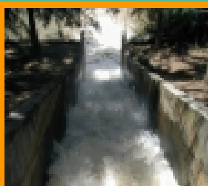
Renewable Energy in Swaziland

Case Study Brochure

2004





Swaziland Government

Ministry of Natural Resources and Energy

REASWA

Renewable Energy Association of Swaziland

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This report has been compiled and prepared by the REASWA on behalf of the Ministry of Natural Resources and Energy – Energy Section (MNRE-ES) for the Government of Swaziland. Further details of the technologies discussed in this document are available from REASWA.

REASWA is a registered, non-profit making NGO whose main purpose is to promote the cost-effective use of renewable energy in Swaziland in an environmentally sustainable and socially acceptable manner. REASWA consists of a cross-sectional membership from government, the private sector, non-governmental organisations and tertiary institutions.

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1) Introduction

Swaziland imports more than half of its energy requirements to fulfil the domestic and commercial needs of the country. The majority of this energy is sourced from fossil fuels, e.g. coal and petroleum. Local energy sources are primarily from biomass (organic matter such as wood, sugar waste, wood waste etc). However these energy resources are frequently used in an inefficient manner.

This is detrimental to the economy in terms of the balance of payments and poor operational efficiencies. In addition, there are major environmental and health impacts. The use of fossil fuels and the inefficient use of energy contribute towards climate change through the emission of carbon dioxide (CO_2) and other greenhouse gases. Climate change is now accepted as a phenomenon with major negative effects on global and local weather patterns. This will impact heavily on land use and agriculture, which is of great concern to countries such as Swaziland which are heavily dependent on agriculture. The use of wood fuel, which is becoming scarce in certain areas as a result of unsustainable overuse, is also a major source of respiratory illnesses and accidents in rural homesteads. The effective use of renewable energy can assist in alleviating these problems on both a local and a global scale.

So what is renewable energy? Renewable sources of energy are those which are continuously and sustainably available in our environment, such as wind, hydro, solar and biomass energy, e.g. wood fuel. Although many people may not be aware of it, Swaziland has abundant resources of renewable energy, especially in the form of solar, biomass and hydro. There is also a limited potential for using wind power, although this may be restricted to certain areas.

The use of renewable energy can impact on the levels of poverty in the country, through improving access to energy services in rural areas and creating opportunities for economic development. Renewable energy can also help address issues related to gender and energy. Through improved, cleaner and more efficient energy sources, such as solar and high efficiency wood stoves, the burden on rural women can be reduced in terms of fire wood collection and the purchase and use of paraffin.

Recognising the importance of utilising renewable energy resources now and in the future, the Ministry of Natural Resources and Energy of the Government of Swaziland commissioned the Renewable Energy Association of Swaziland to prepare and publish this case study brochure. The brochure sets out to demonstrate the opportunities for using renewable energy and to show that it is already in use to some extent within the country. Some of the activities taking place in the country have been highlighted to demonstrate renewable energy in practice.

2) Solar

Overview

The sun is the primary source of heat and light on the earth and is the main source of energy to sustain life. The energy from the sun drives our weather systems, creating wind, evaporating the water from the oceans so that the clouds can then release the rain over the mountains, filling rivers and watering our fields. The sun is essential to help plants grow, to feed our animals and ourselves. The amount of radiation transmitted from the sun that actually reaches the earth depends on a number of factors. These include the atmosphere, the weather and the air quality.

This energy from the sun can be harnessed and transferred into a more useable form. For example, solar photovoltaics (PV) convert the sun's energy into electricity, and solar thermal focuses the sun's energy directly into a useable heat source.

Solar PV uses semi-conducting material to capture the energy in the sun's rays to create an electric current. This electric current will be a direct current (DC), the same as a battery, as opposed to alternating current (AC), the same as the national electricity grid. This direct current is ideal for providing power for lighting and other low power appliances such as radios, black and white TVs and fridges. The power can be converted from DC to AC using an inverter for use in colour TVs, videos, etc. However, solar PV is not suitable for appliances such as irons or cookers, as the power requirements are too high. Generally, solar electricity is collected during the day and stored in batteries for use when it is required.

Solar hot water systems are a type of solar thermal and utilise the sun's rays directly to heat water. This is an effective way of reducing electricity consumption, as electricity is the most frequent method of heating water. Water is circulated from a storage tank to a panel filled with tubes, which is fixed to a roof. If guaranteed hot water is required, an electric element can be installed as a back up.

Solar energy can also be used to heat large volumes of water such as swimming pools and also for other activities such as cooking and drying fruit and vegetables.

Solar Case Study 1: Small Scale Solar PV System

A standard home solar PV system will cost in the region of E4,500. This will generally provide power for three lights and for a black and white TV or a radio, and may include a 50W solar panel, deep cycle battery, charge controller and three CFL lamps.

Gideon Dube of Moneni, near Manzini purchased his solar home system in 1992. It has been running without any problems for over ten years. The system comprises a 53W Siemens panel, a 5 Amp regulator, a 105 Amp-hour battery and six lights. It provides power for a black and white TV and a small radio.

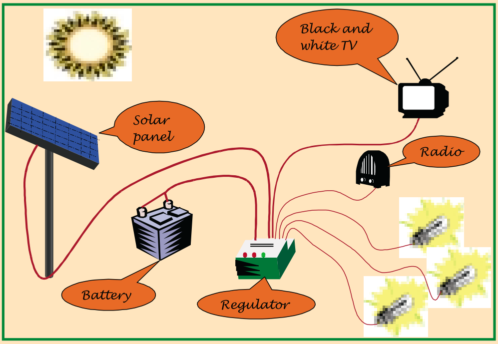

Figure 1: Typical layout of a solar home system

Mr Dube turns the lights on every evening between 6 pm and 10 pm and watches TV most nights. He has even successfully run a sewing machine from his system, which he borrowed with an inverter from a relative.

Figure 2: Mr Gideon Dube's solar home system

During the ten years he has been using solar, the only costs he has incurred are replacing the battery twice and replacing the tubes in the lights every 9 months or so. He was happy to explain about how little the system costs him to run. He never has to pay the utility money for his electricity. Unfortunately, very few of his neighbours have followed suit and bought a system. The area he lives in has electricity, however most people can not afford the initial outlay for either connection to the grid or such a solar system and are not in a position to get a loan or credit.

Mr Dube is a keen advocate of solar and is 100% satisfied. Even after ten years he is still excited about it.

Solar Case Study 2: Medium Scale Institutional Solar PV System

Solar is an ideal energy source for providing basic electrical services for institutions far from the national grid. One such institution is Mphaphati Primary School, which is part of the Mphaphati Solar Village Project.

Mphaphati Solar Village was established with the assistance of the United Nations Education and Science Council (UNESCO) within the framework of the World Solar Programme (1996 – 2005), as part of their interest in promoting renewable energy technologies to alleviate poverty.

The system installed at the school provides power for lighting three classrooms, colour TV and video, overhead projector, radios and security lights.

The system components comprise:

- Five 80Wp Shell Solar (SA) poly-crystalline panels
- Anti-theft frame and padlocks
- 14 x deep cycle batteries (96Ah)
- 3 x 20A charge regulators with audible alarm
- 6 x 2ft 18W lights in each of the three classrooms
- 400W DC/AC inverter
- Colour TV and video
- Overhead projector
- 2 x radio/cassette players

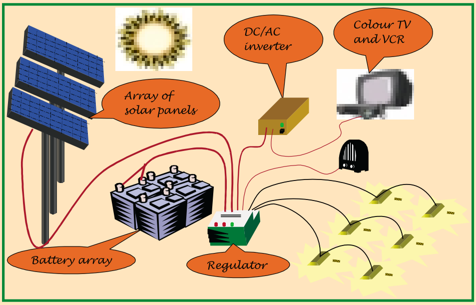

Figure 3: Mphaphati Primary School – system layout

The system was designed to power the television and video for 2.5 hours per day and each of the 18 lights for 5 hours per day, the radio for 4 hours per day and the overhead projector for 2 hours per day. This is based on an average maximum power output from the panels on a sunny day of 3.5 kWh/day.

Figure 4: Mphaphati Primary School

The total cost of the system, including the equipment and installation, is in the region of E60,000. This excludes security lighting, which is necessary to protect the system and provide greater safety for those using the buildings during darkness.

Key ingredients to the success and ownership of the solar village project were the full participation and support of the community. Without this, the project would have undoubtedly failed and the panels would have been stolen. During the three years that the project has been operating, not a single panel has been stolen. A solar committee manages a fund to maintain and repair the project, which comprises contributions from the teachers, students, parents and users of the system. The project is wholly self-sustaining, with the facility being hired out for watching films, football, the news and other social activities such as weddings and religious meetings. Income is also generated from battery and cell phone charging for members of the surrounding community.

The success of the solar village project prompted the country's mobile phone company to introduce a solar powered payphone in the local shop. With this the community can now contact friends and relatives and, when necessary, the emergency services.

Solar Case Study 3: Water Pump

Figure 5: Solar powered water pump

Solar energy can also be used for pumping water for irrigation. During sunny periods of the year when water is most needed, a solar system would work at its optimum.

An example of this is at the Mphaphati Solar Village, where a solar water pump was installed at a community garden as part of the UNESCO funded project.

One of the greatest challenges in designing a system for such outlying gardens is the prevention of theft, especially of the solar panels. At Mphaphati, a portable system was designed to be carried down to the garden whenever it was needed. The panels are transported in a heavy duty bag and laid onto a fixed permanent frame. The pump is carried down in a small rucksack and placed in the river. Due to the seasonal heavy rains, a small temporary weir is constructed only when required; a permanent structure would otherwise be washed away. The system includes two 80Wp Shell Solar polycrystalline panels, a Solarjack SDS/Q128 diaphragm pump, a Solarjack PCA 10/30 controller and a 10,000 litre brick water storage tank.

Figure 6: Solar panels to power water pump

To date, the women's group that runs the vegetable garden is very pleased with the pumping system. Prior to this they were using a petrol pump, however having to buy petrol proved to be expensive for the members. They still use this pump occasionally, when there is a need for large volumes of water, however they greatly favour using the solar system as the energy from the sun is free.

Solar Case Study 4: Solar PV Tools and Gadgets

Figure 7: Solar calculator

In addition to the larger systems above, there are many small-scale applications for solar PV. Solar cells have been used in calculators for a number of decades, thus removing the need to purchase batteries.

In rural areas throughout the country, many people listen to the radio as their main source of communication and keeping up with national and international events and for entertainment. However, these require frequent replacement of batteries, which are both costly and detrimental to the environment when thrown away. There are a number of products on the market which have integrated solar cells into the design of the radio for power. These are available in the country for about E300.

Figure 8: Solar radio

Due to limitations in the land line telephone network in rural areas, many people are buying cell phones to communicate with friends and family and for business purposes. However, cell phones require charging on a regular basis. They can be charged either by plugging into a standard solar home system or a through a dedicated solar cell charger.

Solar Case Study 5: Hot Water System

Most homesteads and institutions throughout the country heat their water using electric geysers. As such they miss out on a widely available and free energy source.

One example of an institution that has investigated and demonstrated the use of solar hot water systems is Swaziland Railways. Throughout their depots in

Sidvokodvo, Mpaka, Nsoko, Mlawula and Matsapha, about 15 systems have been installed and are fully operational. They were installed in 1999, on both staff hostels and individuals' houses owned and managed by Swaziland Railways. The main aim of the programme was to reduce the organisation's electricity bills from their institutional housing.


Figure 9: Swaziland Railways solar hot water system

Each system comprises a 100 litre tank fed by a panel. A number of the systems, such as the one in Figure 9, supply the staff hostels. Each wash house services 8 rooms, most of which are occupied by one family. The geyser is located on the roof of the wash house.

The systems installed are not big enough to provide enough hot water for all of the users. An electric backup is also installed on each geyser, set on a timer, so that during busy periods such as mornings and evenings, the users will have enough hot water.

The first system was installed by a private company, under the observation of Swaziland Railways technical personnel. The other systems were installed by their own personnel. The cost for an installed 100 litre system such as those above would be in the region of E5,500 up to E8,000 for a 200 litre system. Large savings can be made on electricity bills.

Solar Case Study 6: Solar Heated Swimming Pool

There are a number of hotels, clubs and schools around the country with swimming pools, which are deserted during the winter due to cold water temperatures.


Figure 10: Mr and Mrs Barlow's solar heated swimming pool

A swimming pool solar hot water system can raise the temperature of the water by up to 5ºC, making it acceptable and comfortable all year round. These systems are simpler than systems for domestic hot water, whereby temperatures need to be raised up to 60ºC.

Mr and Mrs Barlow, from Ezulwini added a solar system to their swimming pool so that they could start using it for a greater number of months. Although the system was still fairly new and the winter was not yet over, they noticed a marked increase in temperature.

The pool is about 30m^2, situated on the terrace of their house. The solar system comprises 3 panels (2m x 0.8m). The panels are solid polypropylene sheets of small tubes, connected directly to the swimming pool pump. A bypass valve was added for extra protection in case of excessive solar irradiation and the water temperature rises too high. Such a standard system would cost in the region of E6,500.

At night, the water cools down as heat is lost to the air. In order to maintain the temperature of the water, the installation of a pool blanket can help reduce heat losses.

Solar Case Study 7: Solar Cooker

Figure 11: iZola solar cooker

Firewood is the traditional energy source for cooking in many countries of the developing world especially in the dry zones of Africa. However rapid deforestation in some parts of the continent, including Swaziland, is resulting in a scarcity of fuel wood and frequently results in land degradation. Women and children are being forced to travel further and further to collect firewood placing an ever increasing burden on their daily life. The burning of firewood also has an impact on the global environment as CO_2 is released into the atmosphere adding to the greenhouse effect. There are also localised health impacts from the utilisation of wood fuels, for example due to smoke inhalation and burns.

Cooking with solar energy can alleviate such problems. The principle of solar cooking is that the sun's rays are concentrated on to a pot. This does not require any other fuel such as wood, paraffin, gas or, coal. Temperatures over 200^{o}C can be reached and this heat is used to cook, bake, and even heat up an iron.

There is an example of a solar cooker in Swaziland that was built by a couple in

Jubukweni, outside Mbabane. This cooker was built at home using aluminium plates, window glass, hardwood boards, planks and old newspapers.

Figure 12: "Minimum" solar box cooker

3) Wind

Overview

Figure 13: Typical large wind turbine

Wind has long been used as a source of energy. Sailing the oceans before the invention of the steam engine depended on wind energy. Windmills were used over centuries throughout the world for milling grain and for water pumping. From early last century, with the expansion of grid electricity and ease of availability of diesel engines, windmills became less important for milling and water pumping. However, with increasing fuel costs, many people continue to rely on wind for generating electricity and pumping water. Wind turbines generally generate DC power which can be stored in batteries for use when required. This can be converted to AC using an inverter, if necessary for certain equipment and appliances.

For commercial purposes for wind power generation, wind speeds in the region of 7 to 8 m/s (metres per second) at hub height (30 to 50 metres) are required. Lower wind speeds may be acceptable for non-commercial activities. Wind pumps tend to be used for point-of-use generation rather than commercial sale, and therefore wind speeds are less critical. However it should be noted that for a reasonable return on the investment winds speeds of over 7 m/s should be achieved.

In Swaziland, there is a potential for wind pumps and small scale turbines, although the average wind speeds are considered to be fairly low. There may also be opportunities for larger turbines in the Lubombo region, however wind measurement programmes are still on going and further data is required before there is any certainty in the availability of the wind resource. Wind measurement is carried out using anemometers to measure the wind speed and wind vanes to measure the direction, connected to data loggers. The ideal measurement height would be the required hub height for the proposed turbine. The quality and reliability of the data is highly dependant on the measurement period. The longer the period, the more reliable the data will be.

Wind Case Study 1: Small-Scale Turbine

There are few wind turbines in use in the country. Despite this, there is still a high potential for their use in providing power to individual homes or institutions.

A small turbine, such as a 600W Wind Charger could provide an adequate supply of power for basic electricity needs, such as TV and video, lighting and a fridge.

Such turbines are very easy to install and are connected to a battery bank from which power is stored and can be utilised when required.

An average system, including batteries, cabling and an inverter to convert the power from DC to AC, could cost in the region of E10,000.

Figure 14: Small-scale wind turbine – African 36

Due to the seasonal variations in wind and the general low wind speeds, the use of a wind turbine alone may result in a loss of power on occasions. It is therefore recommended that small wind turbines be integrated with other off-grid technologies such as solar.

Wind Case Study 2: Wind Pump

Figure 15: Wind pump at Tsabedze homestead

Throughout Swaziland there are more than 30 wind pumps pumping water from boreholes. These pumps have been installed either by farmers to provide water for their crops, communities for their water needs, or by private individuals. Wind pumps can range in height from three to thirty metres.

In August 1998, a Tsabedze homestead in Mafutseni installed a wind powered pump to cater for their water needs. Mr Tsabedze had come into contact with wind pumps many years before and when it came to deciding on the best way to provide a continuous and clean supply of water to his homestead, wind was the favoured option compared to a diesel pump. Although the initial costs may be high, the running costs are almost zero. Therefore there would be no bills to pay in the coming years.

Figure 16: Wind pump and garden

The wind pump is installed on a 12 metre tower and pumps water from a 107 metre deep borehole. The water is fed into two 4,000 litre tanks and is used for watering the garden and cattle (during the dry season) and for general household activities such as cooking, cleaning and washing. The household often has to tie the turbine blades to avoid unnecessary pumping of water when the tanks are full. An installation such as this can cost in the region of E50,000 to E70,000 (including the drilling of the borehole).

4) Hydro

Overview

Humankind has used the energy from falling water for many centuries, at first in mechanical form and since the late nineteenth century by further conversion to electrical energy. Water power and hydro-power are terms given to power extracted from energy in fast-flowing streams or rivers.

Small-scale hydro refers to the generation of between 1 MW and 20MW of electrical power. Mini-hydro refers to the generation of between 100 kW and 1 MW, while micro-hydro refers to the generation of between 5kW and 100kW. Pico hydro refers to the generation of less than 5kW of electrical power. In general mini and small scale hydro plants are connected to the National Grid, whereas micro and pico hydro are used for stand alone/off-grid applications.

In Swaziland, the Swaziland Electricity Board's hydro based installed capacity is 41.5 MW. There are presently three main hydro plants connected to the National Grid in the country, namely Ezulwini (20MW), Edwaleni (15MW) and Maguduza (6.5 MW).

In addition to the major grid-connected hydro plants, there are also a small number of plants operated by private companies for their own power needs. Some are integrated into the grid to ensure a balanced availability and quality of power, others are stand alone.

Figure 17: Ezulwini Hydro Tail Race

Hydro is highly dependent on there being sufficient water supply. During winter and drought periods, low flows may restrict the amount of electricity available.

Hydro Case Study 1: Ezulwini

Ezulwini Hydro Station was constructed in 1983. Due to limited and varying river flows, it was designed for rapid and frequent load changes such as during the country's morning and evening peak power periods. It is fed from Luphohlo Dam through a 4.3 km long tunnel, followed by a surface penstock (steel pipe) to the power house in the Ezulwini Valley.

The full reservoir covers an area of 210 hectares, the greatest water depth being 45 m. The live (or available) storage is 20 million m^3. The rockfill embankment is 48m high and 450 m long.

At the 20MW power station, the water is fed into two 10MW Pelton type turbines. Each turbine drives a 3.3 kV, 12.5 MVA, 300 rpm alternator, connected to a 66 kV step-up transformer. The expected output in an average year is over 90GWh. The dry season releases will allow Edwaleni and Maguduza to generate additional energy in winter when there is insufficient natural river flow to allow them to generate at full output.

Hydro Case Study 2: Maguga

The Maguga Dam was officially opened in early 2002. The main objective of the dam, which is part of a regional river programme, is to provide for the expected increase in water demand in the basin. The main benefactors of the project will be the irrigated sugarcane plantations, as the dam will enable a substantial expansion of the sugar growing industry in the country. The dam was also designed to allow the installation of a hydro electric power station, to generate electricity for the national grid.

Figure 18: Maguga Dam

Although the dam has been constructed and all of the civil works are in place for the hydro power plant, the actual turbines have not been installed to date. The delays in the installation of the turbines were partly due to environmental concerns regarding discharges. These were resolved and there are plans to build a stilling reservoir to prevent flushing of the downstream river and thus mitigate the environmental effects of the dam and hydro plant. The final decision on if and when to go ahead will depend on the availability of appropriate finance. The potential for utilising the Clean Development Mechanism (CDM) for financing through carbon dioxide reductions is also being investigated.

It is planned that two 9.6MW Francis turbines will be installed, with a total installed capacity of 19.2 MW, to provide power to the grid at peak periods. The power station will generate 76.63GWh annually. Its construction is estimated to cost about E100 million. The dam will be operated in parallel or in tandem with Driekoppies dam in on the Lomati River in South Africa.

Hydro Case Study 3: Mini/Micro Hydro – Swaziland Plantations

Swaziland Plantations is a forestry company in the Hhohho region near Piggs Peak producing sawn timber and pulp. They also share premises and are common shareholders with a pine furniture making company. The plantations, 90% of which are pine, cover an area of approximately 4,000 hectares. In addition to the wood grown locally, they also import wood from South Africa.

Figure 19: Swaziland Plantations turbine house and penstock

The saw mill and furniture making business require a constant and reliable source of electricity. The majority of this electricity is provided by an 800kW hydro power plant, owned and operated by the company.

The hydro plant was initially commissioned in 1952 and was built to provide for the power needs of Piggs Peak. The water is taken from the Mkomazana River and stored in a 35 metre high dam, before being fed into a 1.75 metre diameter, 300 metre long tunnel, which is then connected to the penstock. The head is 76.2 metres. The two 400kW Francis turbines are designed to take a water flow of 0.8 cumecs and have an efficiency of about 85% (when running at full capacity). They are each connected to three phase 415kVA alternators.

The alternators feed into an 800 kVA transformer which is synchronised to the SEB system and feeds a 16 km, 11 kV line direct to the sawmill. During summer, when there is an abundance of water, the hydro plant can provide about 90% of the company’s power needs. This drops significantly in winter.

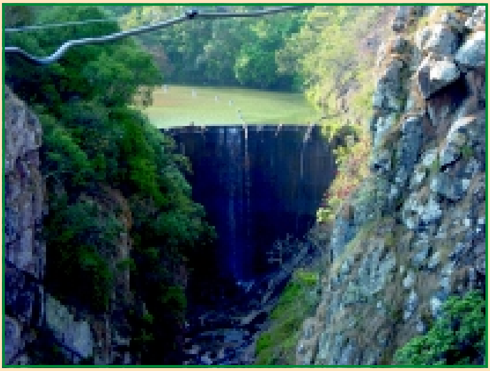

Figure 20: Dam supplying water for turbines at Swaziland Plantations hydro plant

One of the turbines was refurbished in June 2002 and plans are being developed to refurbish the other turbine. A major problem faced by Swaziland Plantations is getting access to the dam for maintenance, due to its remote location and difficult topography. Of greater concern is the siltation of the dam, mainly due to the collapse of the sludge dam walls at the now closed Havelock Asbestos Mine. Presently, the water level is about two metres deep, the other 35 metres of the dam's depth are filled with sludge. In response to this, Swaziland Plantations are undertaking a long term programme to dredge the dam. This is expected to take up to four years to complete at great expense, unless there are further developments at the closed mine site resulting in more sludge and silt being fed into the river.

Swaziland Plantations are strong advocates of hydro and their small plant helps towards keeping production costs down and creating employment.

Hydro Case Study 4: Pico Hydro

Pico hydro is an ideal power source for improving rural energy services. Pico turbines are simple to install and operate. They also can provide an adequate source of power for rural homesteads 24 hours per day from low flowing streams.

Although there do not appear to be any pico turbines in operation, there are plans to introduce them to the streams and rivers of Swaziland in the very near future.

Figure 21: Turgo turbine and jet

Mr Terry Gray, from Pine Valley has been interested in pico hydro for a number of years and is in the process of installing a system onto his property to assist with his power requirements. A small stream crosses through his property bringing water from Sibebe rock to the Mbuluzi. The lowest flows, in winter, are in the region of 5 litres per second.

Some of this water will be redirected through a pipe as it enters the property and fed into the turbine lower down in the property. A head of about 15 metres will be provided by this drop. The turbine that Mr Gray is planning to use is a 90mm ‘Turgo’ imported from Sweden for approximately US$300. Connected to an alternator, the turbine can produce between 250W and 800W depending on the flows, ranging from 2.5 to 5 litres per second, and depending on the size and number of jets used. For low flows a single small diameter jet will be used. For higher flows, two larger jets could be used to give greater power generation.

The power will be fed directly into two standard 110 Ah batteries at 24V DC, which will provide power for lighting and audio equipment in his house. This system is still a prototype under construction, although there are plans to develop it with the aim of local manufacturing. Most parts, such as alternators and batteries can be obtained locally and the turbine blades could be made from simple casting in plastic.

Mr Gray is also in the process of importing a number of ‘pelton’ turbines. One is due to be installed at a community tourism venture close to Sibebe Rock.

A simple pico hydro generation plant can also be made by converting a simple water pump.

Hydro Case Study 5: Ram pump

Ram pumps are water powered pumps that use the energy of falling water to drive a portion of a stream uphill to a point higher than the original source. They were invented about 200 years ago and are good examples of the use of micro-hydro energy. Figure 22 shows a locally manufactured 150mm pump (150mm is the supply pipe diameter) installed near Gelukstad in South Africa. Drawing 10 litres per second from the river at a 4.5 metre high natural waterfall, it pumps 2 litres per second up to a farmhouse for tree irrigation. The house is 24 metres higher than the pump and more than a kilometre away.

Some people will remember that ram pumps were used many years ago in Swaziland to supply water to the steam engines along the railway line to the Ngwenya Iron Ore Mine. Now manufactured locally at a fraction of the cost of importing them from Europe, we can once again look forward to installing more of these no-engine, zero-pollution pumps.


Figure 22: Ram pump

Ram pumps cannot pull water from a borehole nor can they be placed on slow moving rivers as there is no falling water at these sites, however, there are literally thousands of suitable sites for these pumps in Swaziland's highveld areas.

A ram pump is a good science project as working models can easily be made from off the shelf plumbing parts. Models can be made entirely from plastic parts, unlike the ones installed in the field which are made from heavy steel components. Maintenance parts (rubber) are required about every five years.

5) Biomass

Overview

Biomass is the term used for any product arising from biological activity or living thing such as animals and plants. Examples of biomass include firewood, tree cuttings, bark, leaves, maize cobs, grass, vegetable waste, and animal waste (dry and wet). All biomass contains carbon, an essential element in combustion processes. When biomass is burnt, heat energy and CO_2 are produced. Biomass can therefore be described as renewable energy if the amount of CO_2 produced is equal to that absorbed during growing – that is if there is continuous replanting.

If it is burnt in a controlled manner on a large scale, such as in a steam boiler, the heat produced from the combustion process can be used for beneficial purposes, such as process steam or electricity generation. In Swaziland the most abundant biomass suitable for combustion in commercial steam boilers is sugar cane waste (bagasse) from the sugar industries, and wood waste from the pulp and timber industries.

On a domestic level, wood is the most important energy source for most of the population of Swaziland. It is frequently the only energy source for the 70% of households in the rural areas. It is also a major energy source for peri-urban households. Wood fuel accounts for 65% of the country's total energy consumption.

Wood is primarily used for cooking in the household sector. It also provides for space heating and energy for other household tasks such as water heating, ironing and lighting. However, acute depletion of the forest resource (deforestation) has been observed in several chiefdoms of the country. A major cause of deforestation is the increasing and high population with the consequent rising need for more arable and grazing land. Acute removal of the wood resource results in energy poverty, as well as soil erosion and ultimately desertification. This has a negative impact on agricultural productivity, which in turn compromises the food security situation of households. The poor are further relegated to extreme poverty as degraded land impoverishes those who depend on subsistence farming.

As a result of this fuel poverty, people living in the deforested areas are forced to walk longer distances looking for firewood. This exposes women and children, the major firewood collectors, to a variety of socio-economic and health hazards.

Those households that are experiencing fuel poverty are forced to explore other avenues to meet their energy needs. Some households are known to purchase firewood, which results in strained household incomes. Other households are forced to turn to low quality fuel resources such as cow dung, shrubs or hedges, while others switch to commercial fuels such as paraffin or LPG (liquefied petroleum gas). At times it exposes poor households to low quality, sub-standard end-use devices, which can result in health and human hazards.

In addition to the combustion of biomass, certain types of biomass can be fed into biogas digesters, whereby it is broken down in the absence of oxygen to produce methane, a gas which can be used for cooking, heating and lighting. There are presently no operating examples of this in the country.

Swaziland is putting in place several responses to this increasing fuel wood scarcity. At national level, two policy formulation processes are at an advanced stage to address this problem, culminating in a National Forest Policy and a National Energy Policy. Other responses include planting of woodlots in those areas that are heavily deforested.

The Swaziland National Energy Policy recognises the importance of biomass in fulfilling the energy needs of rural communities and fully supports initiatives in the sustainable use of biomass. The establishment of communal multipurpose woodlots and individual tree growing is encouraged. One of the major objectives of the National Forest Policy is to develop community forestry and sustainable management of natural forests and woodlands. It emphasises that these measures must be taken to ensure sustainable supply of wood fuel to meet the needs of communities.

Biomass Case Study 1: Bagasse Fired Power Generation

There are three sugar mills in Swaziland, Mhlume and Simunye, (owned by the Royal Swaziland Sugar Corporation Ltd) and Ubombo Sugar Ltd (Illovo). These industries all produce sugar from sugarcane. Some of the residue left over from the milling process (bagasse) is used to produce cattle feed at one of the mills, but generally the bagasse is used in the steam boilers. The steam produced in these boilers is used for process heat and electricity generation in steam turbines.

Figure 23: Ubombo Sugar Mill, Big Bend, which generates heat and power from bagasse

Simunye sugar mill produces almost 400,000 tonnes of bagasse each year, which is used for power and heat generation within the mill. Coal is used during the off-crop season to supplement the lack of bagasse. Simunye produces approximately 400,000 gigajoules/GJ (which is equivalent to approximately 110,000 MWh) of heat annually and on average 14 MW_e of electricity.

Biomass Case Study 2: Wood Waste Fired Power Generation

SAPPI-Usutu produces unbleached kraft softwood pulp in Swaziland. Bark is stripped from the pine timber logs, and used for combustion in a specialised bark furnace to produce steam for process heat and electricity generation.

About 100,000 tonnes of wood waste are burnt in the bark furnace per year. Coal is gasified as an energy source for the flash drying of the pulp, before compacting it into bales. The company produces on average 9 MW_e of electricity and about 260 000 gigajoules/GJ (which is equivalent to approximately 72,000 MWh) of process heat per annum.

Since there is a continuous programme of replanting trees, all carbon dioxide emitted during combustion is balanced by the carbon dioxide absorbed during growing. The process is therefore a renewable use of resources.

Biomass Case Study 3: Wood Lots

One strategy initiated by the Government of Swaziland to address wood fuel shortages is the establishment of woodlots. A Community Woodlot pilot project was initiated in 1991/1992, targeting those areas with acute and growing wood fuel shortages. The long term aim is to develop a National Woodlot Programme after teaching/training various communities how to grow, manage and maintain trees until they are ready for harvest.

The Project was implemented by the Ministry of Natural Resources and Energy and the Ministry of Agriculture and Co-operatives and financed by the Government of Swaziland. It was piloted in the Bhekinkosi/ Mliba Rural Development Area (RDA) under the Mkhiweni Inkhundla in the Manzini Region. Another site was Zikhotheni in the Hluti/Mahamba RDA under the Shiselweni Inkhundla.

The project’s objectives were:

i) to provide firewood
ii) to provide building poles and timber and
iii) to control soil erosion

The participating communities were provided with training, seedlings and material support in the form of fencing, treated poles and access to heavy plant. In addition a forest nursery of approximately 3,000 seedlings was also established in Luve to increase the community's access to seedlings. During the initial stages only exotic trees were planted, but later indigenous trees were also stocked. Farmers in these areas were trained in forest management. There are also other community woodlots throughout the country, planted by Government in collaboration with communities during national tree planting days under the Forestry Section in the Ministry of Agriculture and Co-operatives. Tree planting days are observed annually in Swaziland and other SADC member countries.

The dominating tree species in the nurseries include some of the Eucalyptus family such as E. Grandis, E. Camdulensis, and E. Paniculata. Other species include Casourina Cannighamia, Acacia Meansii.

Other nurseries are situated in the following areas:

- Central R.D.A. (Ludzeludze)
- Mahlangatja R.D.A.
- Northern R.D.A. (Ntfonjeni)
- Southern R.D.A. (KoNtjingila) and
- Malkerns Research Station

The latter is the biggest nursery and provides both exotic and indigenous trees including fruit trees. In addition, there are nurseries in all commercial plantations that will offer assistance to neighbouring communities on request. There are also nurseries open to the general public, although these mainly offer seedlings for ornamental trees, fruit trees and flowers.

Biomass Case Study 4: Basintuthu Domestic Baking Stove

In order to address the issue of wood fuel shortages, a fuel-efficient woodstove called the Basintuthu Baking Stove was developed locally from a similar Zimbabwean stove called the Tsotso.

Figure 24: Basintuthu Baking Stove

The stove can cook or bake and consumes about a quarter of the wood used by a Welcome Dover, Magic or similar coal stove and costs less than half as much. It has primary and secondary combustion which means that it burns the smoke before it leaves the area of the fire. This is accomplished with the introduction of hot air into the top of the fire where the smoke is ignited, releasing extra heat.

The Basintuthu Baking Stove is designed to be portable so it can be taken outside on sunny days. It can cook two pots or bake 3 loaves of bread. The secret of its success is the small fire which burns not in the 'firebox' but in the vertical tube descending from under the stove body. The stove can be mounted inside the house and connected to a chimney and also used for heating the room. It can cost in the region of E850. Single pot stoves are also available for around E266 but cannot be used for baking.

Biomass Case Study 5: Gone Rural Commercial Grass Boiler

Figure 25: Grass boiler at Gone Rural

The wood fuel saving technology for domestic cooking was successfully adapted to a far larger commercial application: dyeing lutindzi for making handicraft at Gone Rural in Malkerns. Lutindzi is slightly waxy and does not take dye very well. It has to be boiled in dye for about 45 minutes, therefore three large double tanks were made to handle large amounts of lutindzi at a time. Each pair of 165 litre tanks is heated from below by a Basintuthu-style wood burning grate. In this case it is rectangular instead of round and is about half the length of the tank. It can hold a few kilogrammes of wood at a time and is refuelled about once an hour. Each boiler fire can emit about 30 kilowatts of heat. If the heat produced by these three units were to be provided by electric elements, the electric bill would be E275 per day.

Because of the more modern layout of the brickwork and the secondary combustion technology, the new grass boiler uses far less wood per day than the old units which were made with sheltered open fires and oil drums. The tanks hold much more lutindzi so additional fuel savings are made while also increasing production.

More than 250 people are supplied with dyed lutindzi for their handicraft production, representing a significant impact on rural employment.

The grass boilers are a good example of a locally adapted technology manufactured to suit an industrial energy need, using a pollution-free, carbon-neutral, renewable energy resource. They process a wild crop that is hand gathered, generating rural manufacturing employment income from an exported handicraft product.

Biomass Case Study 6: Briquetting

Briquetting is the densification of wood, woodwaste, agro-waste and other combustible waste by compression to produce fuel bricks. These fuel bricks usually have a high heat content per unit of volume. Generally, the quality of briquettes is somewhat higher than wood and they are easier to ignite than wood, cowdung or coal. Additionally, briquettes produce less smoke, provided they are sufficiently dried and are kept away from humidity.

Figure 26: Fuel briquettes

Swaziland's investigations into the making of briquettes date back to 1993. A major company in the forestry industry carried out a study to assess the viability of briquetting its wood waste products. The project never actually took off due to high operational and personnel costs.

The Home Economics Section of the Ministry of Agriculture and Co-operatives, with funding from the Ministry of Natural Resources and Energy, conducted pilot briquetting projects in 1999/2000. The objectives were:

1) to assess the viability of briquettes among households, and
2) to reduce impacts on the environment by recycling resources such as sawdust and newspapers.

The pilot project entailed scouting for old newspapers, which are abundant in the urban and peri-urban areas. The newspapers (and/or cardboards boxes) were shredded and soaked overnight and then mixed with sawdust. Sawdust is an abundant resource that a number of industries churn out on a daily basis. Some large companies offered this waste product free of charge and others sold it at minimum cost.

The mixture is then poured into a mould. Excess water is squeezed out from the mixture, while the sawdust and newspapers are compressed into a transportable paper brick. The brick is then dried in the open over four to seven days, depending on weather conditions.

Although acceptance of these briquettes was mixed since they are not a traditional fuel, retention and use of this technology has been quite high in those areas that are in need of wood fuel.

Other spin-offs from the project were:

(i) Potential business ventures appropriate for rural populations, especially women and youth. During this pilot project, a women's group under Mkhiweni Inkhundla got an order to supply a private company in the Lubombo region with about three tonnes of briquettes. This can be seen as a positive contribution to alleviating poverty

(ii) Partnership with the private sector. The manufacture of the moulds used in the process and some of the raw materials are provided by the private sector. Additionally, a toilet-paper manufacturing company churns out paper sludge in tonnes as a major waste product that they will gladly give away for free. This waste product does not need soaking and perfectly binds the sawdust without additional labour, cost or resources

(iii) Partnerships with the NGO sector and other civic community groups. The briquetting technology was shared extensively with others that have environmental concerns as one of their focus points

(iv) The pilot demonstrated that women can play a fundamental role in participatory community research and the use of alternative energy in ways that can lead to the improvement of the quality of life for rural communities.

6) Other

Case Study 1: Hybrid Systems

A hybrid system is basically a combination of more than one technology, for example wind and solar. The aim of using more than one technology is to increase the reliability of the power source. For example, during the rainy season, when solar radiation is limited, there is a greater chance of increased wind, which can be exploited to provide electricity.

An example of this can be found on Mdzimba mountain, where the Central Bank has located a communications system. This is a two way radio system for internal use. It is essential that a good power source is available at all times to ensure there are no communication breakdowns.

The system comprises:

- two 75W solar panels
- Air 403, 400W wind turbine
- two 105Ah AC Delco sealed batteries.

The turbine has a blade diameter of 1.2 metres and has a built in regulator. The power feeds straight into the batteries. The radio system has its own built in regulator and load shed to prevent over discharging of the batteries.

Such a system would cost in the region of E15,000 to E25,000, depending on the location.

Case Study 2: Play Pump

Provision of clean, safe water is a major priority in rural areas for health and hygiene reasons and for basic daily activities, such as cooking. Women and children frequently spend a lot of time and energy in fetching water from the nearest source. If traditional water resources such as dams, springs, rivers and streams are not available or if they are polluted, boreholes are frequently used, operated by handpumps. Modern alternatives, such as diesel, petrol or electric pumps tend to be prohibited by high fuel and maintenance costs.

A project has been developed, whereby a children's roundabout is used to pump water into a storage tank. The Play-Pump is a novel concept in water provision and is a simple solution to both a regular supply of clean, safe water and free, active entertainment for children.

The Play-Pump, a specially designed and patented children's roundabout, is fitted over a borehole and works as an alternative to the hand pump. As it is rotated by children playing, it pumps water into a storage tank by driving a conventional borehole pump element. Costs for maintenance are minimal.

Figure 27: Launch of Play Pump at Nyamane Primary School

The pump design converts rotational movement to reciprocating linear movement by a driving mechanism consisting of only two working parts. This makes the pump highly effective, easy to operate and very economical. It is bi-directional so whichever way the children turn it, it will pump water. The Play-Pump is capable of producing 1,400 litres per hour at 16 rpm from a depth of 40 metres and is effective up to a depth of 100 metres. A typical handpump installation cannot compete with this delivery rate, even with substantial effort. It is also a sealed system to protect the integrity of the borehole from contamination and surplus water is returned to the borehole so there is no wastage. Also, being sealed, children can not hurt themselves whilst playing.

A number of these systems have already been installed throughout South Africa. The design is proven and recommendations have been received from a number of donors and development agencies. A system has been installed at Nyamane Primary School, near Nhlangano.

7) List of Main Suppliers

COMPANY NAME	ACTIVITIES	CONTACT DETAILS
AfriTool	Installers of solar hot water systems	P.O. Box 4100, Mbabane Tel: 422 0686 Fax: 422 1332 afritool@africaonline.co.sz
Best Company	Suppliers of solar cell phone chargers, wind-up torches and cell phone chargers	Tel: 608-1958
Dantel	Installers of solar and small wind systems for communications systems	P.O. Box 286, Mbabane Tel/fax: 404 5656 dantel@swazi.net
Eco Electronics	Installers of solar hot water systems, solar heated swimming pools, solar PV and small scale wind turbines and pumps	P.O. Box A251, Swazi Plaza, Mbabane Unit 9, SEDCO, Mbabane Tel/fax: 404 8166/603 7000 mwcornwell@iafrica.sz
New Dawn Engineering	Manufacturers and retailers of high efficiency wood stoves and ram pumps	P.O. Box 3223, Manzini Tel/fax: 518 5016 sales@newdawn.sz
Lilanga Solar Systems	Retailers and installers of solar PV systems and components	P.O. Box 4102, Manzini Tel: 505 4175 lilangasolar@swazi.net
Agri Pump and Irrigation	Installers of wind pumps, wind generators, dual wind systems, Solar PV and solar hot water systems	P.O. Box 6899, Manzini Tel: 505 7820 Fax: 505 7835 agri-pump@realnet.co.sz

8) Glossary of Terms

AC - Alternating Current is the power from the national grid.

Bagasse - The solid residue from the processing of sugarcane.

CO_2 - Carbon Dioxide. CO_2 is emitted when biomass and fossil fuels are burned and is absorbed when plants etc are grown. As a result of industrialisation, the extensive combustion of fossil fuels has caused too much CO_2 to be released, which has resulted in changes in the global climate.

CFL - Compact Fluorescent Lamp. These use only a fraction of the power compared to a standard incandescent bulb, but give the same light output. They are ideal for use with renewable energy system as they will help conserve the power available.

Cumecs - Cubic metres per second.

DC - Direct Current as found in batteries.

kWh - Kilowatt hour. A kWh is a unit of electricity.

LPG - Liquefied Petroleum Gas.

NGO - Non-Governmental Organisation.

PV - Photovoltaic. PV panels are formed from semi-conductive material that converts the rays from the sun into DC electricity.

UNESCO - United Nations Education and Science Council.

9) Definitions

The various definitions of pico, micro, mini and small scale hydro are as follows:

The definition by UNDP and WORLD BANK is:
1 to 5 kW is referred to as .... **pico**
5 to 100 kW is referred to as .... **micro.**
100 KW to 1 MW is referred to as .. **mini**.
1 MW to 20 MW is referred to as ... **small.**

The Chinese definition is:
up to 100 kW .... **micro**.
101 to 500 kW .... **mini**.
501 to 25,000 kW.......................... **small**.

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