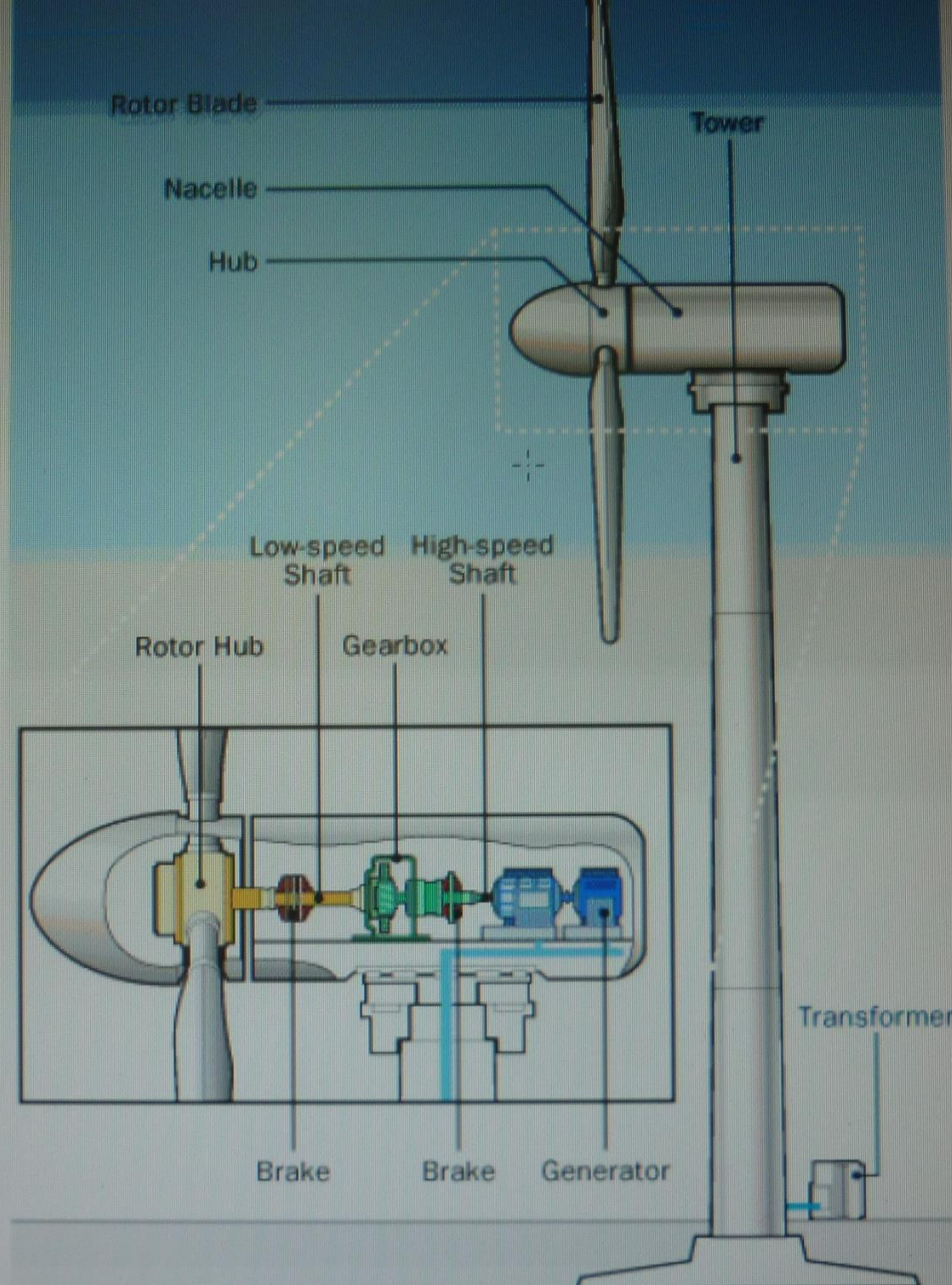


Figure 1.1 Energy conversions in a typical Wind Turbine.

clean coal.

- We will be importing half the amount of gas that we otherwise would.
- The average new car will emit 40 percent less carbon than now.

2.2 Siting of Wind turbines

The placement or "siting" of wind systems is extremely important. In order for a wind turbine system to be effective, a relatively consistent wind-flow is required. Obstructions such as trees or hills can interfere with the rotors. Because of this, the rotors are usually placed on towers to take advantage of the stronger winds available higher up. Furthermore, wind speed varies with temperature, season, and time of day. All these factors must be considered when choosing a site for a wind-powered generator.

The amount of Wind Energy available at any location depends on two sets of factors:

a. Climatic factors including: Time of day, Season, Geographic location, Topography, and Local weather.
b. Mechanical factors including: Diameter of rotor, and Type of Turbine

Utility-scale wind farms must have access to transmission lines to transport energy. The wind farm developer may be obligated to install extra equipment or control systems in the wind farm to meet the technical standards set by the operator of a transmission line.

Figure 2.2 Wind farm, off shore, or on shore.

2.3 Planning Constraints for wind turbines:

There is a number of planning related issues that may make it difficult for you to install a turbine on your site and it would be wise to ensure that you are not going to fall foul of any of these before proceeding.

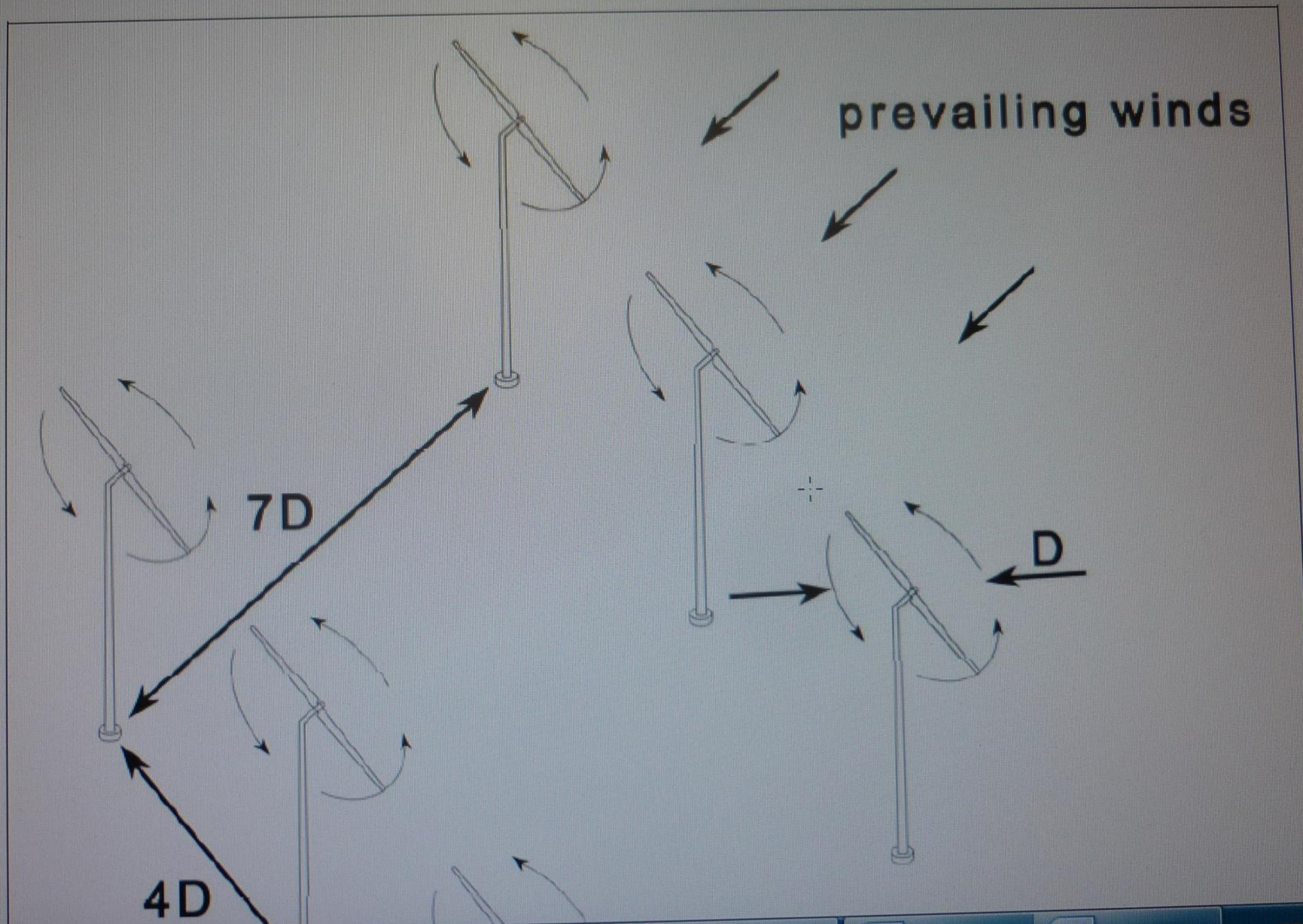
- **Military installations.**
  Avoid these installations, especially if it is an air force base or communication centres.

- **Proximity to built-up area.**
  When housing estates are concerned, ideally consider a distance of at least 200m - 300m depending on the size of the turbine.

- **Designated areas or listed buildings.**
  National Parks or Areas of Outstanding Natural Beauty are more difficult to satisfy the local planning officer to install a wind turbine on it or near it.

2.3.1 Steps to Planning and Building a Wind Farm

- **Wind Farm Design**
  This is important if the project is a wind farm, Wind data is combined with topographical information to design the wind farm. Engineers use this data to model wind flow, turbine performance, sound levels and other parameters to optimize the location of the wind turbines. They also design the access roads, turbine foundations and local electric network, as well as the connection to the electricity grid.



- **Economic and Financial evaluation**
  To prove the economic viability of the project in order to raise the funds to build the wind farm. On one hand, there is a need to estimate the cost of turbines and their installation, as well as roads, electrical system, operation and maintenance, etc. On the other hand, there is a need to estimate the income from the energy production of the wind farm over the lifetime of the project. If there is a net profit, the project has a chance to succeed.

- **Site Preparation**
  Build access roads and clear the areas where turbines will be erected; then prepare the foundations; do the excavating, followed by installing the formworks and pouring concrete.
- **Construction**
  The wind turbine parts are manufactured and pre-assembled into the main components at the factory then shipped to the wind farm site where the final assembly will take place. When all components have been received, the assembly can take place. A crane is used to erect the tower and install the nacelle and rotor with its hub and blades. On the ground, the electrical collection network is installed and connected to the grid through the substation.

- **Commissioning**
  Finally, the wind turbine is tested, all components are calibrated on site and verified against the suppliers specifications, before becoming fully operational.

Wind turbines rely on the movement of the rotor affected by wind to rotate the generator and make electricity. Virtually everything with moving parts will make some sound, and wind turbines are no exception. Turbines are an established and well developed technology, and well designed wind turbines are generally quiet in operation, and compared to the noise of road traffic, trains, aircraft and construction activities, the noise from wind turbines is relatively low. Outside the nearest houses, which are at least half a mile away, and more often further, the sound of a wind turbine generating electricity is likely to be about the same level as noise of leaves rustling in a gentle breeze. This is similar to the sound level inside a typical living room with a gas fire switched on, or the reading room of a library or in an unoccupied, quiet, air-conditioned office.

Source/Activity	Indicative noise level dB (A)
Threshold of hearing	0
Rural night-time background	20-40
Quiet bedroom	35
Wind farm at 350m	35-45
Car at 40mph at 100m	55
Busy general office	60
Truck at 30mph at 100m	65
Pneumatic drill at 7m	95
Jet aircraft at 250m	105

3 Theory of Wind Energy

The principles concerned with converting the potential energy of fluids into useful power relies on three basic fundamentals: conservation of mass, energy and momentum, so it is useful to discuss these before examining the operation of wind turbines.

3.1 Conservation of Mass:

The ***continuity equation*** applies the principle of conservation of mass to fluid flow. Consider a fluid flowing through a fixed conduit having one inlet and one outlet as shown in Figure 3.1

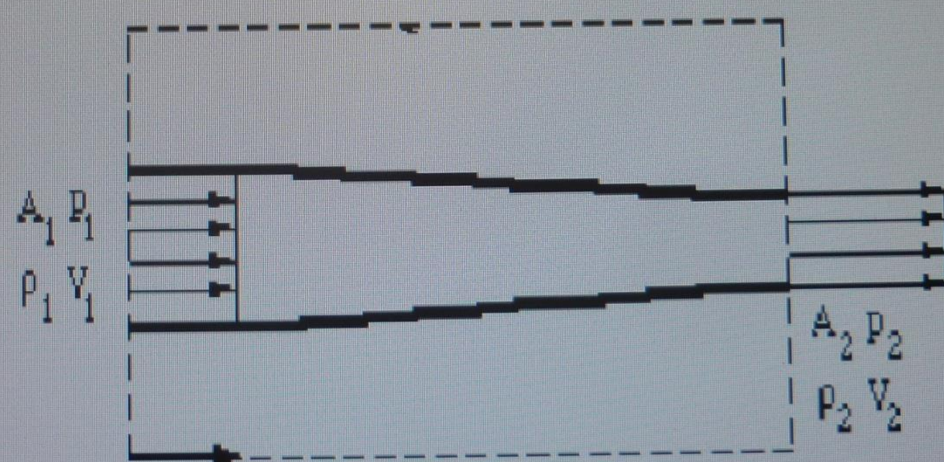


Figure 3.1 Conservation of mass of a fluid flowing in a duct/pipe

If the flow is ***steady*** i.e no accumulation of fluid within the control volume, then the rate of fluid flow at entry must be equal to the rate of fluid flow at exit for mass conservation. If the flow cross-sectional area A (m^2), and the fluid parcel travels a distance dL in time dt, then the volume flow rate (V_f, m^3/s) is given by:

$$V_f = A.dL/dt$$

but since dL/dt is the fluid velocity (V, m/s) we can write: $V_f = V \times A$

The mass flow rate (m, kg/s) is given by the product of density and volume flow rate. Between any two points within the control volume, the fluid mass flow rate can be shown to remain constant:

or $$\rho_1 A_1 V_1 = \rho_2 A_2 V_2 \qquad (1)$$

3.2 Conservation of Energy:

Conservation of energy necessitates that the total energy of the fluid remains constant, however, there can be transformation from one form to another.

There are three forms of non-thermal energy for a fluid at any given point:-

The ***kinetic energy*** due to the motion of the fluid.
The ***potential energy*** due to the positional elevation above a datum.
The ***pressure energy***, due to the absolute pressure of the fluid at that point.

3.3 Conservation of Momentum

Consider a duct of length L, cross-sectional area A_c, surface area A_s, in which a fluid of density ρ, is flowing at mean velocity V. The forces acting on a segment of the duct are that due to pressure difference and that due to friction at the walls in contact with the fluid.

If the acceleration of the fluid is zero, the net forces acting on the element must be zero, hence

$$(p_1 - p_2).\ A_c - (f\ \rho\ V^2/2).\ A_s = 0$$

or $$p_1 - p_2 = \rho\ g\ h_f$$

where $$h_f = f.\ (A_s/A_c).\ V^2/2g$$

For a pipe $$A_s/A_c \ = \pi\ D\ L\ /\pi\ D^2/4 = 4L/D$$

hence $$h_f = (4\ fL/D).\ V^2/2g \qquad (3)$$

This is known as Darcy formula.

has to be determined from the **Moody diagram** (see overleaf). The **relative roughness** is the ratio of the average height of the surface projections on the inside of the pipe (k) to the pipe diameter (D). In common with Reynolds number and friction factor this parameter is dimensionless.

3.4 Ideal Wind Power calculations:

In Theory, Wind power (P) is calculated by the following general equation (the proof for which will be derived in the following section):

$$P = C_p * \frac{1}{2}\rho * A * V^3 \qquad (6)$$

Where

Cp is the power coefficient
ρ is the density of the oncoming air
A swept area of the rotor
V is the velocity of the wind

The actual power is further reduced by two more inefficiencies, due to the gear box losses and the generator efficiency.

the rotor diameter results in increasing the power output by four times.

On the other hand, since power generated is related to wind speed by a cubic ratio. That means if your turbine is rated at producing 1KW at 12m/s then it will produce 125W at 6m/s and 15W at 3m/s.

3.3.1 Theory of Wind Turbines

A windmill extracts power from the wind by slowing down the wind. At stand still, the rotor obviously produces no power, and at very high rotational speeds the air is more or less blocked by the rotor, and again no power is produced.

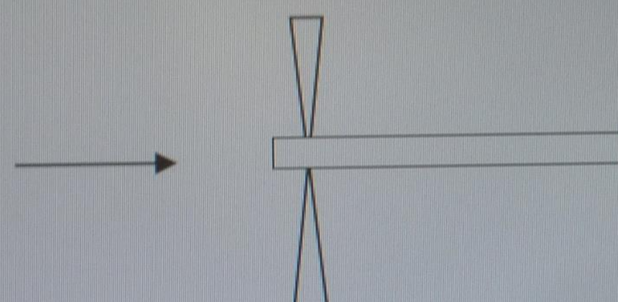


Figure 3.2 Ideal Wind Energy Theory.

The Power produced (P_{kin}) by the wind turbine is the net kinetic energy change across the wind turbine (from initial air velocity of V_1 to a turbine exit air velocity of V_2) is given as:

$$P_{kin} = \frac{1}{2} x m [V_1^2 - V_2^2] \tag{7}$$

Kinetic energy

Kinetic energy is related to the movement of the body in question. Examples of KE such as the flywheel effect and the energy of water flowing in a stream.

Kinetic Energy = ½ mass x velocity squared

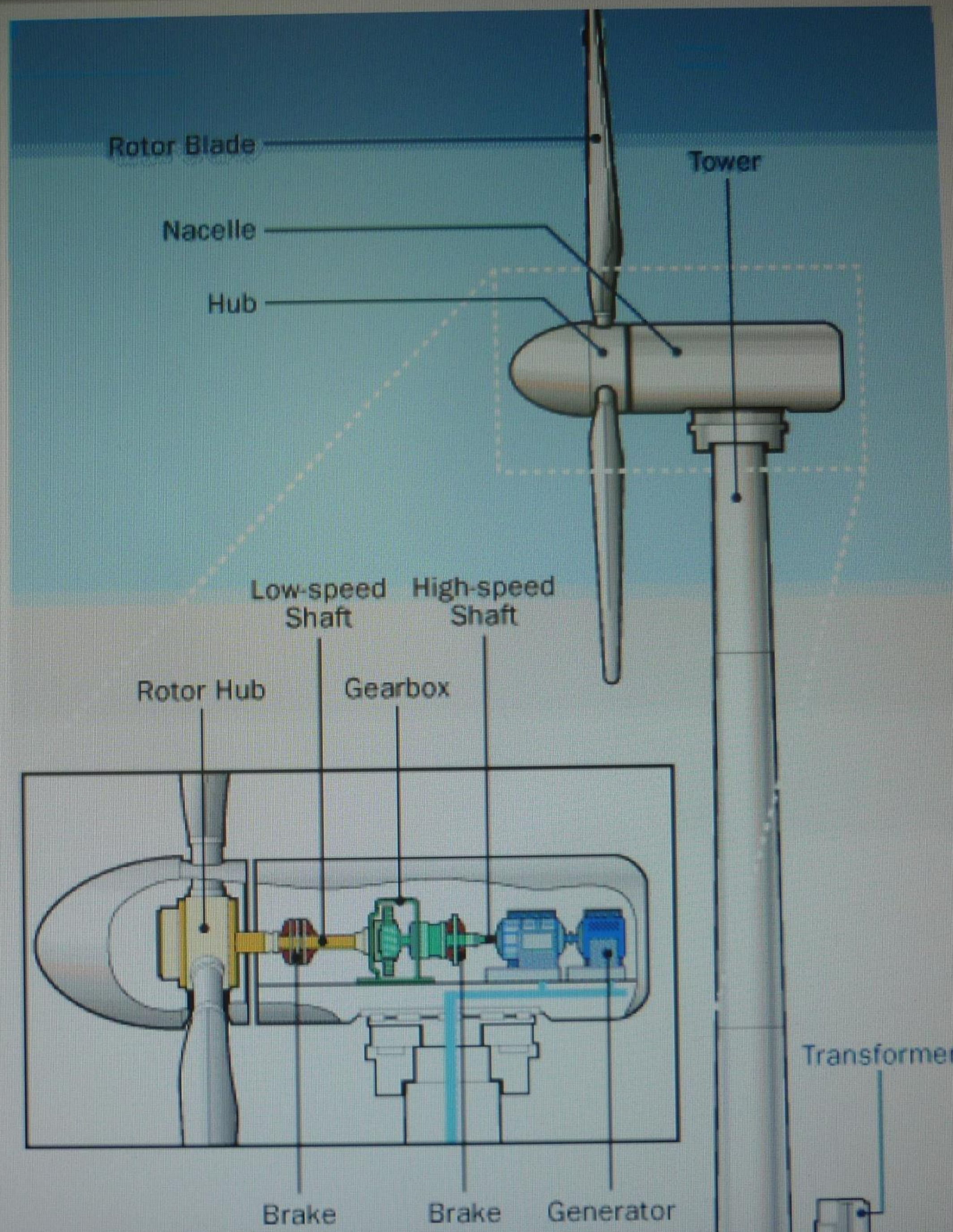
$$E_k = \frac{1}{2} \times m \times v^2$$

The water stream in a river flowing at a velocity of 2 m/s has a kinetic energy of:

Kinetic Energy = ½ mass x velocity squared = $\frac{1}{2} \times 1 \times (2)^2 = 2$ J/kg

1.2.2 Electrical energy

This type of energy as the name implies is associated with the electrons of materials. Electrical energy exists in two forms:



Rotor Blade
Tower
Nacelle
Hub
Low-speed Shaft
High-speed Shaft
Rotor Hub
Gearbox
Transformer
Brake
Brake
Generator

2.3.1 Steps to Planning and Building a Wind Farm

There are many stages of development before a wind turbine/farm can be approved and built. Once a site has been selected for its good overall potential, work begins on several main tasks:

- **Consultation with the local authority**
  It is extremely important to contact the local authority in the area where the turbine is considered before committing any time or costs. Engage them early in the planning process, answer any questions and/or concerns that they might have, and keep an open dialogue with them throughout the whole development.

- **Consultation with the Public near the site**
  The local community who are likely to be affected by the proposal must be met to present the project, solicit their feedback and seek their support. An advertisement in the local paper would be a good idea to inform the general public and invite them for a discussion and debate.

- **Land acquisition**
  Early in the process, developers, if not already the owners themselves usually approach landowners to negotiate "option" agreements to use their land. As the project progresses, the developer will seek to convert the options into firm land lease agreements.

- **Wind Assessment**
  Another very important step is assessing the wind resource. Scientists and engineers use meteorological masts to measure wind speed and other climatic conditions for at least one year. This data is then used to estimate how much energy the wind farm will produce. It is often assumed that this has to be carried out before any serious consideration is planned.