FACTFILE:
GCSE
CONSTRUCTION AND THE BUILT ENVIRONMENT

UNIT 2: SUSTAINABLE CONSTRUCTION

Rewarding Learning

Wind Turbines

Unit
Unit 2: Sustainable Construction
Purpose of FactFile?
Provide further information to both teachers and students on Wind Turbines as a renewable energy technology identifying their component parts. In addition information is given on how this technology can be used in construction and the built environment.
Specific Learning Outcomes supported by the FactFile?
Learning outcome from **Unit 2: Sustainable Construction** Demonstrate knowledge and understanding of the following renewable energy technologies and/or materials and identify their component parts using examples from local, European and/or global contexts related to the built environment: • Heat pumps (ground source and air source); • **Wind turbines;** • Solar panels, including photovoltaic cells and water heaters; and • Biomass. Identify how **wind turbines** as a renewable energy technology can be used in construction and the built environment.
Target audience? Student? Teacher? Both?
Both student and teacher,
How the FactFile supports development of Key Stage 4 Statutory skills?
Communication in reading of the FactFile information and producing written responses to the activities and questions. Problem solving through research activities. Talking and listening in response to the group or individual research activity findings. Use of ICT as a research tool and a platform for collating their findings.

Wind energy

Air moving from an area of high pressure to an area of low pressure is known as wind. Wind is caused by the sun unevenly heating the earth's surface. Wind energy describes the process where electricity is generated by wind turbines. The turbines convert the kinetic energy in the wind into mechanical power.

To efficiently capture the wind energy, wind turbines are mounted on a tower. Wind speeds are faster and less turbulent 20 metres or more above the ground level. Blades on the turbine are used to capture the wind's energy.

Wind energy is a renewable form of energy as the wind caused by the heating and cooling of the earth's surface and its capture does not require the burning of fossil fuel which is a finite resource. Wind is an inexhaustible and free natural resource. In addition the generation of electricity from wind turbines is emission free. The initial impact on the environment from the manufacture and installation of the wind turbine is soon offset by the clean electricity which is produced.

There are two main types of wind turbine which are distinguished by the axis in which the rotor of the turbine rotates.

1. Vertical Axis Wind Turbines (VAWT)

2. Horizontal Axis Wind Turbines (HAWT)

Vertical turbines come in various different shapes and spin on the vertical axis. The main difference between a VAWT and HAWT is the position of the blades. In a VAWT the generator is fixed to the bottom of the tower and the blades are wrapped around the shaft. In the HAWT the generator is fixed to the top of the tower in housing known as the nacelle. Often a HAWT will have two or three blades which are mounted on the rotor. The rotor is connected via a shaft to the gearbox and generator. HAWT are the most common type of wind turbine. VAWT's generally produce less noise and are more popular in residential scenarios where the wind turbines are usually smaller in size.

Example of a Vertical Axis Wind Turbine

Example of a Horizontal Axis Wind Turbine

The flow of air over the blades cause the blades to move. The blades are made from very light and resistant materials which allow them to move even in times of low wind speeds. The blades are attached to the low-speed shaft which is connected to the gearbox. The gearbox raises the speed and transfers to the high speed shaft which is connected to the generator. The generator converts the kinetic energy into electricity. The electricity produced is in direct current and is transferred via cables to be converted to alternating current for use in a building. Large wind turbines which only export their electricity will use a transformer to raise the voltage and direct the alternating current to a substation where the voltage is increased again and fed into the grid for use by the end consumer.

Activity:

Research the configuration of both Vertical Axis and Horizontal Axis turbines and label the following components on a diagram of each turbine:

- Blade;
- Rotor;
- Low-speed shaft;
- Gearbox;
- Generator;
- Brake;
- Nacelle (HAWT); and
- Tower.

Wind turbine Performance

The power of the wind can be calculated by the following equation.

$$\text{Power} = (0.5) \times (\text{turbine wind swept area}) \times ((\text{wind speed})^3)$$

The equation above tells us that the power of a turbine is related to two factors: the wind swept area of the turbine and the wind speed.

Wind swept area is the area through which the blades of a turbine spin. Therefore the power output from a turbine will increase as the length of the blades are increased. Wind speed is the speed at which the wind is hitting the turbine blades. As shown in the power equation above, wind speed will have the biggest proportional increase in the power output. All wind turbines will have a cut-in speed. This is the speed at which the blades will start to rotate and allow the turbine to generate power. When the wind speed is too high and therefore the forces on the turbine structure are such that it could damage the moving parts, then the brake is initiated which brings the rotor to a stop. This is known as the cut-out speed.

The limit to the turbine generator output is known as the *rated power output*, and the wind speed at which it is achieved is known as the *rated output wind speed*. Designing and installing large wind turbines will provide a higher output of power provided that there is the required wind speeds to ensure that the turbine frequently reaches its rated power output. The large load imposed by the turbine components and the forces from the wind mean that engineers must design and construct a foundation which can carry the turbine and transfer the imposed loads into the ground.

Installing Large Scale Wind Turbines

Wind turbines integrated into the built environment

Building mounted turbines can be fixed to the side or on the roof of a building provided there is sufficient exposure to the wind. Generally these turbines are small in size and often have a maximum output of around 2 kW. Before installing a wind turbine the building owner first needs to know what the actual annual demand for electricity is. In addition a reasonably accurate calculation based on the wind swept area and on site wind speeds is required to predict the expected power output from a turbine. To accurately determine the on-site wind speed a survey is carried out on site over a period of time to assess the average wind speeds throughout the year. This will allow the building owner to assess the feasibility of installing a wind turbine.

Turbines mounted in exposed positions near to buildings on poles are often 5 kW to 10 kW turbines and at a hub height of around 12 metres. Home owners and businesses wishing to install a turbine will require planning permission. To achieve planning permission the land owner must make an application. This will consist of an application form, fee and other supporting information such as an environmental statement, noise assessment, and ecological study. Before granting permission the planners will consider all relevant issues highlighted in the reports in addition to the local planning policy for the area, turbine height, site location, and distance from neighbouring buildings and roads.

A site with a number of wind turbines clustered together is known as a wind farm. Large turbines need to be sited away from buildings for environmental reasons due to the noise and flicker created when they are operational. In addition, buildings, trees and other structures reduce the wind speed and therefore the efficiency of the turbines will be reduced if they are placed too close. Large onshore turbines range in size from 100 kW to more than 3000 kW. A typical 3000 kW (3 MW) turbine has a hub height of around 120 metres and blade diameter of around 130 metres.

As turbines increase in size, the cost of purchase and installation generally increases as the components need to be transported to, and assembled on site with large foundations constructed to secure the turbine. In turn these turbines when operational produce a large amount of electricity which ensure that the high costs of installation are paid off when the installer receives an income for the electricity exported to the grid. Wind turbines on their own are not a reliable source of electricity for a building or facility because there will be periods where there will be no wind or when speeds are below the turbine's cut in speed. Turbines will perform best in open areas where they have the maximum exposure to the wind and the average wind speeds meet that of the turbines rated output wind speed. Provided that there is wind, turbines are a very reliable technology, and with an annual service most are expected to have a life span of at least twenty years. They

have the advantage over solar in that they will produce electricity throughout the day and in winter months when solar radiation levels are low. Like other renewables there is the option to store electricity whenever the turbine produces more electricity than there is a demand for. The stored electricity can then be used whenever the turbine is unable to produce electricity.

Activity:

Research and evaluate the advantages and disadvantages of wind turbines as an alternative to fossil fuels. The following areas should be considered:

- cost;
- performance;
- reliability.

Questions to consider?

Label the main components within a HAWT & **Wind turbines.**

Label the main components within a **Solar PV** system.

Identify how wind turbines could or have been used in various building types and construction projects.