# Feasibility of generating electricity for clinics using wind turbines

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## Background and context

Many primary healthcare facilities currently suffer from poor infrastructure quality and problems with the procurement of infrastructure. In 2013 the CSIR embarked on a research project to develop a design terms of reference and blueprint designs for modular conventional clinics and for the rapid deployment of clinics. In the final phase of the project it was intended to construct and commission a new design pilot clinic(s). The outcome of the project was to be high quality clinic facilities and standardised procurement practices.

Studies undertaken by the Infrastructure Unit of the National Department of Health had identified a number of challenges to the delivery of healthcare infrastructure. Many of these challenges are addressed through the Infrastructure Unit Systems Support (IUSS) project with the National Department of Health.

This chapter describes the investigation undertaken to evaluate the feasibility of using wind turbines to provide electricity to the clinics.

## Problem statement

Historical funding models have recognised the entrenched inequity and furthermore undermined affordability of healthcare services in South Africa. The National Department of Health is introducing the National Health Insurance scheme to integrate healthcare services. This will be heralded by a renewed focus on primary health care provision and will be accompanied by an initiative to re-engineer primary health care services. Major implications, such as shifting to increased community outreach services (as opposed to facility-based services); emerging requirements for information networks (for NHI management) are foreseen. As infrastructure is integral to the delivery of health care services, these organisational transformations provide an extraordinary opportunity for Science, Engineering and Technology (SET) input into the strategic planning, design, specification, equipping, and decommissioning of primary healthcare facilities.

Many primary healthcare facilities currently suffer from poor infrastructure quality and problems with the procurement of infrastructure. Buildings and their operations depend on the continued supply of services such as water, sanitation and electricity. However, service delivery failures do occur whether due to operational factors such as regular maintenance or system failure, or do to service protests.

Critical services such as primary health care rely on a stable service provision especially with regard to sanitation, electricity and the proper storage of drugs. Alternative infrastructure service technologies are technologies that can be implemented to provide alternative methods for securing a stable infrastructure service.

One of the strategies that can be employed to ensure an uninterrupted service is to reduce the building's exposure to municipal services. This will assist the building to adapt to major perturbations and events without a disruption in service delivery. Reducing the building's dependence on municipal services will also reduce the operational costs of the building.

## Situational analysis

Primary healthcare services are kingpin to the healthcare services in South Africa. It is recognised that prioritisation of care at this level of service is uniquely suitable to promote good health, prevent ill-health and avert demand for services at higher (more expensive) levels of care. In order for South Africans to benefit in this way, primary healthcare services need to be inclusive, accessible, affordable and high quality.

Primary healthcare service delivery is severely hampered by lack of, and poor quality infrastructure. In many cases the physical infrastructure at clinics is old, inadequate and in some cases not suitable for use. The provision of services (water, sanitation and electricity) is in many cases not adequate, especially in rural areas. In addition to this, no standardised clinic design and lifecycle management tools currently exist. This results in poor infrastructural investment decision making, problematic procurement processes and practices and poor maintenance of existing facilities. Re-engineering of primary healthcare as the main mechanism of healthcare service delivery requires urgent intervention at the infrastructure level.

Studies undertaken by the Infrastructure Unit of the National Department of Health had identified a number of challenges to the delivery of healthcare infrastructure. These included:

1. South African health infrastructure norms and standards for all stages of the building life-cycle are out dated. Lack of a sustainable set of universally adopted, current national norms, standards, guidelines and benchmarks is hampering rapid planning, design, construction and operation of these facilities. Norms and standards have been identified as a priority programme area.
2. Until the 2007/08 financial year, the National Department of Health control over provincial capital expenditure was weak. As a result, many incidents of reallocation of earmarked HRP Hospital Revitalization Programme (HRP) Grant funding were observed and reported. Conventional procurement strategies and methods persist, resulting in long delays in awarding professional services and contracts.
3. There has not been a strong and scientifically based project and program management system in place to monitor and then improve the infrastructure delivery system at either national or provincial level. There has been a steady increase in budget allocation to health infrastructure through various funding mechanisms - Hospital Revitalization Programme (HRP), Parliamentary Infrastructure Grant (PIG) and Equitable Share (ES) - between 2004 and 2011. Even although there has been a concurrent increase in expenditure, of concern, however is the consistent under-expenditure. To overcome this shortcoming a Project Management Information System (PMIS) is required.
4. Delivery capacity of implementing agents (works departments, and others) as well as the provincial department of health did not match budget increase. The roles of National Department of Health on monitoring and oversight were minimal and confined to “watching”. In the 2007/08 financial year the peer review mechanism was introduced. Projects monitoring and oversight support mechanisms should be strengthened.
5. As budget requests are met primarily through Treasury loans, a more “realistic” match between allocation and delivery capacity is required to avoid incurring unnecessary finance costs. Given poor spending patterns, a more considered approach and conservative budget allocation may be advisable and should be investigated. To overcome this shortcoming an infrastructure cost model is required.

In the context of this background the Infrastructure Unit approached the CSIR and DBSA to assist in the development and support of some systems to assist in the optimisation of public health care infrastructure planning, design procurement and operation. This project started in the 2010/2011 financial year and is known as the Infrastructure Unit systems Support (IUSS) project. A work package was defined for each of the five areas mentioned above. The project also has extensive consultation processes – a series of 46 work packages, each with its own committee, is used to get to the development of norms and standards.

There is no accurate data on the number of clinics in South Africa, but the most accurate indication available is a number of more than 3500. This flagship project will build on the norms and standards that are developed as part of the IUSS project to ensure primary healthcare facilities of the appropriate quality are delivered.

## Description of the project

Infrastructure is an integral part of primary healthcare delivery and improvement of the quality of health infrastructure has been identified by the National Department of Health as a high priority for improving healthcare service delivery. This project aimed to optimise the quality, accessibility, lifecycle management and cost of primary healthcare physical infrastructure by building on the work that has been done in the IUSS project on norms and standards for clinic design. A standardised clinic infrastructure solution(s) was to be developed. This would allow implementation of a standard procurement package thereby enabling improved financial governance.

## Goal of the project

The project has a hierarchy of goals and objectives. The ultimate goal of the project was to erect a new basic clinic building and a clinic that could be rapidly deployed with the support of the National Department of Health. The new buildings would make use of alternative construction methods and the procurement of the buildings would be standardised. These buildings would be based on the blueprints developed as part of this project.

## Alternative infrastructure services technologies: wind turbines

It is intended that all the power required to operate a clinic should be generated on site allowing the building to function off-grid. A review was done of wind turbine machines of less than 100kW in size. (Szewczuk *et al*, 2010) Topics covered were:

- Markets and applications
- Market drivers and barriers
- Review of common applications of SWT's

Small-scale remote and off-grid power (residential, village or remote) are used for supplying energy to rural, off-grid applications in the developed and developing world. This market encompasses either individual homes or small community applications and is usually integrated with other components, such as storage and power converters and PV systems.

Residential and on-grid power is small wind turbines used in residential settings that are installed using net metering to supply energy directly to the home. Excess energy is sold back to the supplying utility.

Farm, business and small industrial wind applications are used for supplying farms, businesses and small industrial applications with electric power. The loads represented by this sector are larger than most residential applications, and payback must be equivalent to similar expenditures (4 to 7 years). In many cases, businesses are not eligible for net metering applications thus the commercial loads must use most of the power from the turbine.

“Small-scale” community wind is a system using wind turbines to power grid-connected loads such as schools, public lighting, government buildings and municipal services. Turbines can range in size from very small, several-kW turbines to small clusters of utility-scale multi-megawatt turbines. The key defining factor is that these systems are owned by or for the community.

Wind/diesel power systems are used for providing power to rural communities currently supplied through diesel technology in an effort to reduce the amount of diesel fuel consumed. The rising cost of diesel fuel and increased environmental concerns regarding diesel fuel, transportation and storage have made project economics more sensible.

## Available wind in South Africa

South Africa's wind resources are influenced by the large scale weather patterns that have distinct characteristics between summer and winter.

### Summer Winds

In summer, the "Westerlies" are situated well to the south of the continent (Figure 1). The south-eastern Trade Winds (A) influence the north-eastern part of the region. These winds can be strong, curving sometimes from the Limpopo Province (N) into the Free State Province (F), or moving over far northern areas, such as Zimbabwe and Zambia (Z). In the west, the South East Trade Wind (B) caused by ridging of South Atlantic High, are often strong and persistent. The strong "Westerlies" are only able to influence the western, southern and south-eastern coastal areas and adjacent interior.

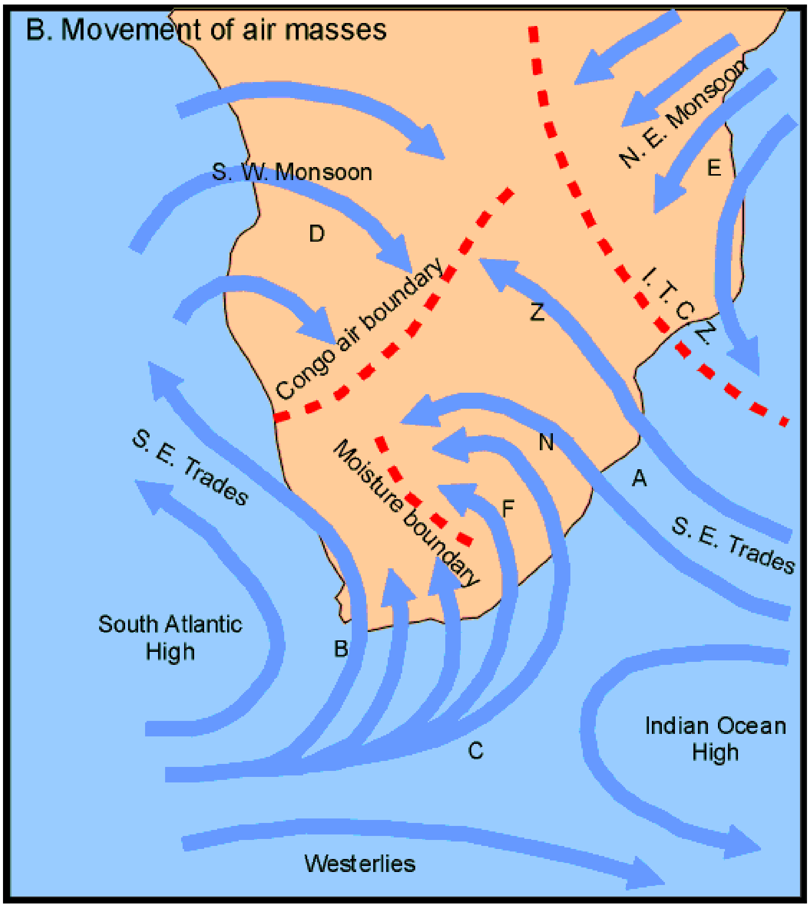


Figure 1: Summer winds over South Africa

### Winter Winds

In winter all the circulation features (Figure 2) are situated more to the north than in summer. Strong winds and gusts during winter are usually caused by strong cold fronts, moving mostly over the southern half of South Africa, and also by the ridging of the high pressure systems behind the fronts.

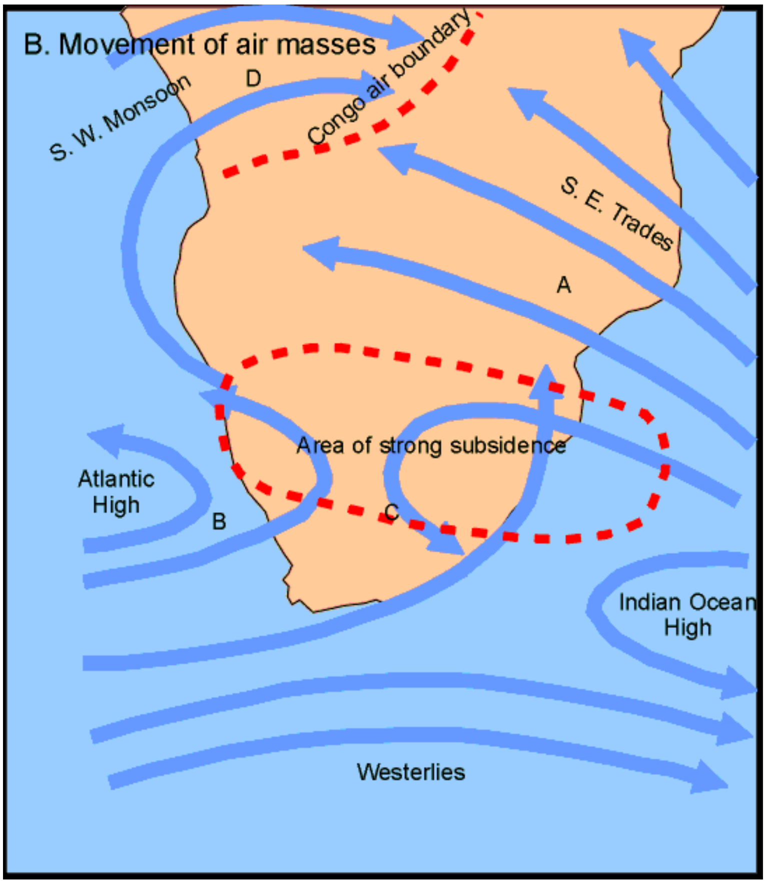


Figure 2: Winter winds over South Africa

The "Westerlies" influence the weather of the southern and central parts of the subcontinent to a large degree. Cold fronts often move over these areas and may reach far to the north. The strong "Westerlies" are only able to influence the western, southern and south-eastern coastal areas and adjacent interior.

Over the years various studies have been undertaken to quantify South Africa's wind resource. Dr Roseanne Diab from the then University of Natal published South Africa's first wind atlas. However this wind atlas based on reviewing good quality that was available from metrological weather stations. The review of this data resulted in broad conclusions being drawn as to South Africa's wind resource.

A meso-scale wind map of South Africa was produced by (Hagemann: 2008) as part of a PhD research at the University of Cape Town. This thesis explores the utility of the MM5 regional climate model in producing detailed wind climatology for South Africa in the context of wind power applications. In terms of the resultant meso-scale wind atlas of South Africa, Figure 3, a significant inland wind resource was discovered over the three Cape Provinces which were previously unknown. Hagemann put forward the case that South Africa's wind resource is higher than some previous studies have suggested and is comparable to some of the windiest markets in the world.

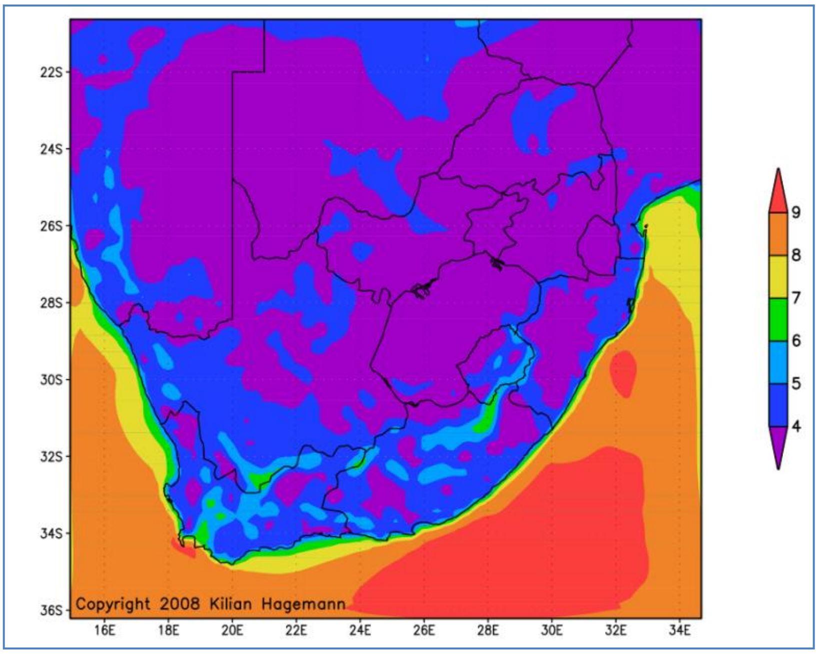


Figure 3: Hagemann's meso-scale wind atlas

Using remote sensing technologies more detailed meso-scale wind atlases for South Africa are available. One such atlas is shown in Figure 4. From this more detailed meso-scale wind atlas it can be seen that South Africa has a good wind resource. There are a number of locations with an annual average wind speed of 8m/s at a height of 80m.

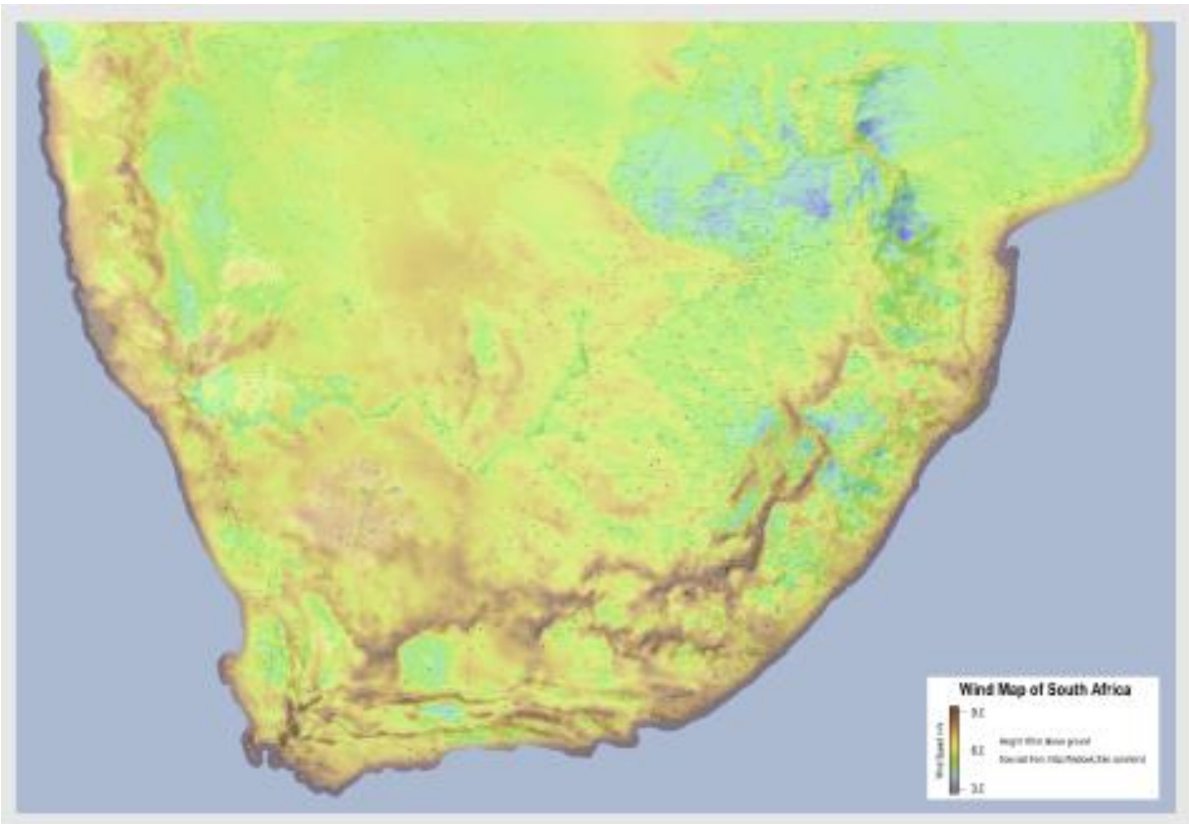


Figure 4: Detailed meso-scale wind atlas for South Africa

Meso-scale wind atlases, such as those shown in Figures 3 and 4, are too course to be used for planning and evaluation purposes and higher resolution atlases and are required known as micro-scale wind atlases. The micro-scale Wind Atlas for South Africa is described in the next section.

## Wind Atlas for South Africa

The main objective of the new Wind Atlas for South Africa (WASA) is to develop and employ numerical wind atlas methods and develop capacity to enable planning of large-scale exploitation of wind power in South Africa, including dedicated wind resource assessment and siting tools for planning purposes. The Global Environmental Facility and the Danish Government are co-funding the multi-year project to develop an accurate wind resource map for the coastal regions of South Africa. The wind resource assessment being done by the CSIR, University of Cape Town (UCT), South African Weather Services (SAWS), South African National Energy Research Institute (SANERI) and Risø-Danish Technical University (Risø-DTU).

Figure 5 shows the area in blue that has been assessed to form the basis of the new wind atlas. Using meso-scale data and information site selection criteria were developed as to the locations of where the 10 wind measurement masts are to be erected. These sites are representative of terrain types, suitable for meso- and micro-scale modelling and geographically spread out evenly over the project area.

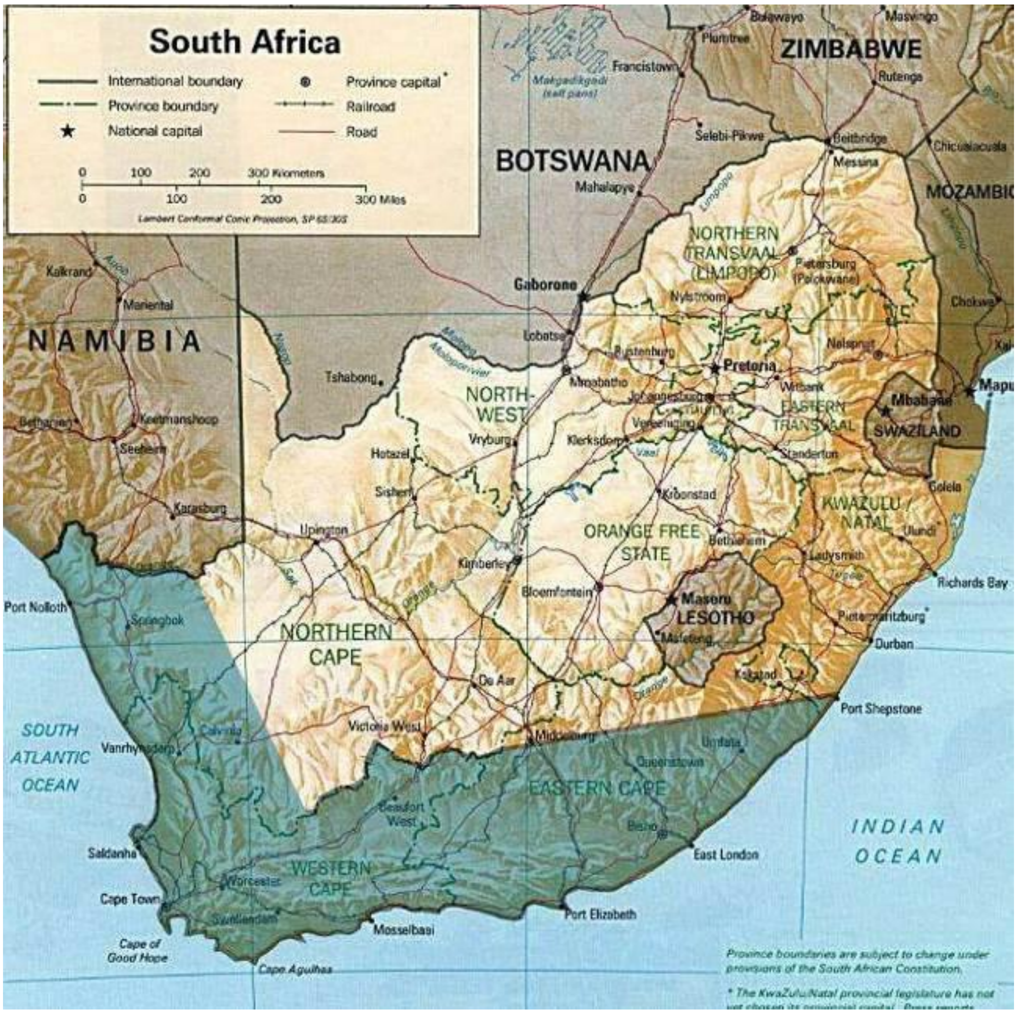


Figure 5: WASA domain in blue

South Africa's first verified micro scale wind atlas was launched by the Deputy Minister of Energy in March 2012 and covers the area as shown in Figure 6 below.

Small wind turbines are a possible option to consider for the provision of electricity for clinics. To determine an optimal system for a clinic the location of the clinic would need to be known and currently the use of Small Wind Turbine's (SWTs) would need to restricted to the area of the verified wind atlas.

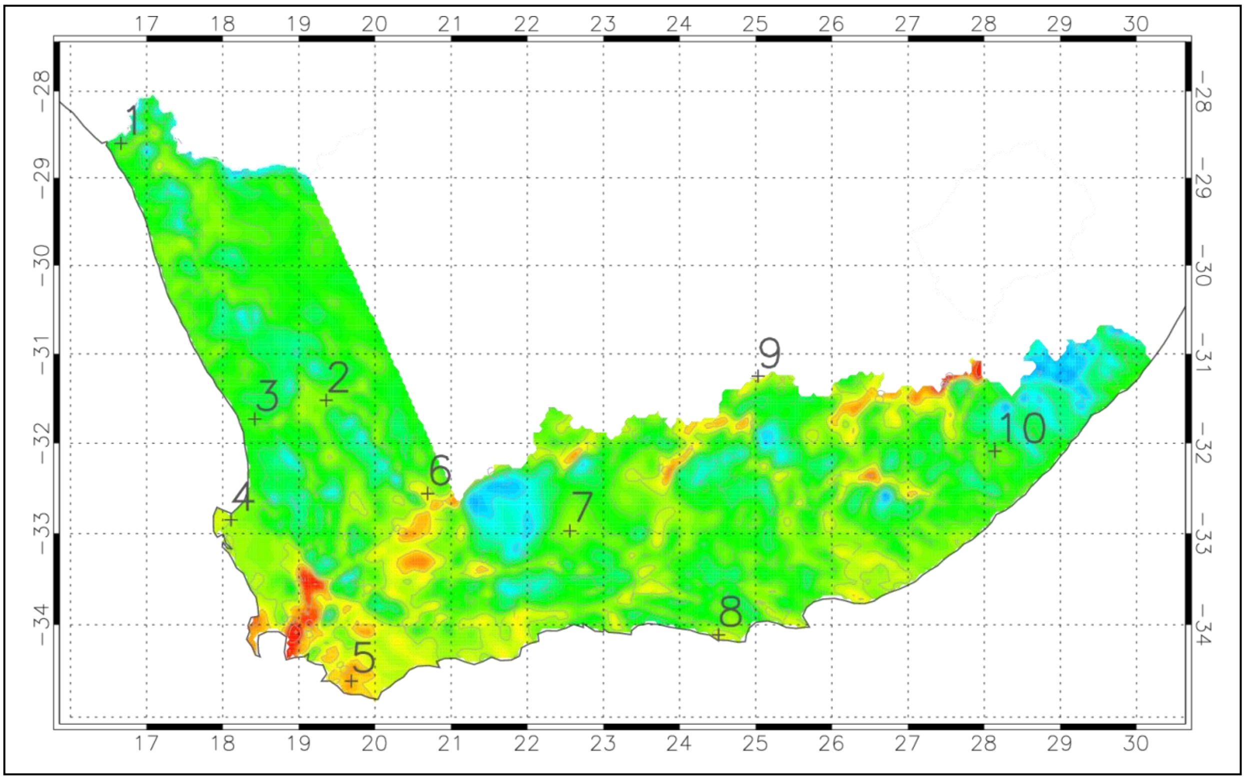


Figure 6: First Verified Wind Atlas for South Africa

## System's analysis

For this investigation it is unlikely that large multi-MW grid connected wind turbines will be considered. However South Africa does manufacture wind turbines of the size that will be considered to power the clinic. These two major South African manufacturers are:

- Kestrel Wind Turbines from Port Elizabeth and
- Adventure Power from East London

In 1986 the CSIR designed, manufactured and tested a small low wind speed wind turbine and will be described later.

Kestrel Renewable Energy is a subsidiary of Eveready (Pty) Ltd, South Africa's icon battery manufacturer brand. Kestrel manufactures a range of small wind turbines rated at 600W, 800W, 1kW and 3.5kW, all of which feature robust turbine construction and unique engineering solutions. The Kestrel e400nb has been UK (MCS) certified with pending USA (SWCC) certification.

Figure 7: Kestrel e400 wind turbine

Figure 7 shows the largest of the Kestrel wind turbines, the e400 with a maximum output of 3300Watts. This Kestrel wind turbine will be used to further energy analysis for this project. The characteristics of the e400 are shown in Table 1.

Table 1: Characteristics of the Kestrel e400

| | |
|---|---|
| Rated Output: | 3000W |
| Maximum Power: | 3500w at $12ms^{-1}$ |
| Rated Wind Speed: | $12ms^{-1}$ |
| Cut in Wind Speed: | $4.0ms^{-1}$ |
| Rotor Diameter: | 4m |
| Number of Blades: | 3 |
| Blade Material: | Fibre glass |
| Tower Top Mass: | 230kg |
| Tower Height: | 12-18m |
| Tower Type: | monopole |
| Over speed Protection: | Pitch Control |
| Generator Type: | Permanent-magnet<br>Axial flux brushless |
| Output Voltage: | 48,110 and 250 Vdc |
| Application | Battery-charging<br>Grid tie<br>Hybrid<br>Water pumping |

Rated output is achieved at the rated wind speed at sea level. Rated power is the optimal power rating of the turbine at the rated wind speed making it maintainable without a cut out wind speed. Rated output is optimised by technology and design, namely by dynamically limiting the output by pitch control. The Axial Flux alternator type reduces the heat losses while energy is being generated in the form of poly phase high frequency output. The full aerofoil blades are moulded from fibre glass and protected from dust and moisture. The e400 conforms to IEC standards and follows the provisions in the directives IEC61400-2 (small wind turbines).

The power curve for the Kestrel e400 is shown in Figure 8.

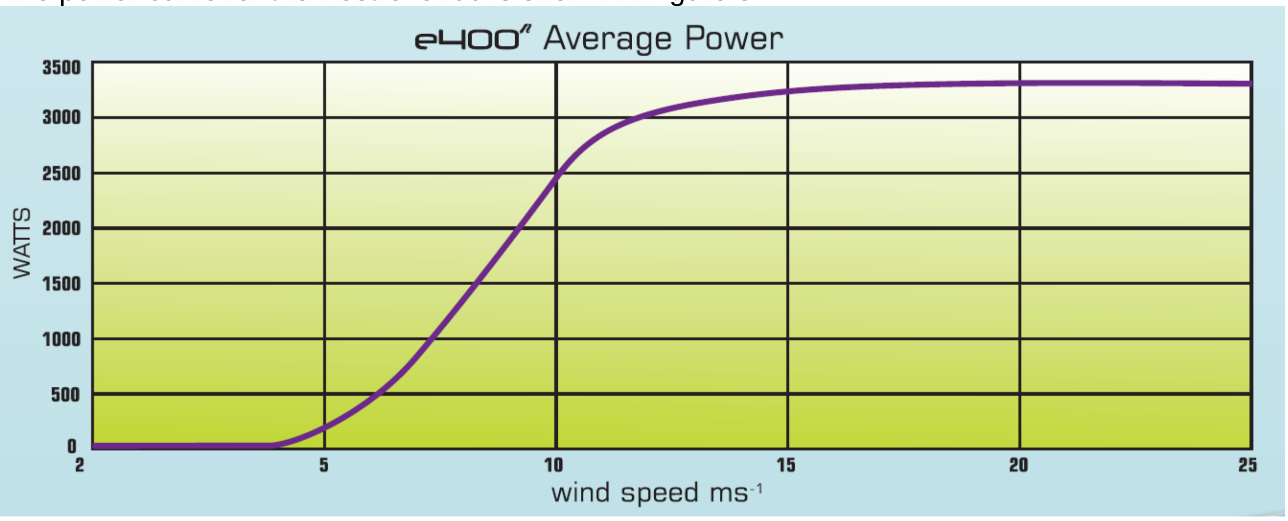


Figure 8: Power curve for the Kestrel e400 wind turbine

Applications of the Kestrel e400 in further detail are:

- Boost solar & other renewable energy installations increasing productivity, reliability & cost effectiveness
- Water pumping systems with suitable water pump controller to reduce utility costs
- Continual & reliable power for repeater stations, suitable for the telecommunications industry
- Grid tie applications using approved inverters to reduce energy costs
- Generate dedicated power for housing, community & health centres not connected to the national grid
- Small wind farm installations
- Adaptable to meeting many electrical needs

Adventure Power manufactures a medium-sized 300kW wind turbine (Figure 9). This wind turbine is a direct-drive machine, i.e. this wind turbine has no gearbox between the wind-turbine blades and the generator. The variable speed, permanent-magnet multi-pole direct-drive generator is designed to operate the rotor blades at peak performance over the complete range of operating wind speeds. It has a stationary stator and permanent-magnet rotor.

The decision regarding the size of the wind turbine of 300kW was influenced by research undertaken by Frost & Sullivan. Frost & Sullivan undertook a study entitled “African Large-Scale Wind Turbine Market” and provided an in-depth analysis of the market drivers, equipment suppliers and industry challenges in the African wind-power market. In this research, Frost & Sullivan, examined the North Africa and Sub-Saharan Africa regional wind-power markets. The research focused on the following segments of the large scale wind-turbine market: 100-600kW, 660-850kW and greater than 850kW.

Despite its potential, the African wind-turbine market is yet to contribute significantly to the power sector in the continent. Historically, the low price of electricity generation from traditional feedstock such as coal and natural gas has limited the interest in renewable-energy power generation. However, higher-than-anticipated economic growth in African states in the last five years has led to a rapid increase in electricity demand, along with a renewed interest in alternative forms of power generation. "As a result of public pressure to provide reliable power supply, governments in Africa are investing more time and resources into exploring renewable energy for power generation," says the analyst of this research. "The success of the wind-power market in Europe and the United States has convinced many governments that wind power can assist in alleviating some of the power shortages in the African continent."

*Figure 9: Adventure Power's 300kW wind turbine*

The energy crisis of the 1970's stimulated interest in power generation by means of wind turbines. A programme for the research and development of wind turbines for generating electricity was launched by the CSIR. The objective of this research programme was to develop small-scale wind energy conversion systems intended for operation in regions with low average wind speeds (Esterhuyse, 1986). This was to compliment the then existing machines that were designed to operate in much stronger winds.

The main objective of the programme was therefore to develop a wind turbine (Figure 10) that could operate continuously in regions with low average wind speeds, such as in Pretoria that has an average annual wind speed of 1,8m/s.

*Figure 10: CSIR's low wind speed turbine*

From the results of test done on the full scale wind turbine it was shown that a turbine rotor could be designed for effectively harnessing the wind energy in regions with very low average wind speeds. This programme also proved that a wind turbine could be built from locally available parts to produce an attractive source of energy suitable for application in the underdeveloped regions of South Africa.

## Feasibility

### Correct sizing

For purposes of this project the electricity consumption for a typical clinic was estimated at approximately 20 kWh/day. The Kestrel e400 wind turbine was selected as the wind turbine around which a hybrid wind/PV system will be designed.
Within the context of this project where clinics are located in windy areas a configuration that can be considered is to combine PV with wind turbines.

### Installation requirements

The full installation requirements could not be determined at the time, but once the full system was designed the installation requirements would be completed. However it should be noted that Kestrel's preliminary quote for the East London IDZ site did not make use of PV panels but two Kestrel e400i wind turbines.
Eveready Diversified Products who manufacture the Kestrel range of small wind turbines were approached to provide a quote and sizing for a wind PV based system for the East

London IDZ. This was done to get a cost and correct sizing as a reference point for a wind/PV hybrid based system for the clinic where the wind resource is good.
Kestrel quoted for a 24 hour battery backup but this can be extended to any autonomy necessary. If 20 kWhrs/day is not exceeded this should not be necessary. Also quoted for are 12 Volt deep cycle lead acid batteries could be replaced by the higher performing 2 and 4 volt solar cells if needed.

However, it should be noted that for this site Kestrel's preliminary design require no PV panels and that two small wind turbines generate electricity.

### Payback period

Preliminary enquiries suggest that the cost of a 20 kWh/day wind based system for a clinic located on the East London Industrial Development Zone is R287,854.56 inclusive of VAT. The payback period can only be calculated when firm cost figures have been obtained: however at current rates and projected rate increases the likely payback period is 20 years.

## Conclusion

Small Wind Turbines are an option to be considered in particular in those regions where the wind resource is known to be good.
The cost of a 20 kWhr/day PV system for a sunny but wind poor location such as CSIR Pretoria campus ranges from R291,718.00 to R319,000.00 inclusive of VAT and requires 48m$^2$ of PV panels.
The cost of a 20 kWhr/day wind system for a windy location such as the East London Industrial Development Zone is R287,854,56 inclusive of VAT and requires 2 x 3000W wind turbines.
Preliminary investigations indicate that a wind system is slightly cheaper than a PV only system, but is site dependent on the availability of wind and solar resources.
In the short term the following three options are recommended for the clinic to function off-grid:

- Photovoltaic (PV) based system for the generation of electricity for sunny but wind free sites such as CSIR Pretoria campus.
- Wind based system for the generation of electricity for windy sites such as the East London Industrial Development Zone.
- Liquid Petroleum Gas (LPG) for heating and cooking.

## References


Esterhuyse J.C., (1986) “Harnessing the wind using axial flow wind turbine”, CSIR Research Report 619, Pretoria, South Africa., ISBN 0-7988-3775-6

Hagemann K., (2008), “Mesoscale Wind Atlas of South Africa”, Thesis presented for the degree of Doctor of Philosophy, University of Cape Town

Szewczuk S.; Markou H.; Cronin T.; Lemming J.K.; Clausen, NE.; (2010) , “Investigation in to the Development of a Wind Energy Industustustrial Strategy for South Africa ”, Prepared for the UNDP