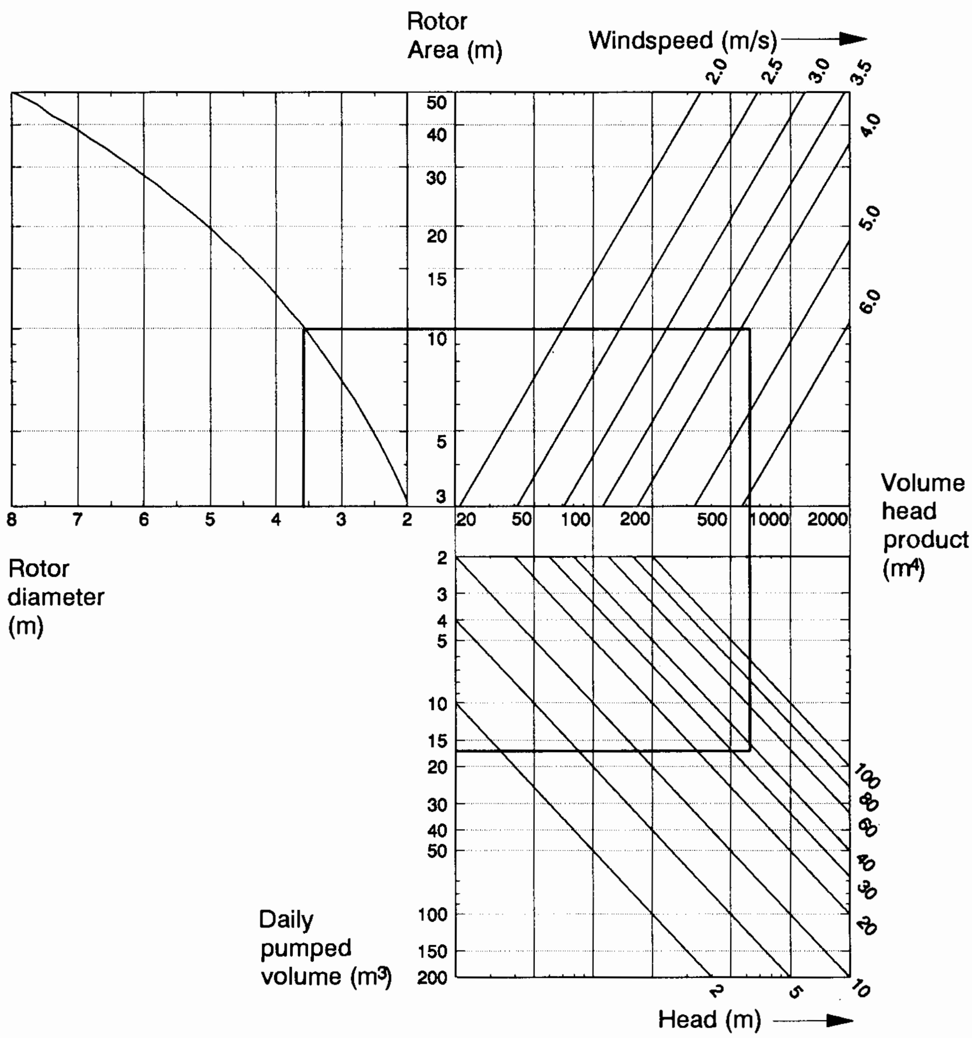
At higher daily volumes, both the diesel and windpump unit costs tend to level out, and which is the more economic depends largely on the diesel cost scenario chosen and the wind speed. For instance, if the high diesel cost case is chosen, then windpumping at 3 m/s is always more economic, but using the low diesel cost case, it is only more economic up to about 15-20 m^3/day. However, windpumping at wind speeds of 4 m/s is more economic than both diesel cases over the whole range of daily volumes, tending towards the lower diesel line at very high deliveries.

With a water depth of 30 m, windpumping with wind speeds of 4 m/s is cheaper or comparable with diesel over the whole range of demands, and considerably more economic below 15 m^3. At lower wind speeds (3 m/s), windpumping is economic below about 10 to 20 m^3/day depending on diesel cost scenario. Windpumping at wind speeds of 2.5 m/s will only be economic if diesel costs are high and daily demand low.

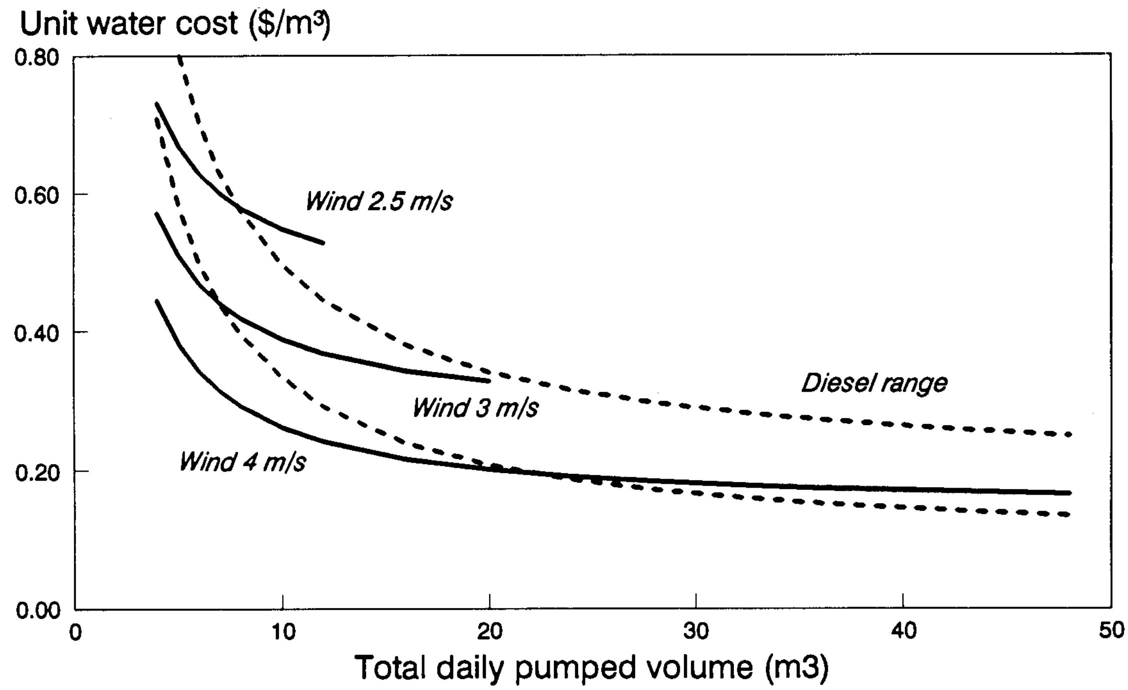
Summary

Given the right water and wind conditions, windpumping can be more economic than (or at least comparable to) other pumping methods. The economics of windpumping depend critically on the mean wind speed, and unit costs are less sensitive to demand than for diesel pumping. However, the following statements will generally be true:

- windpumping with mean wind speeds of 4 m/s or over will probably be comparable with diesel for most applications;
- at very low demands and heads, handpumping may be the best option, depending on the value placed on labour time for pumping; and
- irrigation over heads of about 10 m will seldom be economic using a windpump.
- it is more difficult to economically justify windpumping for irrigation than for water supply due to the large quantities of water required.



Windpump rotor sizing nomogram



Village water supply at 30 m water depth: General life-cycle cost analysis.

Choosing a Windpump

There are three main technical factors that set the limits for a given situation:

- demand for water,
- availability of water, and
- the wind resource.

The first step in the process is to draw a rough scale plan of the site and decide where the various system components should be placed. This is usually dictated by position of the water source and local factors affecting the wind pattern.

For village water supply and livestock watering, a storage tank is usually positioned near to the pump, and should only be as high as is necessary to provide the head for the distribution system (if any).

For irrigation purposes, the two most practical methods are the low-head drip system and the hose-and-basin method. Both are highly efficient and require a driving head of 1 to 2 m. The main difference is the cost. A low-head drip may cost US$2,500 per hectare whereas the hose-and-basin method may only cost a few hundred dollars. The method chosen will also depend on the crop grown.

The size of the rotor that is needed to meet a given duty is dependent on the required hydraulic energy and the wind regime. The hydraulic energy requirement is proportional to both the total pumped head and the quantity of water pumped per day.

Sizing is carried out for each month (or season) separately. The month which needs the largest rotor area is called the "design month".

The three main parameters that are needed for each month (or season) to size the system are:

- total pumped head (m),
- daily pumped volume (m^3), and
- expected mean wind speed (m/s).

The total pumped head is the head that is "felt" at the pump and is the sum of the:

- depth of the static water level below the surface,
- maximum expected drawdown,
- height of the tank (if any) above the surface, and
- additional dynamic head due to friction losses.

The dynamic head is the extra pressure that the pump feels due to friction and turbulence in the pipework. The narrower and longer the pipes the greater this component will be.

The daily water requirement (m^3/day) is the demand at the pump, and so must account for any inefficiencies or leaks in the distribution system.

If possible, the mean wind speed for each month should be measured at the hub height of the windpump, or at least 10 m above ground level.

A nomogram, see figure, can be used to find rotor area and diameter from the three parameters total head, required daily volume and mean wind speed. Results can be found by tracing lines and reading the results where they intersect the axes.

Installation

The installation process can be fairly complicated and time-consuming and care is required in its execution. If the manufacturer does not carry out installation, then they should provide detailed instructions. Poorly-installed machines can easily lead to inferior operation and maintenance problems.

Windpumps are most commonly installed over a borehole or alternatively over an open well. The most important factor in construction is the borehole alignment. A slight deviation from the vertical will be particularly significant with a deep borehole. The windpump pump rods must hang vertically or they will wear and, in extreme cases, cause malfunction of the machine. If the borehole is constructed out of alignment this can easily occur.

After a borehole or well is first completed the drawdown should be tested. This is usually achieved using an engine-powered submersible pump. It is necessary because the drawdown can sometimes double the depth of borehole required and indicate the need for a well with more surface area below the aquifer.

The measured drawdown distance should stabilise an hour or two after beginning the test. In both newly-dug boreholes and wells the water should also be tested for salinity and acidity (pH) to ensure that it is suitable for drinking or irrigation. A high acidity or salinity reading should be double checked before a decision is made as to the suitability of the borehole location, especially if the water is for human consumption.

The windpump manufacturer should provide technical information and instructions concerning the type and dimensions of the foundations. Most frequently these are made up of concrete footings, one for each leg of the tower, encapsulated in a reinforced concrete raft around the mouth of the borehole, or across the well shaft.

The pump rods, coupling the windpump mechanism to the pump, are a crucial component of the system. The most vital requirement for their installation is that the pump rod joiners are sufficiently tightened, but can still be readily disconnected when raising the pump for servicing. A disconnected or broken pump rod can be catastrophic since the lower part, attached to the pump, falls back into the rising main and is usually extremely difficult to recover.

Operation

Efficient and trouble-free operation can be achieved if regular maintenance of a high standard is carried out. Manufacturer's instructions make recommendations for maintenance, usually periodic oiling/oil changes and/or greasing.

In addition to the manufacturer's recommendations it is prudent to consider that:

- the machine is designed to withstand severe situations;
- a correctly-installed and well-maintained windpump should operate fairly quietly;
- the windpump must be repainted periodically to prevent corrosion;
- the pump will require occasional replacement seals and piston cup leathers;
- the water carrying components, delivery pipe, storage tank, etc. need to be examined for leaks;
- air in air chambers can be gradually dissolved in the water, the bleed valve should be opened periodically to allow the air to be topped up;
- after a major overhaul or repair, or the installation of a new machine, nuts and bolts may work loose. These must be checked and re-tightened.

It will nearly always be necessary to climb to the top of the tower in order to service the windpump. Before doing so the windpump should always be disabled by activating the manual furling mechanism and applying the brake, if available.

One potential source of failure is the furling mechanism. The furling mechanism should also be fail-safe. This means that if a critical component fails the rotor will simply furl at a very low wind speed.

In order to service the pump and replace the seals, etc. it must be removed from the borehole. The removal process is the reverse of that detailed for installation. The advantages of using an extractable pump become evident at this stage. The piston and the footvalve can be removed from the borehole without disturbing the rising main.

The footvalve will also occasionally require attention. If the footvalve leaks then the performance of the windpump will decline because the rising main will drain down whenever there is a lull in the wind.

The Anatomy of a Windpump

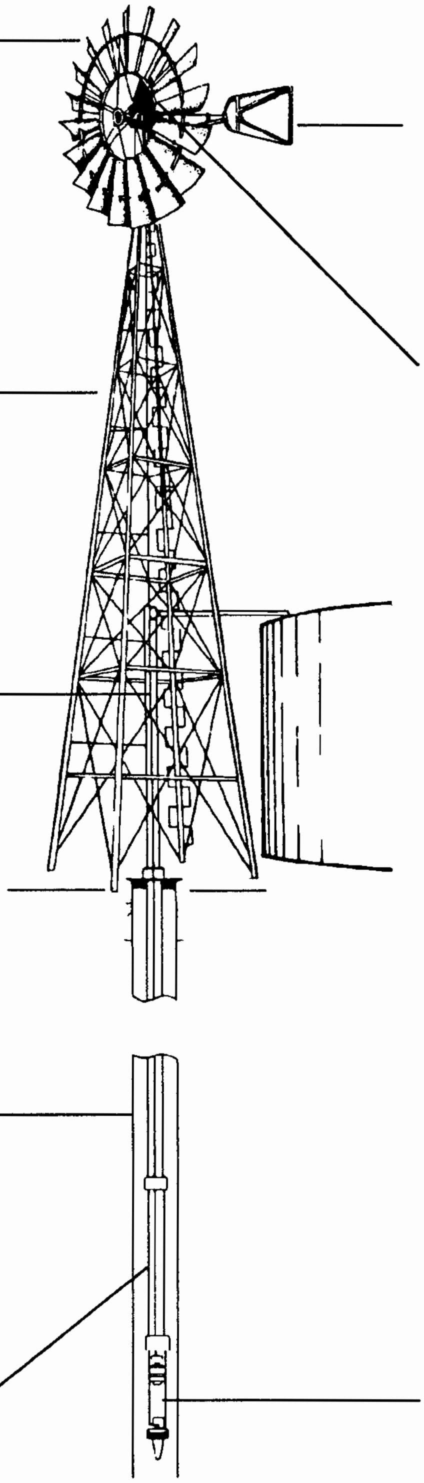
The rotor
This can vary widely in both size and design. Diameters range from less than 2m up to 7m. The number of blades can vary from about 6 to 24. In general a rotor with more blades runs slower but is able to pump with more force.

The tower
Normally metal (galvanized steel) with three or four legs. May be anything up to 15m in height, but usually about 10m. The bases of the legs are fixed, often by bolting to concrete foundations.

The pump rod
This transmits the motion from the transmission at the top of the tower to the pump at the bottom of the well. The motion of the pump rod is reciprocating (up and down) and the distance it travels (called the stroke) is typically about 30cm, depending on the pump. Pump rods are usually made of steel.

The well
With a shallow water-table the pump may be mounted on a hand-dug open well; if the level is deep a borehole must be drilled. The outer walls of the well will be lined to prevent in-fill but the liner should be slotted to allow water to enter the well.

The rising main
This is the pipe through which the water is pumped, and also encloses the pump rod.



The tail
Keeps the rotor pointing into the wind, like a weather vane. The whole top assembly pivots on the top of the tower, allowing the rotor to face in any direction. Most machines incorporate a mechanism into the tail which will turn the rotor out of the wind to prevent damage when it becomes too windy.

The transmission
Turns the rotation of the rotor into reciprocating motion (up and down) in the pump rod. Normal types use a gearbox or are direct drive. With direct drive the pump rod moves up and down once for each turn of the rotor. Using a gearbox allows the pump to be geared-down so that it does fewer pumping strokes for a given rotor speed, but with a larger output per stroke.

Well-head components
At the well-head the water is piped away to a storage tank through the 'discharge pipe'. The pump rod usually runs through a seal at the well-head called a 'stuffing box' which prevents water escaping around the rod.

The pump
Normally submerged below water level. On the downward stroke the cylinder fills with water; on the upward stroke the water is lifted by the piston up the riser pipe. Pumps come in various cylinder bores and stroke lengths. The pump hangs on the rising main.

Electricity from the Wind*

Although the use of windpower goes back many centuries, it was only at the turn of the century that its use for the generation of electricity was developed. One of the pioneers was Paul la Cour who experimented with windpower in Askov, Denmark between 1897-1902. In 1902 the small town of Askov was supplied with wind electricity for lighting. Small wind generators for recharging lead-acid batteries became commercially available for the first time by the early 1930s. Much larger experimental wind turbines for feeding electricity into the mains power grid also appeared during the 1930s, in the Soviet Union and France. The United States built the first megawatt sized windmill in 1941. During World War II, when fuel oil was difficult to get, many farms, especially in Denmark employed wind generators.

Plentiful cheap oil in the 1950s and 1960s led to a decline in interest, but the 1973 "oil shock" followed by legislation and fiscal incentives introduced in the late 70s have helped Denmark to become one of the leading users and exporters of wind electricity generating technology today.

Today the two biggest users of windpower for feeding electricity into their electricity grids are Denmark and the US State of California. Both produced nearly 3% of all their electricity needs in 1992 from wind power. Denmark has a target of generating 10% of its national electricity from the wind by the year 2000. Other countries are starting to follow this example.

The wind generators used today, tend to be at opposite ends of the size spectrum. At the small end of the scale are many thousands of 50W battery chargers with rotors less than 1m in diameter and at the large end the latest generation of machines for "wind farms" are mainly of 200 to 750 kW with rotors up to 30m in diameter. The costs of such systems range from as little as US $300 for the smallest systems to more than $500,000 at the other extreme.

Little use of wind electricity generators has so far been made in the developing countries, although the technology has considerable potential in some areas. The notable exceptions are China (where large wind turbines have been set up to feed the grid and as many as 50,000 small wind turbines are used for charging batteries for nomads in Inner Mongolia) and India, which has an ambitious programme for integrating grid connected wind turbines to the mains in order to reduce fossil fuel utilization. Bharat Heavy Electrical Ltd (BHEL) has manufactured two 55kW wind turbines, and also developed a 200 kW prototype. From 1986 to 1992 about 40 MW of windpower, mostly danish designs, have been installed in India, and the target for the year 2000 is 1000 MW. Water pumping windmills and battery chargers are also manufactured in India, in 1992 about 3000 windpumps and 100 battery chargers were installed. The Government of India is presently undertaking the biggest ever windmapping exercise, to promote wind energy.

There are in practice at present just three practical categories of application for wind electricity generation: small systems for charging batteries, medium sized systems running in conjunction with a diesel generator and large systems integrated with the mains electricity grid.

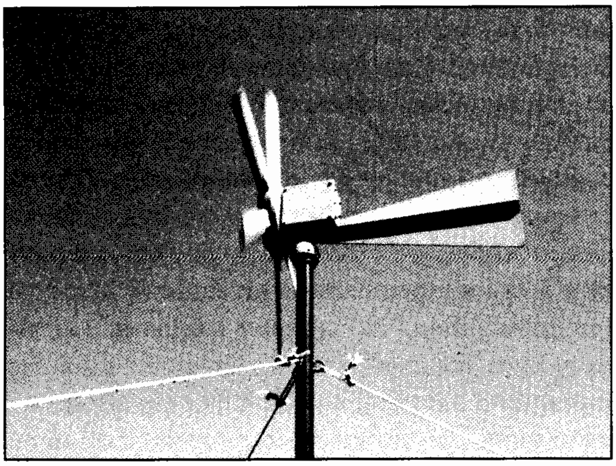
Battery Charging

The most common type of small wind electric system involves the use of a wind generator to maintain an adequate level of charge in an electrical storage battery. The battery in turn can provide electricity on demand for electrical applications such as lights, radios, telecommunications or electric livestock fencing. Overcharging is prevented by a voltage regulator that can dump surplus energy as heat at times when there is more energy available than can be used. Small wind battery charging systems are most commonly rated at between 25-100W in a 10m/s wind speed, and typically have a rotor diameter of from 50cm to 1m. A few machines of this kind are in quite large-scale production notably in the UK, the Peoples Republic of China and the USA. At least 150,000 such systems are in use today and annual production has been increasing. It is probably in the range 20,000 to 30,000 units per annum.

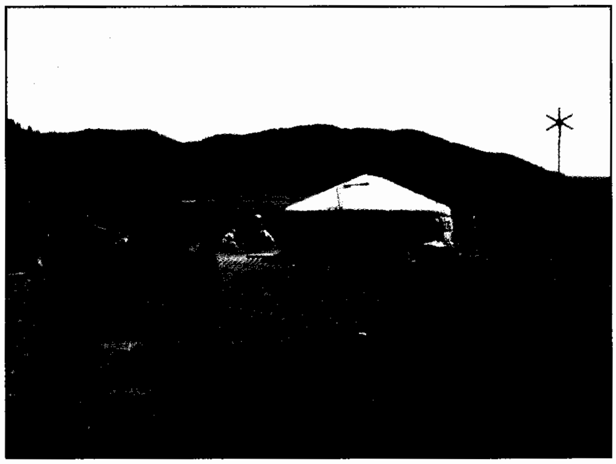
The main use in the more developed industrial countries is for the luxury leisure market such as for use in isolated holiday homes, caravans, and yachts for lighting or powering TVs, videos, etc. But they are also being taken up in developing countries in remote settlement for lighting or powering radios, TVs, telecommunications and pumps.

A UNDP/UNDTCD project in the Mongolian Peoples Republic, provides an interesting insight into the application of wind electricity generators in a development application. Initially three different wind electricity generators were tried. The Rutland 50W wind generator (supplied by Marlec from the UK), the Dyna

* *written by **Peter Fraenkel** and **Varis Bokalders**.*



50W Marlec WG910, one of the most sold wind battery chargers (rotor diameter 90 cm).



A version of the 50W windcharger, on the left, made in Mongolia as a joint venture with Marlec.

Technology 200W Wind Charger (a long established design from the USA), and the Electro 5kW Wind Generator (a more recent Swiss design).

The Marlec machine is the only one of these 10 years later that remains in service (or in production). The 200W Wind Charger was significantly more expensive and found to have a lower energy capture than the Marlec machine despite having a power rating four times greater, due to its high cut in wind speed. The Electro 5kW Wind Generator proved to be too large, expensive and troublesome. This illustrates the probable reason for the success of the small 50W machines: they have a high "load factor" (i.e. they can extract energy from light winds as well as medium to strong winds) and in addition they are relatively inexpensive, uncomplicated to install and run and reliable in operation.

Charging batteries with a wind turbine rated at more than about 1kW requires relatively large and expensive batteries and sophisticated control circuitry. Therefore the use of larger wind turbines for battery charging results in disproportionately expensive systems, with items like the batteries and inverter often costing considerably more than the windturbine.

Wind-diesel Systems

Since larger stand-alone systems are too costly to implement using batteries for storage, the alternative is to use systems that are either designed to work together with another power source such as a diesel-generating set or which use a diesel as a back-up system at times of little or no wind.

Wind-diesel systems can range from a single 5kW diesel generating set operating in conjunction with a 10kW wind turbine at the lower end of the size range, to several megawatts of diesel capacity (normally involving several generating sets) running a mini-grid system, with perhaps a megawatt or more of wind electricity generation.

The rationale for wind-diesel systems is based on the premise that diesel-generated electricity is generally more expensive than wind generated electricity. The unit cost of diesel generated electricity is typically US $0.15-0.20 per kWh for megawatt sized diesel generating sets, increasing to US $1.00 (or more) per kWh for the smallest sizes of generating set (taking all costs into account). In contrast, a medium sized wind turbine, rated at from 50 to 200kW given a favourable wind regime, can generate electricity at US $ 0.10-0.20 per kWh. Consequently, a wind-diesel system can (in theory) reduce the average unit cost of electricity, and save diesel fuel. It can also reduce diesel operating hours and thereby lower the maintenance requirements and increase the life of the engine. However, in practice, the effective substitution of windpower for diesel is not straightforward.

Load-control is the most commercially-developed type of wind-diesel system at this time, being used mainly for small island communities (typically needing about 50kW peak load). It is a concept pioneered by Windharvester in the UK where only a small fraction of the rated output of the wind turbine is considered as "firm power" to be used for priority loads as lights, televisions or computers, which cannot tolerate occasional outages. Therefore, most of the rated output is taken up by non-priority loads such as water heating, refrigerators and freezers or other applications which can stand occasional gaps in power availability. Any temporary lulls in the wind are handled by cutting off most of the non-priority load, e.g. a 50kW system would often require 45kW of non-priority load. In such a case, if the wind is sufficient to produce at least 5kW the wind turbine runs and the diesel is shut down, but if occasional lulls occur such that the wind turbine cannot meet the priority load of about 5kW, then the diesel is automatically started. Load switching is handled by a programmed controller utilising a micro-processor, i.e. a small computer, fed with information by wind speed sensors.

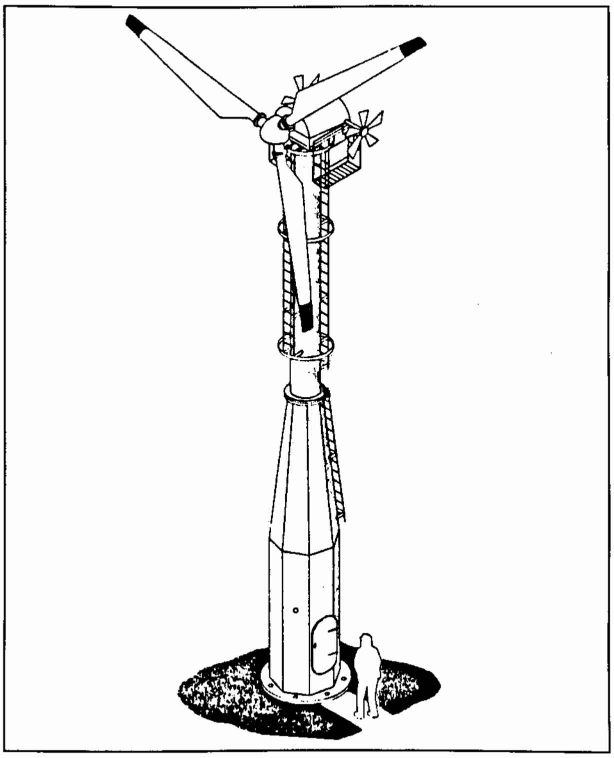
Small stand-alone wind electricity generators could perform important specialised roles in development (eg. lighting and telecommunications for remote communities in arid regions and on islands, ice production for fisheries, fresh water production by reverse osmosis, etc). Research and development into autonomous wind-diesel systems which can operate continuously together in parallel is quite recent and dates from the late 1970s. At the present time the technology is close to commercial readiness but still remains semi-experimental. A number of successful load-controlled wind-diesel systems have been installed for island communities, especially around the UK, but also in Greece, China and Ireland.

Grid-connected Systems

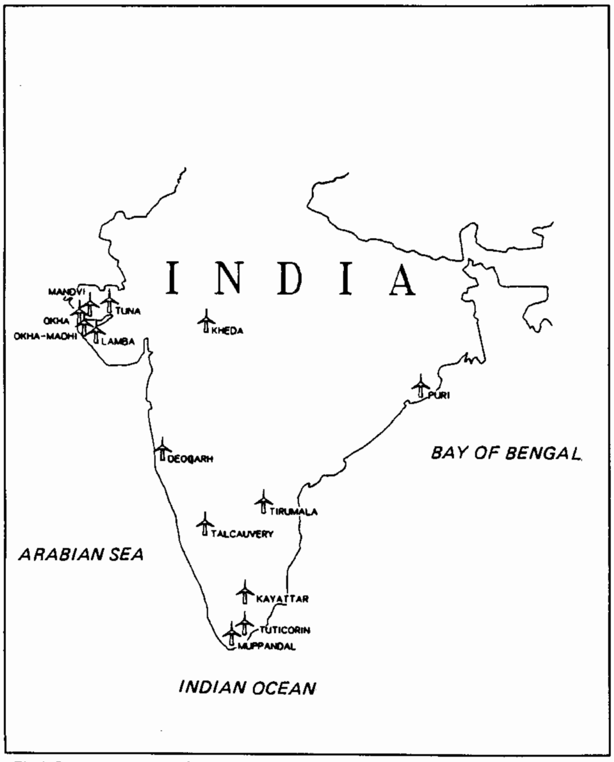
There has been a massive growth in the use of grid-connected wind turbines in the last few years, and the technology has improved considerably in cost-effectiveness as a result. In the early to mid-80s most development was in connection with wind farms in California and to some extent in Denmark, but in the last two or three years countries like the Netherlands, Germany, the UK and Spain have also started commissioning significant numbers of grid-connected wind turbines. So far little has been done in developing countries with grid-connected wind turbines with one or two exceptions. Among these the main users of large machines are China and India; both countries have a major experimental programme to introduce large windturbines. In both cases machines have initially been imported from the industrial countries (particularly Denmark and the USA) but efforts are under way to start manufacturing wind turbines in both China and India.

A problem for many of the developing countries, located in the tropics or semi-tropics, is that they do not have such favourable wind regimes as countries in the more temperate latitudes. However, one or two remote island communities have particularly favourable winds and a notable example is the Cape Verde archipelago which has a number of grid connected wind turbines serving the grid for the capital, Praia.

In the future wind enectricity will become much more common also in developng countries. Small stand alone systems for battery charging, can be a useful complement to photovoltaics in remote areas. Windgenerators connected to the grid will be a common sight in windy regions. Wind-diesel systems still need some development before they can give power in remote places, where there is no electric grid.



15kW Windharvester, used in wind-diesel systems.



Grid-connected "Windfarms" in India.

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Windpower Monthly (65$/year)
Wrinners Hoved, 8420 Knebel, Denmark
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Wind Energy Weekly
A weekly bulletin available from the American Wind Energy Association, Washington DC, on the electronic conference "en. energy" on the APC system of networks (green net).

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The Danish Centre for Renewable Energy
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TOOL Technical Development with Developing Countries
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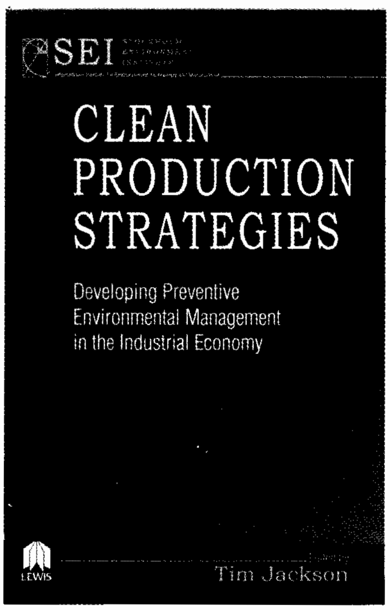

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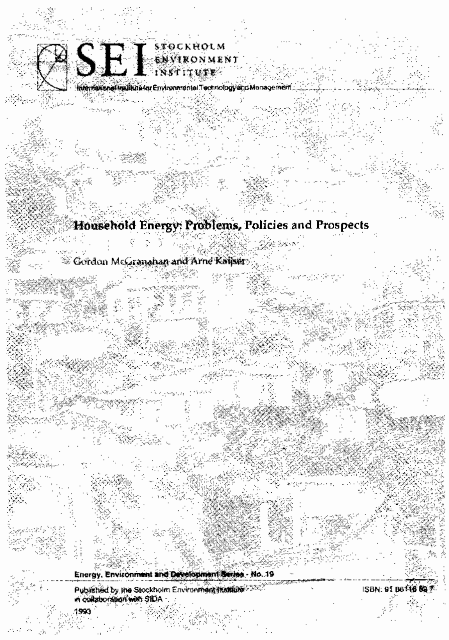
Household Energy: Problems, Policies and Prospects.

By Gordon McGranahan and Arne Kaijser

There are many household energy problems which deserve attention. Energy sector assistance only towards large-scale supply and distribution cannot solve the problems of the poor. The most obvious mistake in the way funds have been allocated is that too much money has been devoted to decreasing the financial burdens of commercial fuels used by the relatively well off.

Household energy problems of the poor, such as stove improvement and biofuel supply enhancement, have been poorly funded, overly ambitious and at times ill conceived. For donors there remains a serious incompability between, on the one hand, the exigencies of large-scale funding and government-to-government cooperation, and, on the other hand the numerous but small-scale initiatives appropriate to assisting the poor.

Many of the activities most needed to alleviate household energy activities are best addressed through multisectoral activities, incorporating energy concerns.



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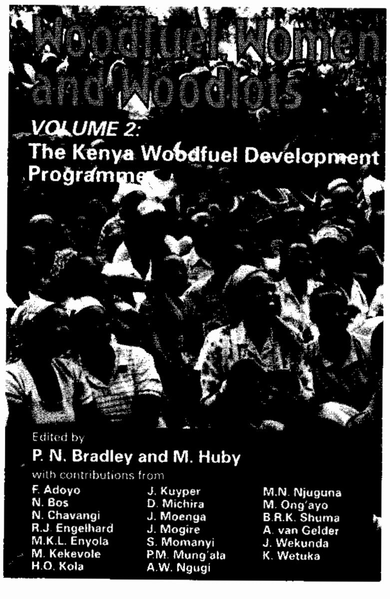
Volume 2 describes the development programme that was put together after the initial research phase. It details the fate of individual components of the programme, whilst at the same time teasing out more general conclusions about the nature and practice of rural development. By comparing and contrasting customs relating to wood production through agroforestry and the gathering of woodfuel, two areas which in the western Kenyan case are not necessarily related, local farmers and the programmes development agents put together an innovative development challenge. The success of this programme bears testimony to the flexible and painstaking way in which this rural consensus was constructed.



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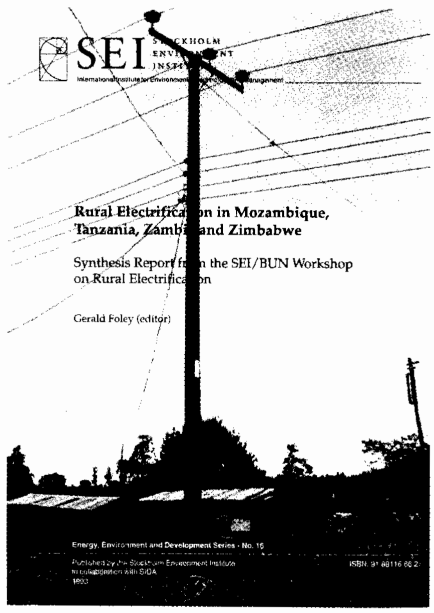
Rural Electrification in Mozambique, Tanzania, Zambia, and Zimbabwe. Synthesis Report from the SEI/BUN Workshop on Rural Electrification.

Editor Gerald Foley

The objectives of the workshop was to review the present state of rural electrification in four countries in Africa, and identify problems, potential solutions and promising new approaches. Within this framework, it was intended that special attention should be given to bio-electrification (the production of electricity using biomass fuels), and the potential role of solar, wind and small hydro in the production of electricity for rural use. Position papers were presented by delegates from each of the countries represented. Additional special topic papers were presented by resource persons. The conclusions and recommendations of the workshop are presented and discussed, in this synthesis report.

The workshop was organized jointly by SEI and Biomass Users Network (BUN). It was sponsored by the Swedish International Development Authority (SIDA) and held in May 1992 in Nyanga, Zimbabwe.



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