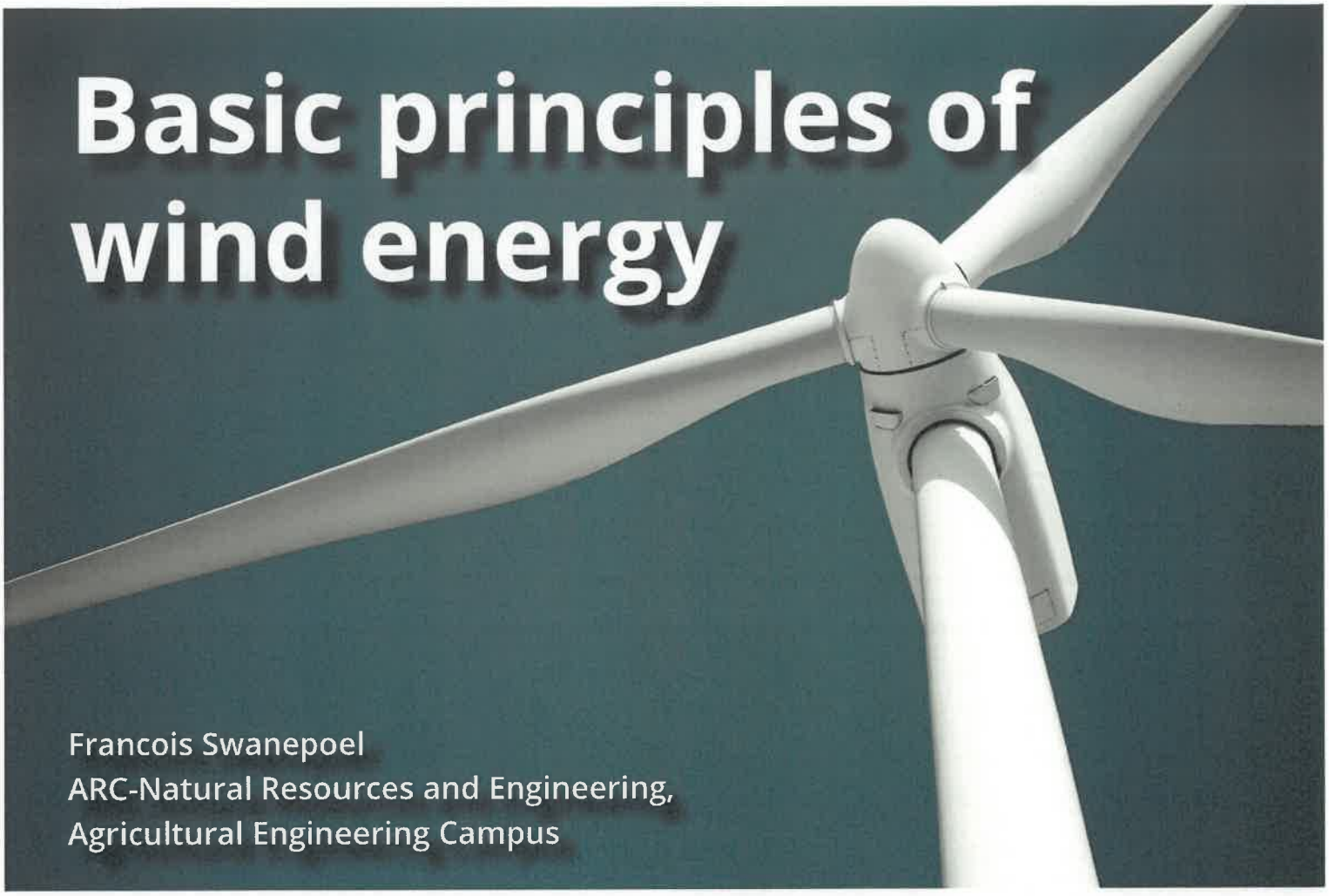
Basic principles of wind energy



Francois Swanepoel
ARC-Natural Resources and Engineering,
Agricultural Engineering Campus

Where does wind come from? While the exact kinetics of wind is extremely complicated and relatively little understood, the basics of its origins are relatively simple. The sun does not heat the earth evenly. Not only do the poles receive less energy from the sun than the equator does, but dry land heats up and cools down more quickly than the seas do. Uneven heating of the earth's surface by the sun causes the wind. The warmer air in some places rises. The resulting low-pressure area draws in cooler air.

Wind variability and turbine nameplate power

Wind power is an affordable, efficient, and inexhaustible source of electricity and it is pollution-free.

The power in the wind can be extracted by having it act on moving wings connected to a rotor, which converts some of that power into torque on the rotor. The amount of power transferred depends on the wind speed, the swept area, and the air density. Because so much power is generated by higher wind speeds, much of the average power available to a windmill comes in short bursts. Half the energy available arrives in just 15% of the operating time.

Since wind speed is not constant, a wind generator's annual energy production is never as much as its nameplate rating. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor. A well-sited wind generator will have a capacity factor of as much as 35. Though short-term, hours, or days, the output of a wind plant is not completely predictable. The annual energy of output tends to vary only a few percent between years.

Small-scale wind power

Wind turbines range from small four-hundred-watt generators for residential use to several megawatt machines for wind farms. The small ones have direct drive generators, direct current output, aeroelastic blades, lifetime bearings, and use a vane to point into the wind, while the larger ones generally have geared power trains, alternating current output, flaps and are actively pointed into

the wind. As technology progresses, large generators are becoming as simple as small generators.

Do I have a good site?
Sitting a wind generator is extremely important to the performance of the machine. It is the difference between a machine that gives you lots of energy and a garden sculpture. The ideal location for a wind turbine is 6 meters above any surrounding object within 75-meter radius.

Sitting a small wind turbine
Many potential users of small wind turbines think how nice it would be to put up a wind turbine next to their house and use the free power of the wind. Unfortunately, whilst the wind is free, the means to extract the power from it is not. Buying and installing a turbine costs money and there are also operation and maintenance costs. Consequently, serious consideration must be given to sitting the turbine to get the best performance and reliability from it.

The electricity produced by a wind turbine over a year depends critically on the annual mean speed at the site, for example, a site with 10% higher annual mean wind speed than another produces more than 20% extra energy. Sites only a hundred meters apart can be significantly different.

The output from a wind turbine is highly sensitive to wind speed. It is essential that turbines should be sited away from obstruction with a clear exposure or fetch for the prevailing wind. Wind speed also increases with height, so it is best to have the turbine high up and most small turbines have towers much higher relative to their diameter than large ones.

It is generally agreed that the ideal position for a wind turbine generator is a smooth hilltop with a flat clear fetch at least in the prevailing wind direction. The wind speeds up significantly near the top of the hill and the airflow should be reasonably smooth and free from excessive turbulence. Excessive turbulence causes fatigue damage and shortens a turbine's working life.

In practice especially for very small machines which need to be located near to the user, ideal sitting will not be easy. As far as possible though, keep away from local obstructions such as large trees and houses or use a taller tower to ensure that the turbine is well above the obstructions.

Before considering the installation of a wind turbine the potential site should be assessed. Initial indications of wind strength and direction can be obtained by observing the deformation of vegetation and trees and in many cases the user may already have a good feel for the winds in the locality.

A more reliable way to evaluate the wind resource, which is strongly recommended when there is doubt over whether the wind is strong enough is to take regular measurements over a period of several months, preferably a year. It is not straightforward to use data even from nearby sites and probably the nearest wind station where records have been kept is many kilometres away. However, measurements taken at a proposed site can be compared with measurements taken elsewhere at the same time and used as a guide to the probable correlation over long periods.

Clearly, the expenditure on-site assessment should be about the proposed size and cost of the installation. Very little or no cost is justified in evaluating a site for a 50-watt battery charger whereas a 60-kW wind turbine for example, would in general merit site measurements.

Basic requirements
1. Get a reliable estimate of the winds to be expected at the proposed site. There is no substitute for actual measurements. The turbine manufacturers should be prepared to help.
2. Mount the turbine on as high a tower as possible and well clear of obstructions but do not go to extremes. Easy access will be required for erection and foundations for the tower may be needed depending on the size and tower type. It is also important to ensure that the wind turbines can be easily lowered for inspection and maintenance.
3. Try to have a clear smooth fetch to the prevailing wind e.g. over open water or

smooth ground. If possible, site the turbine on a smooth hill.

4. Use cable of adequate current carrying capacity (check with the turbine supplier. This is particularly important for low voltage machines). Cable costs can be substantial.
5. Consult your local council as to whether you need planning permission. You should try to minimize the environmental impact of the turbine and it will be helpful to inform your neighbours of your plans at an early stage.

Do I have the correct wind resource?
Wind is the "fuel" for your wind generator. Wind turbines start operating at wind speeds of 4 to 5 meters per second, i.e. a "gentle breeze" where leaves and small twigs on trees are in constant motion and reach maximum power output at around 15 meters per, "strong breeze" to "near gale" when whole trees are in motion, and it becomes hard to walk against the wind. At very high wind speeds, i.e. gale force winds of 25 meters per second, wind turbines shut down.

The mechanics and workings of wind turbines
Most wind turbines have three blades which face into the wind, the wind turns the blades, this spins the shaft, which connects to a generator, and this is where the electricity is made.

What are wind turbines made of?
The blades are made of glass-fibre-reinforced polyester or wood-epoxy. The tower is from steel or can sit on top of a wooden pole.

How does a wind turbine make electricity?
The simplest way to think about this is to imagine that a wind turbine works in exactly the opposite way to a fan. Instead of using electricity to make wind like a fan, turbines use the wind to make electricity. The generator uses magnetic fields to convert the rotational energy into electrical energy.

What happens when the wind stops blowing?
Wind turbines only operate when the wind blows. When the wind stops blowing, the electricity supply stops. That is why, for small installations, the wind turbine charges a battery and the electricity supply to the equipment comes from the battery.

How long do wind turbines last?
A wind turbine typically lasts around 20-25 years. During this time, as with a car, some parts may need replacing.

Inquiries: *SwanepoelF@arc.agric.za*