

WATER PUMPING WITH WINDMILLS IN ZIMBABWE

B Byabura-Kiryra, Research Engineer, Institute of Agricultural Engineering,
P O Box BW 330, Borrowdale, Harare, Zimbabwe

ABSTRACT

The paper outlines the research that has been carried out to assess the available wind energy and water pumping performance of windmills in Zimbabwe. A summary of a cost comparison between a windpump, diesel, electric, solar and handpump is included. Results indicate that there are moderate to low winds over most areas of the country. The difference in performance figures of the same type and size of windmill located at different sites shows the importance of careful windmill siting covering, borehold yield, water demand and available windregime. A survey of windmill location within Zimbabwe indicated that windmills are more often sited where the money is than wind. Based on the cost comparison, windmills are more suitable for low energy water pumping requirements where hand or ox-driven water pumps would not be feasible. For the high energy pumping demands, ie large volumes of water at high heads, diesel or electric pumps are still more cost competitive.

INTRODUCTION

Windmills have been used for centuries in America, Europe and Asia as a source of mechanical energy for water pumping, grain milling and more recently for generating electricity. There was a general decline in the use of wind energy after World War II due to the rapid development of the diesel engine, the availability of low-priced oil and widespread rural electrification by the national grids in the developed countries.

With the increase in the cost of petroleum based fuels of the 1970s, there has emerged a renewed interest into the application of windpower, especially in the oil-importing countries. Zimbabwe being one of these countries, has to find alternative energy sources to meet her major priorities for national development among which is rural water supply.

Water-pumping using windmills has been practised in Zimbabwe for several years mainly to supply water for domestic use and for livestock. As is general in most developing countries, the principal inhibiting factors for the popularity of windmills has been high capital costs of imported windpumps compared to diesel pumps, lack of expertise to install and maintain them and designs that are outdated and unsuitable for small-scale manufacture, thus limiting local production.

A survey of windmill useage throughout Zimbabwe showed that a few hundred windmills are in use today, mostly the Climax models imported from South Africa. Production has started in Zimbabwe so as to reduce the foreign exchange requirement for importation of windmills.

The paper outlines the research that has been carried out within Zimbabwe to evaluate (technically and economically) the viability of using windmills for water pumping and to determine the optimum windmachines necessary to suit the available windregimes.

WIND ENERGY RESEARCH

Wind energy research in Zimbabwe focuses on collection and analysis of wind energy data, field monitoring of pumping performance of windmills on a daily basis and testing of various windmachines using field simulation techniques.

Wind data

The Department of Meteorological Services maintains a daily record of windspeeds recorded at the various recording stations in Zimbabwe (Figure 1). Table 1 gives figures of mean surface winds from these records covering a period of 10 years up to 1973. Wind power obviously varies with time, ie by month, hour of the day and a short period of a few minutes. Hence the data for hourly averages presented in Table 1 may not be useful in establishing the energy in the wind. As the power in the wind varies as the cube of the windspeed, the absolute windpower is about treble the power calculated using the cube of the average windspeed. However, the average windspeed is still a reasonable good first guide when comparing different windmill sites (McNaughton 1982).

One of the important parameters to obtain from the wind data is the frequency and duration of occasions of nil power generation, ie when a specified threshold starting windspeed for a windmill was not attained. This information helps to establish whether a given site is suitable for a known type of windmill and to estimate the necessary storage capacity to ensure a continual water supply.

Types of windmills

There are two principal types of windmills in use worldwide: the vertical and horizontal axis windmills. These two categories can also be divided into low-cost and high-cost commercial windmills.

Three types of low-cost windmills have been built and tested at the Institute of Agricultural Engineering (IAE). These are the Cretan sail-type windmill, the Savonius rotor and the multibladed horizontal axis windmill. The Cretan sail windmill failed after operating for a few months due to the heavy rotor and inability of the turntable to revolve freely. Attempts to get useful work out of the Savonius windmill built from oil-drum sections via a roller vane pump, piston pump and electric alternator were all unsuccessful in the absence of strong winds. The multibladed windmill was damaged after operating for two years owing to the lack of an efficient storm protection mechanism. It was therefore concluded that the low-cost small-scale windmill was inappropriate for Zimbabwe.

The majority of commercial windmills use in Zimbabwe are the Climax, multibladed horizontal-axis type imported from South Africa. These are sold in various sizes designated Nos 6, 8, 10, 12, 14 and 18, the designation number corresponding to the rotor diameter in feet.

Wind power and windpump performance

Byabura-Kirya (1984) has outlined the procedure for estimating the theoretical power available in the wind and using it to predict the windmill and pump system output. The optimisation of the pumping performance of a windpump involves a complex exercise of windmill-pump matching. The main problem is due to the fact that the power in the wind is proportional to the cube of the windspeed

while the power from the pump commonly coupled to windmills in Zimbabwe (reciprocating piston pump) is proportional to its own speed. Ewens (1982) has found that sizing a pump so that the windmill starts in the average windspeed of the location and furling at the pump's maximum speed, and three times the average windspeed maximises the water output. The overall efficiency of a windpump is expressed usually as the overall coefficient of performance.

Testing of windmills

Field tests

The Ministry of Energy, Water Resources and Development carried out a monitoring exercise of two windmills (Climax No 18) manufactured by Stewarts and Lloyds of Zimbabwe. Water pumped and windspeed were recorded at hourly intervals at one of the sites (A) and daily at the other site (B).

At site (A) an average of 3.5m^3 of water per day was pumped in an average windspeed of 1.6ms^{-1} from a borehole 57m deep. At site (B) 6.4m^3 per day was pumped on average from a borehole 50m deep (total head 60m). The windspeed at the windmill site was not recorded but the average windspeed for the year 1983 obtained from the nearest Meteorological Station (Masvingo) was 3.4ms^{-1} . Site (B) was a much better site than (A) with the windmill at (B) giving an output of about twice the value from an identical windmill at the other site.

Laboratory tests

The windmills were tested at the IAE using simulated borehole conditions. This has been achieved by passing the water from the pump through a pressure tank with trapped air. Different pumping heads are obtained by controlling the tank pressure and regulating the outflow by a remotely controlled solenoid valve.

Windspeed recorded on a multi-channel compiler instrument is obtained for hourly (day time only) and 24 hour day intervals. The data so obtained are used to compute the average daily, weekly, monthly and yearly windspeeds. Windspeed frequency histograms and speed-duration curves can be compiled using the same data. Figure 2 shows windspeed and energy distributions for a typical low and high windy month (1983 data). A computer program is being developed to derive a mathematical relationship between the data compiled at the testing site and a Meteorological Station 20km away. By recording the water pumped by the windmill at the same interval as the windspeed, the performance of the windmill can be established. Three types and sizes of windmill have been tested:

1. Acrobat (manufactured in Finland) - small size (1.2m diameter rotor), lightweight (30kg for mill and tower), ease of installation.
2. SMK (Zimbabwe) - medium size (3.05m diameter rotor), oil bath lubricated gearbox (3.5 : 1 ratio).
3. Climax No 18 (Zimbabwe) - large size mill (5.5 diameter rotor), direct drive transmission.

Performance curves for the three windpumps obtained over the testing period so far are presented in Figure 3.

In Zimbabwe, the water requirement for farmers (human and livestock), schools, hospitals and small rural communities generally varies from 3-20m³/day and the water table depth is 10-50m for deep boreholes. Using a baseline water demand of 5m³/day, it can be deduced from Figure 3 that the SMK windmill can meet the demand up to about 15 m water table depth, while the Climax No. 18 can meet the same demand up to 45 m depth. The Acrobat windmill designed for low lift water pumping does not meet the minimum rural community requirements and is thus not appropriate for Zimbabwe. Note that the average daily windspeed for the testing site at the IAE has been 3.1 ms⁻¹ for the two year testing period which is just short of the national average of 3.2 ms⁻¹.

COST OF WATER PUMPING WITH WINDMILLS

Cost of windmills

The three low cost windmills built at the IAE in 1979 cost from Z\$300 to Z\$650 (raised to 1984 prices using a steady 12% inflation rate). The commercial windmills (Climax models) imported from South Africa costs from Z\$2000 to Z\$8750 for the Nos. 8-18. The locally manufactured windmills Nos. 12 and 18 cost Z\$3625 and Z\$6100 respectively (1984 prices).

Cost comparison with other water pumping systems

Elliott (1983) carried out a cost comparison analysis between diesel, electricity, solar, wind, human and animal powering pumps. He considered pumping against various heads and pumping rates ranging from 3-60m and 10-1000 m³ day⁻¹ respectively. The method used for the analysis was that developed by Medford (1980) to compare conventional to renewable energy sources. By this method, the present value of an energy system after a life span of the equipment is given by:

Present value = Capital costs + (recurrent costs) x N

$$\text{Where } N = \frac{1}{a-r} (e^{(a-r)T} - 1)$$

a is the petroleum escalation and general inflation rate factor; e is the mathematical exponent = 2.718; r is the discount rate (decimal); and T is the time to obsolescence of the system (years).

Elliott established that windmills were not viable for high-volume water pumping requirements in Zimbabwe. In such situations, diesel or electric pumps are most cost competitive. But for low energy pumping, ie low volumes (less than 10 m³/day) and heads (less than 50m) and for rural locations some hundreds of miles from a developed town where the transport of fuel or extension of an electricity line would be prohibitive, the use of a windmill may be justifiable.

EXTENT OF WINDMILL USE

A survey was carried out by the major windmill distributors in the country (Stewarts and Lloyds Ltd) to find out the location, present state and type of use of windmills. Most of the windmills in use up to 1983 were Nos 8-14 and located in commercial farming areas. They were generally used for cattle watering and supplying water for domestic needs. The depth of boreholes varied from 7m (23 ft) to 49m (160 ft) with an average depth of 24m (79 ft). The recorded estimates

of average daily output varied from 1140 to 9000 litres. The general view of users was that the windmills were a cheap and reliable source of power for water pumping besides a few complaints about the high initial costs and some occasional periods of insufficient wind at windmill sites.

CONCLUSIONS

1. Because of the low windspeeds prevalent in Zimbabwe, the conventional multibladed farm windmill has proved the most successful.
2. Windmills should be used for low energy water pumping demands in remote rural locations in situations where hand, diesel or electric pumps would not be feasible. Careful selection of a site is required and ample storage should be allowed for to fully optimise the windmill output.
3. Local manufacture of windmills give them an advantage over other water pumping systems like diesel engines or solar powered machines as less foreign currency is required for importation.
4. There is a need for further coordinated research in the country to determine the optimum windmill types and sizes to suit the available wind regimes. More comprehensive economic analyses should be carried out to justify the use of windmills instead of hand, animal, diesel, electric or solar powered pumps.

REFERENCES

Byabura-Kiryra B (1984) Wind energy utilisation in Zimbabwe. In: Proceedings of the making use of renewable energy conference. Professional Conferences Zimbabwe (Pvt) Ltd., Harare, Zimbabwe.

Elliott K M (1983) Water pumping costs for small-scale irrigation in Zimbabwe. Paper presented at Energy in Agriculture Symposium, Harare, Zimbabwe.

Ewens M (1982) The scientific approach to wind power and its practical use in pumping water. In: Proceedings of the Symposium on water pumping with windmills. Bulawayo, Zimbabwe.

Medford D (1980) Do renewable resources ever become economic? Proceedings of the Commonwealth Workshop on low-cost energy for water pumping. Commonwealth Secretariat, London.

Meteorological Services Department (1974) Mean surface winds. Climate Information Sheet No 53. Harare, Zimbabwe.

McNaughton D L (1982) Some Zimbabwean wind data in relation to a windmill feasibility study. Proceedings of the Symposium on water pumping with windmills. Bulawayo, Zimbabwe.

TABLE 1: Mean surface windspeeds over Zimbabwe (ms⁻¹)

STATION	MONTH												YEAR
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	
Binga	2.5	2.4	2.5	2.6	2.5	2.5	2.2	2.6	3.0	3.4	3.0	2.8	2.7
Buffalo Range	2.6	2.2	2.3	2.0	2.9	2.9	2.0	2.5	3.2	3.5	3.1	2.8	2.5
Bulawayo (Goetz)	3.5	3.5	3.6	3.3	3.5	3.8	4.0	4.2	4.3	4.1	3.4	3.2	3.7
Chipinge	4.2	4.0	4.0	3.9	3.6	3.5	3.5	4.1	4.7	5.0	4.7	4.3	4.1
Chirundu	1.3	1.2	1.4	1.5	1.5	1.6	2.0	2.5	3.2	3.1	2.2	1.5	1.9
Masvingo	2.6	2.5	2.4	2.2	2.0	2.0	2.2	2.6	3.2	3.3	2.9	2.6	2.6
Kadoma	2.4	2.8	2.9	3.3	3.4	3.9	3.8	3.9	4.1	4.5	3.8	3.1	3.5
Grand Reef	1.9	1.9	1.7	1.7	1.4	1.3	1.6	2.2	2.9	3.2	2.7	2.2	2.1
Gweru	3.4	3.4	3.5	3.1	3.1	3.2	3.2	3.9	4.3	4.2	3.7	3.5	3.5
Inyanga	2.5	2.6	3.0	3.1	2.9	2.9	3.2	3.4	3.8	3.8	3.2	2.6	3.1
Kariba	1.6	1.6	1.6	1.9	2.0	2.0	2.0	2.3	2.8	3.1	2.5	1.9	2.1
Karoi	2.7	2.6	2.9	3.0	3.0	3.1	3.2	3.6	4.1	4.1	3.5	3.0	3.2
Kwekwe	2.1	2.2	2.6	2.5	2.6	2.7	2.7	2.8	3.2	3.3	2.7	2.3	2.6
Harare (Belvedere)	2.6	2.6	2.8	2.8	2.8	3.0	3.3	3.5	3.9	3.9	3.2	2.9	3.1
Kutsaga	3.1	3.1	3.3	3.3	3.2	3.4	3.5	4.0	4.5	4.7	3.9	3.5	3.7
Victoria Falls	2.1	2.1	2.3	2.1	2.1	2.1	2.3	2.7	2.5	3.1	2.8	2.3	2.4
Country average	2.6	2.5	2.7	2.6	2.6	2.7	2.8	3.2	3.6	3.6	3.2	2.8	2.9

Source: Climate Information Sheet No. 53, October 1974

FIGURE 1: Map of Zimbabwe showing met station distribution

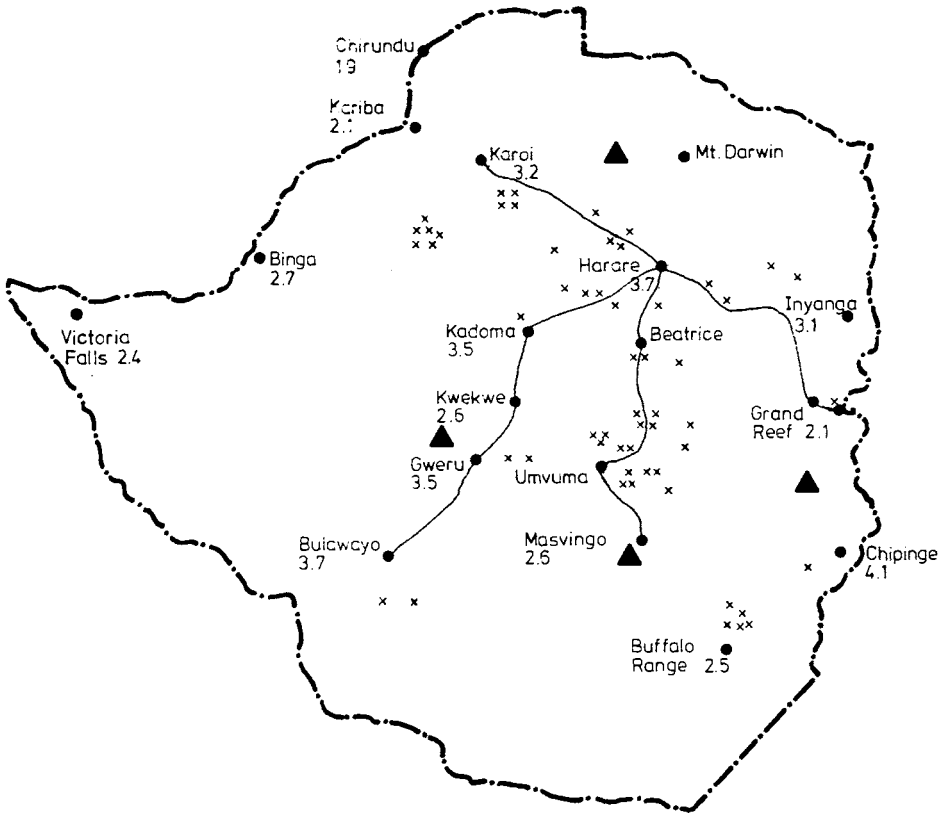


Figure 1: Map of Zimbabwe Showing Met Station Distribution.

x ————Dot represents location of operational Windmill.

Binga Annual mean windspeed
2.7 (m/s)

FIGURE 2: Windspeed and energy distributions for a typical low and high windy month

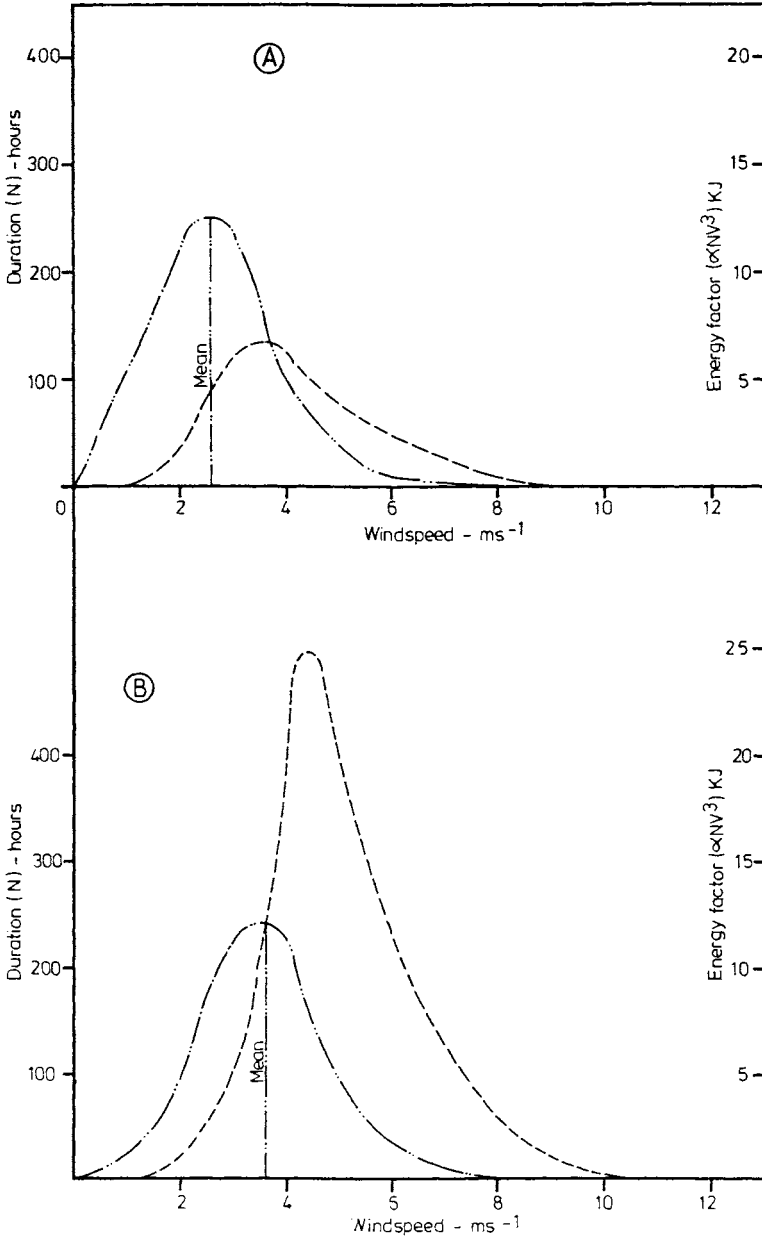


Figure 2 : Windspeed and energy distributions for a typical low and high windy month
A : April B : September (1983, IAE.)

--- Energy
-.-.- Windspeed

FIGURE 3: Performance curves of 3 windmills tested at IAE

