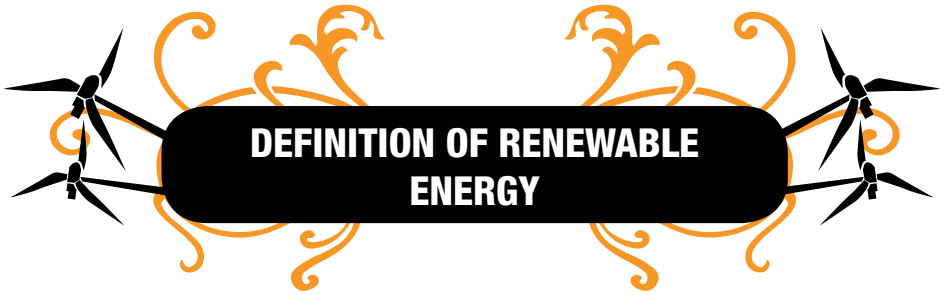
CHAPTER 4

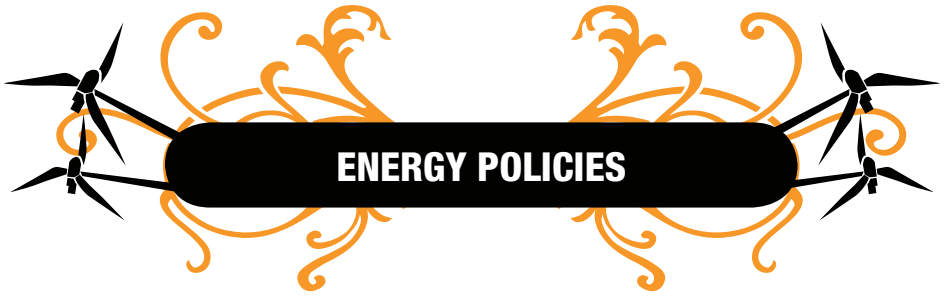

by Riaan Meyer and Graham Gariseb, Centre for Renewable and Sustainable Energy Studies, Stellenbosch University

"We've embarked on the beginning of the last days of the age of oil. Embrace the future and recognize the growing demand for a wide range of fuels or ignore reality and slowly—but surely—be left behind."

**Mike Bowlin, chairman and CEO of ARCO (now BP)**




Renewable energy refers to energy that is derived from sources that are essentially inexhaustible or from natural resources such as wind, sunlight, rain, tides and geothermal heat, which are renewable (naturally replenished), produce few hazardous emissions or pollutants, and have minimal impact on ecosystems.




In the apartheid era, energy policy was driven by a need to be self-sufficient, which resulted in a national dependence on coal – the country's main energy reserve. South Africa continues to be dependent on coal. The energy sector is dominated by a few large players and poor communities have inadequate access to affordable and safe fuels. Current policy represents a shift in direction towards improving access to energy, particularly for previously disadvantaged communities, although sustainability has yet to emerge as a key priority.

## Energy White Paper of 1998

The aims of this paper are to:

- Increase access to affordable energy services;
- Improve energy governance and restructure government assets;
- Manage energy-related environmental impacts;
- Secure supply through diversity and open markets;
- Stimulate economic development – create SMMEs and export opportunities;
- Assist previously disadvantaged people to gain entry to the energy sector;
- Allow unrestricted market access to the liquid fuels market;

## Municipal Systems Act No 32 of 2000

Section 23 of the Act requires that municipalities:

- Produce integrated development plans for the medium-term development of their municipal areas to meet the needs of their communities;
- Provide sustainable services to their communities;
- Promote increased community involvement in the provision of energy services.

## White Paper on Renewable Energy & Clean Energy Development (Draft 2002)

Though this paper does not provide guidance on the use of renewable energy applications, it does provide the following:

- This paper sets a 10 year target of 10,000GWh/annum renewable energy production for South Africa
- This paper acknowledges the important role of renewable energy in the long-term energy planning and applications in South Africa

## National Energy Regulator Act of 2004

Though this Act gives NERSA (National Energy Regulator of South Africa) the mandate to regulate the liquid fuel markets in South Africa, to prevent monopolistic control and to promote private sector activities and participation in the energy sector,  little has been achieved in this regard.

## Petroleum Products Amendment Act 2003, Act 58 of 2003

This Act was promulgated to:

- Promote efficient manufacturing, wholesaling and retailing in the petroleum industry;
- Facilitate an environment conducive to efficient and commercially justifiable investment;
- Promote the advancement of historically disadvantaged individuals;
- Create employment opportunities and small businesses in the petroleum sector.

## Gas Act of 2001

The gas act of 2001 provides a regulatory framework for the storage, transmission, distribution and trading of gas, it  establishes a gas regulator and promotes access to transmission by third parties.

Many provinces and municipalities are setting targets and goals in order to achieve energy and electricity reduction targets and renewable energy goals. This chapter will also unpack the various techonological options available, particularly those which can be applied on a neighbourhood level.


## Solar water heaters

A solar water heater is a device that utilises heat energy from the sun to heat up water for domestic use. The picture below shows a flat plate solar water heater. Heat from the sun is collected in the flat plate solar panel. The panel consists of copper tubes and aluminium fins that are painted black. The warm water that is produced is stored in a storage tank directly above the collector panel. Most solar water heater systems have an electric element as backup to allow for water heating during overcast days. Various types and models of solar water heaters are available on the market. Apart from the flat plate collector, evacuated tube collectors are also a popular choice especially in coastal areas, as they are better suited for locations that have a higher number of overcast days. Currently all evacuated tube collectors are imported, which explains why the locally

manufactured flat plate collectors are dominating the South African market at present. Prices for solar water heaters range between approximately R3 000 for a 55L system to around R21 000 for a 300L system[1].

Flat plate solar water heater, Lynedoch Eco Village outside Stellenbosch

Photo: Riaan Meyer

CASE STUDY

## Solar Water Heaters for Kwanokuthula

Solar water heaters are not only for the high and middle income sector, but can also be a viable solution for the low income sector. In April 2008, 184 solar water heaters were installed in Kwanokuthula, a low income area on the outskirts of Riversdale in the Western Cape.

**Solar Water Heater installed in Kwanokuthula, Riversdale (Photo: Graham Gariseb)**

Atlantic Solar systems were installed; each unit comprised an 80L tank and a 1.5m² flat plate collector panel. The systems were installed without any electric backup, but gave owners the option to add an electric backup element at an additional cost of around R200. The per unit cost of the systems was R7 000 each, and included installation, piping and a hot water tap inside each housing unit. Solar water heaters can cost as little as R300 for simple systems.

[1] A list featuring different types of solar water heaters that have been tested by SABS, including prices, is listed on the Eskoms website: www.eskomdsm.co.za/sites/default/files/u1/Accredited_participating_suppliers_list.pdf

# SMALL WIND TURBINES

A wind turbine is a device that first converts the kinetic energy of wind into mechanical energy, and then from mechanical energy to electrical energy. Small horizontal axis, domestic size wind turbines are available in various sizes ranging from 500W to 5000W, and have rotor diameters ranging between 1.5m to 3m. The picture below shows a 1000W horizontal axis wind turbine. It has a rotor diameter of about 1.5 m and is used to power a stand-alone Trunz water filter at the Sustainability Institute near Stellenbosch.

Small 1kW wind turbine and Trunz water filter at the Sustainability Institute near Stellenbosch

Photo: Graham Gariseb

The power output from a wind turbine is typically provided at a rated wind speed of 12meter/second (m/s). Most small wind turbines have a cut-in wind speed around 2.5m/s to 3.5m/s.

The electric output from a wind turbine does not increase linearly with wind speed, it increases exponentially. In other words, a wind turbine that produces 1,000W at a rated speed of 12m/s, does not provide half the rated electric power (600W) at half the rated wind speed (6m/s); the output at half the wind speed would be less than half the rated power, and for the case mentioned above it is predicted to be around 200 to 300W.

Small wind turbines can only produce electricity when the wind blows and batteries are used to store electricity for later use.

In addition to the common horizontal axis turbines, vertical axis turbines are also available. The key advantage of this type of arrangement is that the wind turbine does not have to be pointed in the wind direction to be effective. Vertical axis wind turbines have lower start up speeds, typically in the order of 1 to 2.8 m/s.

## WIND SPEED CONVERSION TABLE

| Speed in meter/second [m/s] | Speed in kilometer/hour [km/h] | Comment |
|---|---|---|
| 1 | 3.6 | Typical cut-in speed for vertical axis turbine |
| 3.5 | 12.6 | Typical cut-in speed for horizontal axis turbine |
| 6 | 21.6 | Half the typical rated wind speed |
| 12 | 43.2 | Typical rated wind speed for small wind turbines |

## Local small wind turbine supplier

Kestrel is a South African manufacturer of small wind turbines and located in Port Elizabeth. They produce four horizontal axis turbine of 600W, 800W, 1,000W and 3,000W electrical output. The cost of a 1,000W turbine is around R31 000, including the turbine and controller box. A complete installation including the turbine, pole for the turbine, batteries, cables, 4kW inverter and installation costs around R105 000.

Omnicon an installation company, have done various installations of this type on farms that have no Eskom power. They recommend that solar PV panels are installed to supplement the wind power generation.


Pico hydro systems utilise flowing water from a river or stream to generate electricity. Below is an example of a 1000W system installed at a farm near Ceres. The installation of Pico hydro systems is very site specific. The advantage of a successful installation is that it generates electricity 24 hours per day and battery storage is optional.

Pico hydro systems are available in systems as small as 200W. Typically prices for the Pico hydro turbine and generator range between R4 500 (200W system) and R14 000 (1kW system). Some Pico turbines are low-head turbines and only require a vertical water head of 1.8m. A 300W low-head (1.8m) system would require a water flow rate of 40 litres/second and costs around R5 500.

Pico hydro installation, Nollie se Kloof, Ceres district

(Photo: Riaan Meyer)

## BATTERY STORAGE

Due to the intermittence of renewable electricity generation, batteries are required to store the generated energy. The battery voltage typically ranges from 12V - similar to a car battery - up to 48V, at 12V increments. A charge controller and dump load are used as an interface between the renewable energy source and the batteries. This controls the charging of the batteries and dissipated excess energy in the dump load. An inverter is typically installed to convert the battery output which is in DC (direct current) into 220V AC (alternating current) allowing it to be used in households.

CASE STUDY

# Nollie se Kloof

A farmer in the Ceres district constructed a guest house in the mountains near a river. He obtained a quote from Eskom to extend the existing electric infrastructure to his new guest house and compared this cost with installing a renewable energy system. Ultimately, the farmer installed a hybrid system consisting of a small wind turbine, solar PV panels, a Pico hydro turbine as well as the necessary battery and inverter systems.

The 1kW wind turbine was erected in close proximity of the guest house. The area is shaded due to a mountain directly north of the guest house. Due to the shade, the 720W solar PV array was erected about 120m away from the guest house, allowing more direct sunlight to the PV panels. A river flows past the guest house. Upstream of the guest house a small portion of the river is diverted into a 100mm pipe, and is directed to a location close to the guest house where a 1000W Pico hydro turbine is installed. The water is returned to the river. The net head available at the turbine is 26m and the water flow rate can be controlled through a manual valve. At 6.8 litres/second the output from the turbine is 360W. If the water flow rate is increased the turbine can deliver up to its rated output of 1,000W.

A 36V battery bank consisting of 18 cells of 2V each is installed. The batteries store the electricity generated by the various sources, and have a capacity of 27kWh in total. A locally manufactured inverter, rated at 6kW, converts the 36V DC from the batteries to 220V AC which is used in the guest house. The picture below shows the batteries (bottom), inverter (bottom left corner), dump load (grey box top right) and other equipment.

**Battery backup system and auxilary equipment at Nollie se Kloof**

**Photo: Riaan Meyer**

The system is sufficient to supply the guest house (which sleeps 16 people) with the following electric equipment: electric kettle, fridge, freezer, microwave, TV, HiFi and various lights. Water heating and cooking are done with bottled gas. The total system initial cost was R121 600, including installation, in 2005. Contact Nollie se Kloof on telephone/fax: 023 312 1982 or telephone: 023 312 1407 for more information.

# SOLAR OVENS AND COOKERS

In locations with an abundance of sunlight, solar ovens and solar cookers can be utilised. The figure below shows a solar oven, the Sunstove 2000, produced in South Africa. Food is placed in black pots inside the cooker and the solar oven is placed outside, facing the sun. The ovens can cook most types of food that can be prepared on an open fire or electric stove, including stews, mielie-pap and bread.

Cooking times with solar ovens are considerably longer compared to conventional cooking but the advantages of a solar cooker are:

- It needs little attention while cooking, leaving the cook free to attend to other matters
- The risk of being burned, especially children, is almost entirely eliminated
- No hazardous gasses are released

Two different
models of the Sunstove 2000

Photo: www.sungravity.com

Solar ovens and cookers are available in all shapes and sizes. They can be classified as either solar ovens or solar cookers:

- A solar oven is an insulated box with limited reflective surface. It produces relative low temperatures and only needs to be adjusted every 3 to 4 hours
- A solar cooker is characterised by having a large reflective surface focussing the solar energy on a pot to produce a relative high temperature. They must track the sun on a continuous basis

## Local solar cooker manufacturers

### Sunstove 2000

The Sunstove is manufactured from moulded plastic (a portion is from recycled material), scrap aluminium plate reflectors, off-cut glass-fibre insulation and has a durable poly-carbonate lid. The Sunstove retails between R300 - R490. See contacts chapter for details.

### Lazola

The Lazola is a solar cooker is manufactured in Calitzdorp by Elnatan. This stove is manufactured from stainless steel, has a double glass lid and can reach relatively high temperature. It retails around R2 900.This is a new project with more models to follow. See contacts chapter for details.

# BIOGAS DIGESTERS FOR THE PRODUCTION OF GAS FOR COOKING

A biogas digester manufactures biogas from organic waste materials e.g. sewage and animal dung. The figure below presents a biogas digester during the construction phase. Biogas is generated when bacteria degrades biological material in the absence of oxygen. The process is known as anaerobic digestion. Biogas mainly consists of methane ($CH_4$) and carbon dioxide ($CO_2$) which make up 2/3 and 1/3 respectively of the gas produced. In small scale biogas digesters, the gas can be used directly for (mainly) cooking. Typically 1m$^3$ of uncurbed biogas will provide 2 hours of cooking. 2.5m$^3$ of uncurbed biogas is equivalent to 1kg of LP gas.

Biodigester during construction

Photo: Agama Energy

CASE STUDY

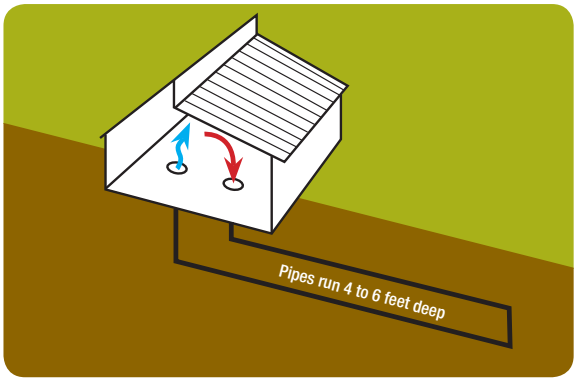
## Stanford Valley Farm and Conference Centre

The Stanford Valley Farm and Conference Centre is located 10km outside Stanford in the Western Cape. A 13m³ biogas digester was installed by Agama Energy in September 2006. The biogas digester is fed by 30 toilet connections, restaurant food waste and animal manure. During the process, liquid effluent overflows into the horizontal planted gravel filter, which overflows into a UV polishing pound, where it is aerobically treated before being recycled for irrigation. The energy generated by the biogas digester is used for cooking purposes in the restaurant.

# GEOTHERMAL HEATING/COOLING SYSTEMS

Earth tubes (cooling or heating tubes) utilise the earth's near constant subterranean temperature to warm or cool a building. These systems are also known as ground-coupled heat exchangers. Air can be moved through these tubes by utilising a fan (in an active system) or the air can flow with natural convection in a passively designed system. Water can also be used as energy carrier instead of air – mainly in active closed-loop systems.

Most air systems are constructed from a 100mm to 600mm diameter, smooth-walled (to reduce moisture and mould trapping), plastic-coated metal pipes or plastic pipes coated with inner antimicrobial layers. Pipes are typically buried between 1.5m and 3m underground where the ambient earth temperature is almost constant year round in the temperate latitudes where most humans live. This results in an earth temperature that is lower than the ambient conditions during summer days and higher than ambient conditions during winter nights.




**This figure presents an open-loop air-tube system used for both cooling and heating.**

Open-loop air-tube heating/ cooling system

Figure: www.energybulletin.net

# SOLAR PHOTO VOLTAIC (PV) PANELS

A solar PV panel is a device that converts solar energy directly into electricity. The photo below presents a solar PV panel installation on a farm near Ceres. The installation consists of four PV panels of 180W each, with the ability to produce a peak electric power output of 720W. On average, the installation can generate 3.6 kWh (3.6 kilo-Watt-hours (units) of electricity) per day.

Solar PV is perhaps the most expensive of the listed options, and is not as financially viable as most of the solutions listed above. However, with the cost of electricity ever on the increase, this solution will become more affordable.

PV panels can be stand-alone systems as shown above or may be roof-mounted. In Southern Africa, fixed installations should preferably face north to harness the optimal amount of sunlight. Shading on the panels (from trees and other structures) should be avoided.

PV panels can only produce electricity when the sun is shining. Batteries are used to store electricity, allowing this to be used at a later stage. Solar PV panels currently retail around R50/W, hence 180W panels are priced at around R9 000.

720W stand alone solar PV installation, Nollie se Kloof, Ceres district

Photo: Riaan Meyer

CASE STUDY

## Solar Roof Tiles

Solar PV panels are also available in the form of roof tiles. The picture below shows a solar roof tile installation at the Drie Geuwels Guest House, located at the Sustainability Institute outside of Stellenbosch. The PV roof tiles are of a similar shape and size as normal tiles and only make up a portion of the total roof area, as can be seen from the picture below. The peak output from the PV installation is 1.7kW. The daily energy generated from this installation is monitored and can be seen at www.sieckmann.biz/content/ProjectsSustanabilityInstituteReports.htm. The electricity generated by this installation is fed directly into the guest house through a grid-tied inverter and is used to supplement the electricity currently provided by Eskom. No batteries are installed.

**Solar roof tile installation at the Sustainability Institute near Stellenbosch.**

**Photo: Riaan Meyer**

# CONCLUSION

Renewable energy is derived from natural resources like wind, sunlight, rain, tides and geothermal heat, which are able to be naturally replenished. Renewable energy sources have a lower environmental impact than modern non-renewable energy sources like oil and coal, and produce far few hazardous emissions. South Africa has the potential to harvest wind and solar power on a large scale due to its climactic position and wind availability. Technological solutions including solar water heaters, pico hydro systems, biogas digestors and geothermal heating and cooling systems can assist in providing energy and in reducing peak load from the National grid.