Disseminating Windpumps in Rural Kenya - Meeting Rural Water Needs using Locally Manufactured Windpumps

Mike Harries MA [i]
Chairman and Founder, Kijito Windpumps,
Bob Harries Engineering Limited,
P.O. Box 40, Thika, Kenya

Abstract

Around half the population in rural sub-Saharan Africa does not have access to reliable and clean water sources (World Bank, 2000). The use of wind energy for water pumping provides a valuable opportunity for meeting rural water needs. Bobs Harries Engineering Ltd. (BHEL), a local company in Kenya, is involved in the manufacture of *Kijito* wind pumps. With over 20 years experience in the manufacture and installation of over 300 wind pumps (both in Kenya and abroad), BHEL has developed a range of reliable and sturdy machines capable of withstanding storms and pumping water for years, with only minimal maintenance and attention. This article presents a historical review of the design, field-testing and manufacturing experiences of BHEL in the development of wind pumps for water pumping in remote rural areas. Using case studies of wind pump installation projects, the article outlines the challenges facing the dissemination of wind pumps in Africa and the benefits of windpumps to rural and remote areas. Policy options that may improve the dissemination and use of windpumps are proposed.

Key words: *windpumps, rural, Kenya*

1. Introduction

As a source of power, wind has been used for over 2000 years (Karekezi and Ranja, 1997). Numerous farming and livestock industries in USA, Australia and South Africa are still dependant on wind power for pumping water.

The best places for strong steady winds are temperate latitudes (between 40^0 and 50^0), and areas that are close to the sea. Wind speeds increase with altitude making hilltops favourable sites. The fact that winds are intermittent makes some applications such as water pumping more appropriate than others, such as direct electricity generation (IIED, 1981). In temperate regions, wind is a good alternative to solar energy, given the lower level of sunshine and comparatively higher wind activity (Kimani and Naumann, 1993).

Table 1. Estimate of Wind Power Potential

The successful exploitation of wind energy is highly site specific and largely depends on the wind resources of the area being exploited. Electricity generation from wind energy requires a wind speed greater than 5 meters per second (m/s). For windpumps, lower wind speeds can be sufficient. However, most windpumps will not start below a wind speed of 3 m/s and will furl at about 12 to 15 m/s (Karekezi and Ranja, 1997).

Table 2 Average Wind Speeds for Selected African Countries

Windpumps have registered notable success in countries. In Kenya (*see brief country profile*), the manufacture of windpumps is now an established industry. Wind powered waterpumps have led to increased agricultural productivity in rural areas, and, improved water supply for remote rural populations. In addition, windpump use has contributed to industrial development by giving rise to a new manufacturing industry (Karekezi, 1992).

{Insert brief country profile: Kenya here}

1.1 Windpump Technology Fundamentals

The following are the fundamentals of wind pumping technology:

- The output of any wind-powered machine is directly proportional to the square of the rotor diameter and to the cube of the wind speed passing through it.
- A dense (multi-bladed) rotor extracts torque from the wind at low wind speeds and shaft rotations per minute (r.p.m.). Unfortunately, it has to supply its maximum torque to lift the water and pump rod weight the very first time it rotates.
- A two or three bladed rotor as used in wind generators, extracts torque from the wind in proportion to the wind speed. It does this by either very fast r.p.m. as in the case of small DC wind generators, or a very large rotor diameter as in the case of the large AC wind turbines. Although the shaft rotations in large machines may be fairly low due to the very large diameter, the blade tips can be passing through the sound barrier, which has repercussions for the actual design and noise pollution.
- The speed of the wind across any surface is influenced by the ''friction'' it encounters, which is obviously much greater where there are trees or tall buildings near the wind pump. This friction is gradually reduced when the rotor is high above the source of that friction.
- Due to the flywheel effect of the rotor, once a wind pump has started to rotate, it can keep turning at substantially lower wind speed.

1.2 Development of the Kijito Windpumps

Bobs Harries Engineering Limited (BHEL), located near Thika Town, in Kenya, manufacture wind pumps for water pumping locally. The machines, which bear the brand name *'Kijito'* come in a range of rotor diameters from 8ft (capable of pumping heads of up to 36.5m, to the larger 24 ft diameter windpumps, which are able to lift water from deep boreholes of 152m.

The motivation behind the development of the Kijito windpumps was the dismal performance of diesel engines in the rural and arid areas of developing countries. The track record of the diesel engines in terms of reliability and running costs was below standard. Windpumps are competitive with diesel pumps for small and medium-scale water supply applications, if the wind speed in the least windy month is above 3.5 m/s. In remote areas where diesel fuel transport costs are high, windpumps can be economical at even lower wind speeds, as long as the water level is high. Windpumps are also economical in many remote cattle posts where small, dispersed water supplies are needed for livestock (Karekezi and Ranja, 1997).

Table 3. Cost Comparison between a Windpump and a Diesel Pump (US$)

2. ITDG/ODA Windpump Development Programme

The inception of the Kijito windpumps can be traced to the Intermediate Technology Development Group (ITDG), who had initiated some work on windpumps. The initial windpumps made from canvas and other locally available materials water required constant maintenance and had frequent breakdowns. With the initial assistance of Christian Aid, ITDG developed on improved machine with metal blades but was only able to operate on shallow wells. ITDG made some changes to this initial design and then sought to make contact with six developing countries, which would be interested in trying to develop an "appropriate" wind pump.

Through BHEL, in 1998, Kenya became the first country appointed as a collaborator in the ITDG programme. Later, Botswana, Egypt, Oman, India and Pakistan joined.

Only Kenya and Botswana showed interest in assisting the development of the "Appropriate Wind Pump". The other countries not keen in participating in the research and development phase. Botswana was more interested in developing a rotary drive wind pump that could be used to drive the "mono" type pumps that were common in the country. This left only Kenya to carry out almost all the practical development and field testing, done by BHEL in their workshops at Thika, Kenya.

1.3 Kijito Windpump Initiative

BHEL began the development of the *Kijito* by obtaining an old wind pump and studying its design. They realised that it was based on mainly cast iron components and also used gear wheels. They concluded that simpler construction techniques would be more suitable, if future manufacture in the third world countries was to become a reality.

After entering into collaborative effort with ITDG, the initial development was carried out at Thika in the farm workshop during 1977/78, and the first prototype built in January 1979. Fortunately, the Directors of a large ranch in Nanyuki (Ol Pejeta Ranching Ltd), decided to invest in wind pumps. The first commercial machine was installed in July 1979 at their Eland Downs Ranch on a 100 m borehole. Later, orders for a further ten machines followed. In September 1979, Bobs Harries Engineering Limited (BHEL) took over the responsibility for future wind pump development, under the registered trademark "*Kijito*".

1.4 Change of Direction

It then became apparent that if the *"Kijitos"* of the future were going to compete with the established designs from Australia, some major changes to the original ITDG machine and to the whole concept were required. From their experience in Kenya, BHEL felt that the real answer lay in a more expensive machine. This machine could consequently lift water from deep boreholes, and operate with minimal amount of maintenance. The reason as to why small diesel engines so often failed in rural Africa was not because their design was bad, but that the level of maintenance required was seldom readily available. It therefore did not seem to make much sense, to develop a wind pump that needed constant attention and frequent repairs, with the extra expense involved.

The Overseas Development Administration (ODA) of the British Government became actively involved in providing the much needed technical design assistance, initially through ITDG and then later on through Mr. Mike Neal and Associates of Farnham. This backup was mainly provided through Mr. Paul Dawson who was seconded to work with BHEL in Thika for a year, and then continued as a consultant through to 1985. BHEL were also very fortunate to obtain financial assistance from the Barclays Bank International Fund of London.

BHEL had definitely benefited from many of the design aspects that had been drawn up by Mr Paul Dawson. Following his year spent in their workshop, BHEL had the designs drawn on their own computer aided design programme. Over the proceeding couple of years BHEL ironed out the many shortcomings in the original ITDG design.

Most of the design changes were as a result of BHEL's practical field test on the Ol Pejeta form, with each step in the development of the design being built and then tested again. Since there was no funding for this work, BHEL had to maintain a cash flow by selling machines as and when it could. Furthermore, there were many inevitable problems with the earlier machines, thus, BHEL went the windpumps.

After close examination of the manufacturing processes of the old, well established and reliable multi-bladed "farm" wind pumps, the following substantial improvements were made to the original design:

3. Eliminate the typical cast iron transmission with its relatively complicated geared system, and develop a fabricated direct drive transmission. This not only reduced the actual weight of steel required by more than 50%, but this meant that it could be made in a fairly simple rural workshop.

4. Design a transmission that had a stroke that could be varied after installation, hence maximising its output under different wind conditions.

5. Produce a hinged tower structure that would make it possible to assemble the whole machine at ground level, then winch it up into position. This feature would also facilitate future maintenance/cleaning of the borehole, by just laying the wind pump back to allow a drilling/cleaning rig to carry out the work uninterrupted.

6. Implement the above with a motive of encouraging manufacturing in other countries under a Licensing Agreement, thus creating employment and a greater awareness of the benefits and expertise of wind pump technology in that country.

1.5 Recent Developments

More recently BHEL has been involved in the development of a range of small Windpumps called the Kijito "2000" Series. These are based on a design developed in Holland by the Government sponsored CWD Wind Project, used with permission. The concept behind these machines is to provide a much simpler (and cheaper) design, that would be suitable for the smallholder farmer, who has a water source about 20m below ground, and needs a limited amount of water for a few livestock and his/her domestic needs. This series comes with a rotor of either 6 or 8 feet diameter.

BHEL is currently seeking to develop a locally made DC Wind Generator, which will be based on BHEL's wide experience with the slow turning dense Kijito range of rotors.

3. Dissemination of the Kijito

BHEL has supplied windpumps to the following countries within and outside of the Sub-Saharan Africa (Table4):

Table 4. Windpumps Supplied by Bobs Harries Engineering Limited

As shown in table4, most of the installations have been for domestic and livestock water supply, and to a lesser extent, irrigation. The next section briefly describes some of the installations of the Kijito in Kenya.

3.1 Case Studies: Kijito Windpumps at work

<u>*Case Study 1- Lerata Makutano*</u>

Table 5 Case Study – Lerata Makutano

Lerata Makutano is situated north of Archer's Post, close to the Samburu National Park, in the Rift Valley Province of Kenya. At the inception of the project there was concern that water pumping would lower the water table and result in environmental degradation of the area. However, a couple of years later the vegetation cover had increase several-fold due to the water spillage from the pump.
In areas such as Lerata, which have the basic stand-alone windpump installation, one can fully appreciate the concept of using wind power. A diesel generator in the same situation would need constant maintenance and a dedicated operator, who would need to be housed. Diesel supply would also be problematic and in most cases very expensive. In addition, a common problem with portable generators is that they are easily stolen. The Kijito windpump, on the other hand, only needs maintenance every six months. It pumps water throughout the day and night when there is wind. In addition, it is difficult to steal a 30ft windpump.

BHEL encourages clients to undergo a maintenance course, which is provided free of charge for a duration of two weeks. The trainees are involved in actual installation of their windpump. In addition, BHEL representatives make impromptu visits to sites to ensure that the machines are fully functional.

Case Study 2 – Gatongora, Ruiru

Table 6 Case Study 2 – Gatongora, Ruiru

Gatongora is situated north of Nairobi, close to Ruiru Town, in the Central Province of Kenya. The Gatongora Development Group comprises 40 members. Inspite of proximity to the national electricity grid, the cost of electricity for pumping water was prohibitive. They therefore approached BHEL, and realised that wind pumping would be considerably cheaper than electric pumping. They were able to arrange financing through a micro finance institution, and the water pump was installed.

Once the project was completed, a committee appointed by members of the community managed the water pump. Water was sold to the community, with proceeds being used to repay the loan from the micro-finance institution. Currently, community members have to come to the water pump to collect their water. However, it is envisaged that in the future, when more funds become available, water will be channelled to each household.
In the past, funds collected for repairs and loan repayments from community projects were mismanaged. However, in this case, with the community benefiting from the project, the misuse of funds has been eliminated, since everyone has a stake.
Case Study 3 – Mugie Ranch

Table 7 Case Study 3 – Mugie Ranch

Mugie Ranch is situated north of Rumuruti Town in Rift Valley Province, Kenya. It is a very large ranch with 15,000 head of sheep. Rumuruti is a very dry area, and a long way from any major town, which would make the diesel pump option extremely expensive.

There are four windpumps installed in Mugie ranch. Twelve years after the installation of the first one, three more were requested. This was mainly due to the exceptional performance of the first (Kifuruti), which ran for twelve years without a leather washer change in the cylinder. This was as a result of a well-drilled borehole. In most cases, windpump breakdown is usually due to worn washers, rather than a problem with the windpump.

Mugie is one of the few cases where a hybrid system (wind and diesel) has been installed. BHEL has developed a combination valve, which enables a submersible pump to be installed below the windpump cylinder, and is therefore able to be used by the diesel generator. Most of the time, the windpump is in use, but there is the option to use the generator if necessary, giving a constant supply of water, at a fraction of the cost of only using a diesel or electrical installation.

4. Factors Affecting the Dissemination of Windpumps –The Local Manufacturer's Perspective

Most of sub-Saharan Africa has wind speeds above 3 m/s (Karekezi and Ranja, 1997). Therefore, wind pumping is a viable and useful option for improving water supply to rural areas. The following factors are crucial to the successful dissemination of windpumps, and are drawn from the experience of BHEL.

4.1 The Manufacturing Process

Currently, BHEL have a staff of 20 skilled personnel who manufacture the entire range of windpumps and pump cylinders. At the beginning of the Kijito windpump venture, the BHEL team had very basic skills. The initial step was building pieces of the originally improved Cretan Sail machine they had seen at Reading University in 1977. Fortunately, the ODA supported engineering and expertise enhanced their technical capability. A very informal organisational and management structure has also been very instrumental.

BHEL has only had one trained engineer on their staff, from Makerere University, who worked with them for several years. A lot of the training was provided in-house, since the manufacture of windpumps was a new venture in the country.

4.2 The Installation Process

The organisational issues are relatively easy to handle in the manufacturing process, which is centralised. On the other hand, for the installation process, the factors are completely different and for a small company, it is sometimes nearly overwhelming due to the following reasons:

- Windpumps are often installed in very remote areas;
- Long distances on often bad/non-existent roads are common, and requires a 4-wheel drive vehicle. BHEL is fortunate to have a small four-seater bush plane. Inspite of the fact that the plane is quite expensive to run, it would have been difficult to disseminate and install the *Kijito* windpumps in the remote places without it.
- Due to security problems, there have been times when the installation team has had to carry out their work under armed guard.
- Wind pumps are quite bulky, and therefore require quite large vehicles for transportation.
- Installations are often done in remote communities that have little experience in maintaining a mechanical device.
- Water is a very emotional resource, and sometimes the very fact that you are providing water, can cause conflict between those who have the water and those who do not have it.
- As mentioned earlier, there has been corruption amongst the leaders of the community.

These and other problems have often made it very difficult to always deliver the service to the people that BHEL would like, especially when it is being done on a limited budget. For instance, BHEL cannot afford portable radio communication, so sometimes when the BHEL team does face severe problems in remote areas, they cannot immediately be contacted.

4.3 Maintenance of the Kijito Windpump

Although the maintenance of windpumps is very minimal in comparison to diesel pumps, it is very different. In the past, there were a group of people who were experienced in windpump maintenance, but today that is no longer the case. Each time BHEL installs a windpump in a community, they train the community on maintenance of the windpump from the basics. However, not everyone likes to carry out their maintenance 9 or 12m above the ground. Therefore, inspite of this training, sometimes the maintenance is not done correctly. Consequently, machines experience breakdowns, which are usually relatively minor in nature (washers which are worn out, or broken pump rods). The net result is that no water comes to the surface, and this usually results in the technology being blamed rather than the simple lack of maintenance.

Amongst all these factors, maintenance of the actual machine is the most crucial factor. BHEL has tried to work on this issue by producing a very detailed Maintenance Manual, and also by offering a training course to all customers, though this has not always worked well. BHEL has also recognised that the local community must not only "own" the project but also take responsibility for looking after it. In quite a number of cases, windpumps installed by institutions such as Government, NGOs and churches have broken down because the community is waiting for the institution to come and fix the problem.

4.4 Financing and Economic Issues

BHEL has operated under extensive financial strain. The Government has not been able to provide a favourable fiscal environment for the development of windpumps in Kenya. Potential donors and aid groups support has also not been sufficient. Although BHEL received substantial assistance from some institutions such as Barclays Bank and ODA, several other funding institutions that they approached were not supportive because the amount of assistance BHEL needed to support the development was too small. An additional fact was that BHEL were seen as a commercial operation. Back then, many donors thought that the only way to help a country was through Government controlled and managed projects, and commercial ventures were not considered.

5. Problems Encountered in the Development and Dissemination of the Kijito windpump To Policy Perspective

BHEL has found that bringing the Kijito windpump to the commercial production stage was more difficult than anticipated. Some of the problems BHEL encountered can be summarised as follows:

1. Initially, there was a lot of scepticism because people believed that BHEL was trying to resurrect a technology discarded by the developed world, which was therefore inappropriate. For instance, in the early days of development, Government water officials refused to grant permission to an NGO, which was actually meeting all the expenses of running a Government borehole, to install a windpump. They did not understand that the conditions in developed countries years ago are similar to those faced in many parts of Africa today. Africa still has large agricultural communities living in the rural and arid areas without access to the grid.

2. There was also the failure to realise the benefits of local manufacture of windpumps, which is seldom the case with diesel or solar pumping systems. Apart from the imported ball bearings, the entire Kijito Windpump range is manufactured using local components at the BHEL Thika workshops.

3. In spite of the relatively poor track record of more conventional water pumping systems in rural and arid areas of Africa, few policy makers would want to take the "risk" of suggesting the installation of a windpump that "might" fail.

4. As far as the development of wind pumps is concerned, over the years, there have been a number of amateur initiatives and well-publicised failures. This has damaged the reputation of the whole technology. BHEL had some spectacular failures in the early days of development, but kept at it until it arrived at a technically sound product. This cost BHEL a lot of time and money, as customers who bought its machines in those early days were not charged for the repairs and modifications that were carried out.

5. Corruption has also played a large part in hindering the dissemination of windpumps. Some community leaders are able to extract substantial funds from the community, which allegedly go towards the provision of fuel and maintenance for the more conventional diesel or diesel electric pumping systems. Often, a proportion of these funds is misappropriated. On the contrary, windpumps require little maintenance and no fuel, therefore the opportunity to misappropriate funds is not there. In one instance, some Communities leaders tried to sabotage a BHEL windpump installation, hoping that it could be replaced by a diesel engine.

Perhaps these and some of the other problems that BHEL have faced over the years, were summarised rather well by the controversial *Machiavelli*, when he wrote in "*The Prince*": *"It ought to be remembered that there is nothing more perilous to conduct, or more uncertain in it's success, than to take the lead in the introduction of new things; since the innovator has for enemies, all those who have done well under the old system, and lukewarm defenders in those who may do well under the new."*

Unfortunately BHEL have found these words to be very true, in their efforts to re-introduce windpumps as a competitive and indeed, attractive and practical alternative, to small diesel engines in rural Africa. However, recently the tide seems to have started to change, and African Governments, aid agencies, and individuals have started to see that under the prevailing conditions, windpumps once again have become an appropriate way of lifting water.

Some financial initiatives that might help the future spread of windpumps are:

- Government subsidies or tax exemption for all windpumps installations
- Availability of finances which would enable commercial operators to set up a revolving fund, so that customers could pay for windpump installations over a long period.
- Provision of appropriate funding to help large-scale operators to set up a "Utility" type windpump installation, which would mean that the maintenance of the system should be much better managed.

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Table 1. Estimated Wind Power Potential (average possible production in GW)

World	6050
Africa	1200
Australia	330
North America	1600
Latin America	610
Western Europe	550
Eastern Europe	1200
Asia	560

Source: Karekezi and Ranja, 1997

Table 2. Average Wind Speeds for Selected African Countries

Country	Average Wind speeds
South Africa	8.5
Namibia	8.0
Lesotho	5.0
Seychelles	5.0
Eritrea	5.5
Uganda	4.0
Zimbabwe	3.5
Sudan	3.0
Tanzania	3.0
Kenya	3.0
Botswana	3.0
Mozambique	2.6
Burundi	2.5
Zambia	2.5

Source: Karekezi and Ranja, 1997, AFREPREN, 2001

Table 3 Cost Comparison Between a Windpump and a Diesel Pump (US$)

	Diesel Pump	Wind Pump
Capital Cost	6000	10000
Annual operating and maintenance cost	250	100
Fuel cost	292	0
Discount rate	10%	10%
Unit cost (US$/cubic meter)	0.18	0.19

Source: Karekezi and Ranja, 1997

Assumptions:
Lowest monthly average wind speed is 3.5 m/s. Windpump output is 20 cubic metres per day at 60 meters head. Diesel pump efficiency is 25%. Fuel cost is US$0.60 per litre.

Table 4 Windpumps Supplied by Bobs Harries Engineering Limited

Country	Number	Details
Canada	1	Demo in Princes Park Calgary
USA	1	Demo for World Fair – UNICEF
Rwanda	1	Umutara for German Agro Action
Jordan	1	Demo for University
Holland	1	Demo for Dutch Windpump Project
Niger	2	Project Tapis Vert
Botswana	2	For assessment by RIIC
Comoros	2	UNICEF
Britain	3	Demos for use by ITDG
Nigeria	4	World Bank Project in Kano
Sudan	7	Various
Uganda	10	AEE and others
Somalia	15	Various
Tanzania	26	Catholic Church and others
Kenya	220	Churches, rural communities and ranches

Source: Karekezi, Majoro and Kithyoma, 2001

Table 5 Case Study 1- Lerata Makutano

Site	*Lerata Makutano*
Customer	Catholic Diocese of Marsabit
Kijito Windpump Size	20ft rotor 30ft tower
Installation Date	July 1985
Water Source	Borehole
Pump Depth	30.48m
Cylinder	2¾" deepwell
Water Rest Level	17.68m
Use	Livestock & domestic

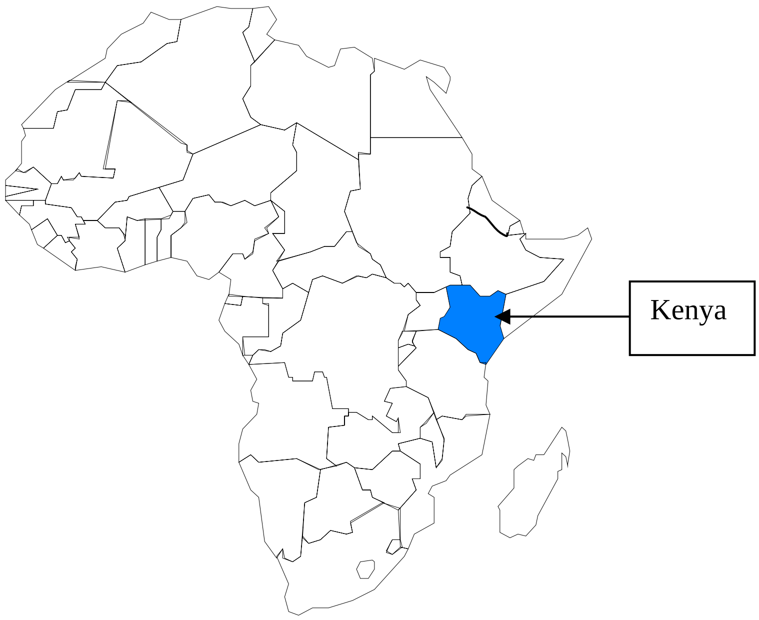
Table 6 Case Study 2 – Gatongora, Ruiru

Site	Gatongora, near Ruiru
Customer	Gatongora Development Group
Kijito Size	24ft rotor on a 40ft tower
Installation Date	October 1999
Water Source	Borehole
Pump Depth	67m
Cylinder	3¾” deepwell
Water Rest Level	43m
Use	Livestock & domestic

Table 7 Case Study 3 – Mugie Ranch

Site	Kifuruti	LionHill	Mutumayu	Kitenya
Customer	Mugie Ranch	Mugie Ranch	Mugie Ranch	Mugie Ranch
Kijito Size	20ft / 30ft	26ft / 40ft	26ft / 40ft	24ft /40ft
Inst Date	Dec 1987	March 2000	March 2000	March 2000
Water Source	Borehole	Borehole	Borehole	Borehole
Pump Depth	61m	73m	146.34m	91.46m
Cylinder	3¾”	3¾”	3¾”	3¾”
Water Rest Level	15.2m	37.8m	134.75m	91.46m
Use	Livestock	Livestock	Livestock	Livestock

Brief Country Profile: Kenya



Kenya: Selected Indicators
• **Population (million):** 28.7 (2000) • **Area (km^2):** 580,000 • **Capital City:** Nairobi • **GDP Growth Rate (%):** 0.4 (2000) • **GNP per Capita (US$):** 350 (1998) • **Official Exchange Rate:** KShs. 78.56 = 1 US$ (Jan 2002) • **Economic Activities:** Tourism, agriculture, forestry, manufacturing, mining, construction, commerce • **Energy Sources:** Geothermal, hydro, solar, biomass, imported oil, imported coal • **Installed Capacity (MW):** 1,173 (2001) • **Electricity Consumption per Capita (kWh):** 122.1 (2001) • **Electricity Generation (GWh):** 4,081 (2001)

Sources: Business in Africa (2001); AFREPREN (2001); EIU (2001)

End Notes

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[i] This article is based on the experience of Mr. Mike Harries, who set up Bob Harries Engineering as a small part of his farm. Over 20 years, BHEL has developed into the key windpump manufacturer in Kenya, and one of the largest windpump manufacturing company in East Africa.