It's Only Natural: Science resources for 11- to 16-year-olds

Teachers' notes

Contents

Introduction

This pack is part of the Department of Trade and Industry's **It's Only Natural** programme, which is all about **renewable energy resources** in the UK.

The programme includes these materials for the Science curriculum, and another set of materials for the Geography curriculum.

The science resources are designed for students aged 11 to 16 years.

The key objectives of the pack are to provide students with information about what renewable energy is, what the sources are and how each source works.

The **It's Only Natural** pack is for teachers in England, Wales and Scotland. Since school structures vary between these countries, and to allow for flexibility for less- or more-able students, the materials have been organised into two age levels roughly corresponding to 11–14s and 14–16s.

Contents of the pack

This programme contains the following.

- These teachers' notes.
- **Introduction to renewable energy** information sheet
- **Renewable energy information cards** at two levels (level 1 aimed at 11- to 14-year-olds, level 2 for 14- to 16-year-olds) on bio-energy, hydrogen fuel cells, geothermal energy, hydroelectricity, solar, tidal, wave and wind energy.
- A **website**, www.dti.gov.uk/renewables/schools, which contains case studies, links to relevant online resources and PDFs of this pack.
- **15 activity sheets for students**, to support the activities described in these notes. The activities can be used in isolation to cover one or two lessons, or they can be fitted together to create a longer programme of study, depending on the time available. The activities are designed for use in Science/Environmental Studies lessons for 11- to 16-year-olds.
- Two **posters**: one about renewable energy in general, and one about the energy transfers involved in using different types of renewable energy.

The energy issue

Increasing population and industrial expansion mean that there is a continually increasing demand for energy. The fossil fuel resources that supply most of the world's energy needs are finite but we are far from exhausting them. Most estimates of proven oil reserves are high enough to meet projected world demand over the next three decades. Proven reserves of gas and coal are even more plentiful than those of oil and there is considerable potential for discovering more of all these fuels in the future.

In addition to this, most scientists now believe that the earth's climate has begun to change at a greater rate than it has done for many thousands of years. The reason for this is believed to be our continued emission of increasing amounts of greenhouse gases, such as carbon dioxide and methane. The undisputed source of the vast majority of these emissions is the burning of fossil fuels.

There is a growing consensus that we need to change the way we meet our energy requirements, and this change needs to come sooner rather than later. This is why the UK Government has signed the Kyoto Protocol, which came into force on 16 February 2005, and is committed to generating 10 per cent of its energy needs from renewable sources by 2010.

This pack has been created because it is important that young people understand the issues and the technology involved in the question of how we meet our energy needs in the future. After all, climate change and dwindling supplies of fossil fuels are set to become the major issues for their generation.

Background information

The subject of energy, fossil fuels, global warming and pollution is huge – and these notes and activities do not attempt to cover everything. The focus is on renewable energy. The wider debate about global warming is not covered as a separate topic, and these resources do not attempt to make a detailed comparison between renewable and non-renewable sources of energy. There is no direct comparison with nuclear energy, and the option of reducing consumption is not covered here. That doesn't stop teachers from including those aspects of the debate in discussion or follow-up.

This resource is designed to be flexible, and can be used either as a complete resource or as a 'pick and mix' selection of activities.

Education for Sustainable Development

There is also the relevance to Education for Sustainable Development (ESD), which the Qualifications and Curriculum Authority promotes as "an approach to the whole curriculum and management of a school". See www.nc.uk.net/esd.

The Clear Skies initiative offers grants to people who are interested in renewable energy projects. The money is available for new energy systems that use renewable technology – solar water heating, wind power, hydroelectric, wood fuel systems and ground source heat systems. Homeowners can get grants of up to £5,000 and, if your school has community links, there could be up to £100,000 worth of help on offer. See www.clear-skies.org for more information about the initiative.

The PV programme provides grants of between 40 and 50 per cent towards the installation of solar electricity equipment. You can apply calling the PV helpline on 0800 298 3978 or visit the website, www.est.org.uk/solar/about/.

The activities

A brief outline of the activities is given below, with full teachers' notes and curriculum links given on the following pages.

Activity	11–14	14–16
1: Build a biogas generator: practical class activity, students working in pairs; some simple apparatus and pre-preparation required.	■	
2: Build a hydroelectric power plant: practical class activity, students working in groups of 2 to 4; some simple apparatus and pre-preparation required.	■	
3: Where to site a wind turbine: practical class activity, students working in pairs; some simple apparatus and pre-preparation required.	■	
4: Build a wind turbine: practical class activity, students working in pairs; some simple apparatus and pre-preparation required.	■	
5: Solar water heating: practical class activity, students working in pairs; some simple apparatus and pre-preparation required.	■	
6: Renewables at home: individual project activity.	■	
7: Build a wind turbine and generator: practical class activity, students working in pairs; some simple apparatus and pre-preparation required.		■
8: Build a solar cooker: practical class activity, students working in pairs; some simple apparatus and pre-preparation required.		■
9: Build a solar water heater: small group project activity potentially cross-curricular with Design and Technology; some simple material and access to hand tools required.		■
10: Renewables at school: small-group project activity, students working in groups of 2 to 4.	■	■

Risk assessment

For each activity, it is the responsibility of the supervising teacher to carry out all risk assessments with regard to the activity and to make sure that any such risk assessment complies with the requirements of the particular institution in which it is being conducted.

Activity 1: Build a biogas generator

Curriculum links

Ideas and evidence in science	E: Scientific enquiry Sc1: 1a,b
Investigative skills: planning; obtaining and presenting evidence; considering evidence; evaluating	E: Scientific enquiry Sc1: 2d-g,j-p S: Investigating: Preparing for, carrying out and reviewing and reporting on tasks W: Scientific enquiry 3.5-7, 3.9-10, 3.14-20
Green plants as organisms: nutrition and growth	E: Life processes Sc2: 3a,b S: Living things: The processes of life W: Life processes and living things 3.2-3
Changing materials: chemical reactions	E: Materials and their properties Sc3: 2i S: Earth and space: Changing materials W: Materials and their properties: 2.12
Energy resources	E: Physical processes Sc4: 5a-c S: Energy and forces: Conversion and transfer of energy W: Physical processes 5.1-3

Key question

- How can we make and collect flammable methane?

Recommended age: 12–14 years

Number of lessons: 2

Assumes prior knowledge of the broad issues surrounding renewable energy and the role of photosynthesis in 'fixing' solar energy in biomass

Materials and equipment required (per group)

- *Activity sheets 1.1 and 1.2*
- *Level 1 Bio-energy information card*
- Biogas generator kit (see below)
- Selection of material to put in generators. Assemble before the lesson and keep in separate buckets: grass cuttings, food scraps from the school canteen, leaf litter, mashed fruit, etc. Horse manure or manure from any ruminant works well as long as it is fresh but there must be careful supervision when handling it. Chicken manure should not be used as it can produce hydrogen sulphide gas.
- Distilled water or tap water left to stand for 24 hours (fresh tap water may kill useful bacteria because of the chlorine content) to 3/4 fill the plastic bottle
- Rubber gloves, aprons, goggles, plastic beakers, access to scales, a bucket and stirrer

The biogas generator kit (see *Activity sheet 1.1* for details of construction)

- 1 x large plastic bottle (2 litres or bigger)
- 1 x single-hole bung that fits the opening of the bottle, with right-anglebent glass tube inserted
- 2 x 50cm lengths of rubber tubing
- 2 x 10cm length of glass tubing (to connect the lengths of rubber tubing and mylar balloon)
- 2 x tube clamps
- Enough black paper to cover the bottle
- A large funnel that fits into the neck of the bottle
- A Mylar balloon for gas collection

Note before starting

It can take a month or more for your biogas generators to start producing flammable methane. This is because the aerobic bacteria present will initially produce carbon dioxide. It is only when the oxygen is used up that methane in flammable concentrations will be produced. It might therefore be useful, if possible, to schedule the two halves of this activity on either side of a school holiday.

Lesson 1 (Students work in pairs.)

To introduce the lesson, discuss the following points. You may also like to distribute copies of the *Level 1 Bio-energy information card.*

- The primary source of the vast majority of the energy we consume is actually the sun.
- The sun's energy is captured by green plants during photosynthesis.
- Burning biomass gives off carbon dioxide, but careful management can mean that any carbon dioxide given off can be absorbed by newly planted trees. This means that bio-energy can be 'carbon neutral'.
- Bio-energy can also be produced in the natural process whereby bacteria break down biomass to produce methane gas. The methane gas can then be burnt to produce electricity through turbines and generators.
- The advantages and disadvantages of using biomass as a source of energy. Explain that students are going to work in pairs to build their own biogas generators. They will have a selection of different types of biomass to try in their generators. The purpose will be to decide which type of biomass (or mixture of types) produces the most methane.

Activity sheet 1.1 gives instructions for setting up the biogas generator and shows a diagram of the generator. Talk through and demonstrate the method of the experiment.

Students will need to weigh the different organic materials and record these weights on *Activity sheet 1.2* before putting them in their generators. Students will need to wear rubber gloves, goggles and aprons when handling the feedstock for their generators.

The completed and functioning biogas generators need to be kept warm. However, try to keep them out of direct sunlight as this will encourage algal growth, and the UV content of the light may kill the bacteria.

Lesson 2

Start with a recap of the previous lesson.

Students then need to measure the volume of the gas they have produced and record those readings on *Activity sheet 1.2.* This can be done by simply connecting the mylar balloon to a gas syringe or setting up apparatus for collection of the biogas from the balloon over water. Results can then be pooled to create a table which should show the best material or combination of materials for use in a biogas generator.

The experiment can be extended with a teacher demonstration to investigate the 'quality' of the methane produced. If possible, each group can provide a sample of methane in a corked and labelled boiling tube. The teacher can then ignite each sample in front of the class. Pure methane should burn in plenty of oxygen with a clean blue flame, producing only water and carbon dioxide. The students should be asked to observe each sample and make their own observations. Pure methane is odourless, so if their gas smells it is impure.

To finish the activity, students can write a conclusion and evaluation of the experiment they have carried out.

Extension/Homework

Students can consider what other factors might affect the operation of their biogas generators. For example, what would the optimum working temperature be and why? Can they estimate how big such a generator would have to be to provide usable amounts of methane?

Activity 2: Build a hydroelectric power plant

Curriculum links

Ideas and evidence in science	E: Scientific enquiry Sc1: 1a,b
Investigative skills: planning; obtaining and presenting evidence; considering evidence; evaluating	E: Scientific enquiry Sc1: 2d-g,j-p
	S: Investigating: Preparing for, carrying out and reviewing and reporting on tasks
	W: Scientific enquiry 3.5-7, 3.9-10, 3.14-
20 Energy resources	E: Physical processes Sc4: 5a-c
	S: Energy and forces: Conversion and transfer of energy
	W: Physical processes 5.1-3

Key question

- Can we use water to generate electricity? Does the height of the water running through a turbine affect the voltage level of a power plant?

Recommended age: 12–14 years

Number of lessons: 2

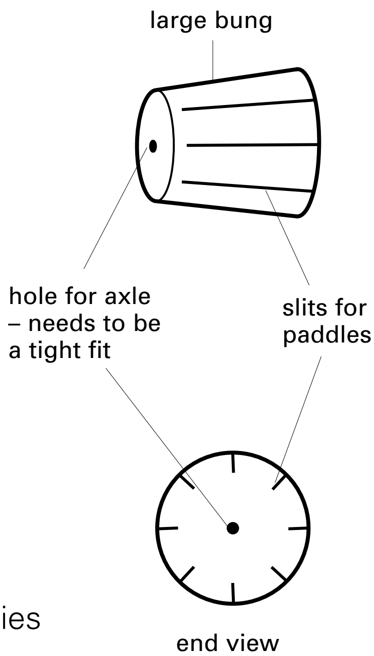
Assumes prior knowledge of the broad issues surrounding renewable energy and the qualitative relationship between pressure and depth in a fluid. Students will also need to be aware that an electric motor can act as a generator if rotated by an external force.

Materials and equipment required (per group)

- *Activity sheets 2.1* and *2.2*
- *Level 1 Hydroelectricity information card*
- Hydroelectric power plant kits (see below),
- Plastic buckets, rubber hoses, tape measures, retort stand and clamp
- Mops will also be necessary as water may be spilt on the floor

The hydroelectric power plant kit (see *Activity Sheet 2.1* for details of construction)

- 1 x 2-litre/4-pint plastic milk bottle
- 1 x 1.5v electric motor
- 1 x large diameter cork or rubber bung, as per diagram
- 14 or more plastic teaspoons
- 1 x generator-axle joining blocks
- 1 x axle
- 2 x jumper leads with crocodile clips at each end
- 1 x ammeter
- 1 x voltmeter
- 1 low-voltage bulb and holder (or LED)
- Selection of leads
- Vaseline



Lesson 1

Arrange students into groups of 2–4. To introduce the lesson, discuss the following points. You may also like to distribute copies of the *Level 1 Hydroelectricity information card.*

- The primary source of the vast majority of the energy we consume is actually the sun.
- The sun's energy drives the water or hydrological cycle, which means that the gravitational potential energy of the water in a lake or reservoir is actually transferred, through a number of stages, from thermal energy from the sun.
- The basic principles behind hydroelectricity.
- The advantages and disadvantages of using hydroelectricity, including the environmental impact. Explain that the aim of the activity is to build a small water turbine, and to use it to generate electricity by allowing water to flow through it. The experiment will then be taken further in Lesson 2 to see if there is any relationship between the voltage generated and the pressure of the water powering the turbine.

Distribute *Activity sheet 2.1*. Talk through and demonstrate the method of construction.

End with a summary of the lesson and review of any results and observations. Briefly run through the procedure for Lesson 2.

Notes

- It is important that the axle makes a snug fit where it passes through the wall of the milk container. If it is too loose, water will leak out and cause a short circuit within the motor/generator. Adding a blob of Vaseline to the inside of the milk container where the axle passes through provides some lubrication and water resistance.
- Joining the motor to the axle can be problematic. The easiest way of doing this is to use a small block of polythene or nylon-type plastic and to drill a hole through it of slightly smaller diameter than the motor shaft and the water turbine axle. The motor shaft and axle can then be pushed into the plastic to form a secure joint. These generator-axle joining blocks will need to be prepared in advance.

Lesson 2

Review the previous lesson and explain the second stage of the experiment. Hand out *Activity sheet 2.2.*

Students will need plastic buckets and 2m lengths of rubber tubing. The turbine assembly will need to be held in an empty bucket on the floor. A second bucket needs to be half filled with water and raised above the level of the turbine assembly. Water from this bucket can be siphoned through the turbine to power it. For hygiene reasons, it is best not to attempt to syphon the water by sucking it through the tube.

Students need to take readings of the current and voltage generated with the water bucket raised to different heights to simulate different hydrostatic heads. The data collected can be tabulated and displayed as a graph.

Students should find that as the height of the water bucket increases, so the voltage generated increases. They should be encouraged to see the connection between increasing the gravitational potential energy of the water in the bucket by raising it further from the ground and the higher voltage generated.

Extension/Homework

More-able pupils could be introduced to the concept that voltage multiplied by current gives us the power in a circuit. The experiment could also be extended to investigate the efficiency of their turbine. For a known mass of water at a known height, the total gravitational potential energy can be calculated. By measuring voltage and current in the circuit attached to the turbine and the time it operates for, the total electrical energy output can be calculated. It is then a simple matter to calculate the efficiency.

Activity 3: Where to site a wind turbine

Curriculum links

Ideas and evidence in science	E: Scientific enquiry Sc1: 1a,b
Investigative skills: planning; obtaining and presenting evidence; considering evidence; evaluating	E: Scientific enquiry Sc1: 2d-g,j-p S: Investigating: Preparing for, carrying out and reviewing and reporting on tasks W: Scientific enquiry 3.5-7, 3.9-10, 3.14-20
Energy resources	E: Physical processes Sc4: 5a-c S: Energy and forces: Conversion and transfer of energy W: Physical processes 5.1-3

Key question

■ Can we measure the speed of the wind using simple everyday objects? Where would be the best place to put a wind turbine at school?

Recommended age:

11–14 years

Number of lessons: 1

Assumes prior knowledge of the broad issues surrounding renewable energy

Materials and equipment required (per group)

- *Activity sheets 3.1* and *3.2*
- *Level 1 Wind energy information card*
- Anemometer kits (see overleaf). These kits can be pre-assembled and kept as a class set, or they can be built by the students who are going to use them. For the purposes of this activity, it is assumed that the students will assemble their own anemometers.

The anemometer kit (see *Activity sheet 3.1* for details of construction)

- 1 x large protractor
- 1 x ping-pong ball
- 1 x bubble level
- 30cm of nylon fishing line
- 1 x sewing needle
- 20cm length of wooden dowel with slot cut in one end to fit protractor (the slot should be pre-cut)
- 1 x drawing pin
- 1 x A5 sheet of stiff card
- Access to a hot glue gun
- Modelling clay or Blutack

Lesson

Arrange students in pairs. To introduce the lesson, discuss the following points. You may also like to distribute copies of the *Level 1 Wind energy information card* included in this pack.

- The primary source of the vast majority of the energy we consume is actually the sun.
- The sun's energy causes the wind by uneven heating of the earth's surface.
- The basic principles behind wind energy.
- The advantages and disadvantages of using wind energy.
- The UK is the windiest place in Europe and therefore has excellent wind energy potential. Lead into a discussion on whether it might be possible to build a wind turbine to supply power to the school. Discuss where would be the best place to site such a turbine.

Distribute the anemometer kits and *Activity sheet 3.1*. Talk through and demonstrate the construction of the anemometer and explain how it is used. Take care to explain how to convert angle measurements to wind speeds using the table on *Activity sheet 3.1*.

Once each pair has constructed their anemometer they can go and take some readings. In the interests of time, it is best if each pair is sent to one or two pre-assigned locations around the school to take their readings.

The readings can be pooled and tabulated and the whole class can then decide where would be the best place to site a wind turbine.

Extension/Homework

Students can be asked to consider whether their readings were entirely valid as they were all made at ground level. They might want to consider why wind turbines are generally set on towers or masts.

Students could also be asked to design a questionnaire to find out people's attitudes to living near a wind farm. Designing the questionnaire will help them to consider what possible viewpoints people might have on this. They could pilot their questionnaire with family and friends.

Activity 4: Build a wind turbine

Curriculum links

Ideas and evidence in science	E: Scientific enquiry Sc1: 1a,b
Investigative skills: planning; obtaining and presenting evidence; considering evidence; evaluating	E: Scientific enquiry Sc1: 2d-g,j-p
	S: Investigating: Preparing for, carrying out and reviewing and reporting on tasks
	W: Scientific enquiry 3.5-7, 3.9-10, 3.14-20
Electricity and magnetism: circuits	E: Physical processes Sc4: 1a,c
	S: Energy and forces: Properties and uses of energy
	W: Physical processes 1.6
Energy resources	E: Physical processes Sc4: 5a-c
	S: Energy and forces: Conversion and transfer of energy
	W: Physical processes 5.1-3

Key question

- How can we harness wind energy to power machines at home and at school? How can we optimise the energy we get from wind turbines?

Recommended age:
12–14 years

Number of lessons:
1 or 2

Assumes prior knowledge of the broad issues surrounding renewable energy. Students will also need to recognise that an electric motor can also be used as a generator.

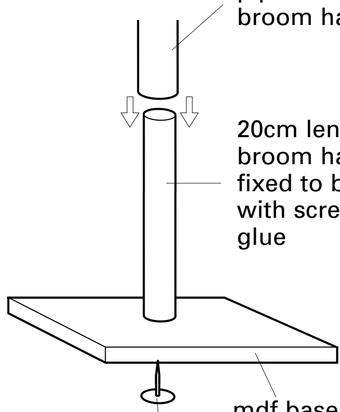
Materials and equipment required (per group)

- *Activity sheets 4.1* and *4.2*
- *Level 1 Wind energy information sheet*
- Wind turbine kits (see below),
- Hot glue gun, low-voltage bulb and holder (or an LED), electrical jumper leads, tack hammer.

The wind turbine kit (See *Activity sheet 4.1* for details of construction)

- Corriflute parts pre-cut to shape (corriflute may be available in your D&T department, if not find it online at www.mutr.co.uk)
- Wood/mdf block
- Thin bamboo or balsa wood strips
- An electric motor

- Plastic propeller that fits the shaft of the motor
- 2 x small cable ties
- 1 x small flat-head nail
- 30cm length of 40mm plastic waste pipe
- Base assembly (needs to be pre-prepared as in diagram)



Lessons (1 or 2 x one-hour lessons)

Arrange students into pairs and introduce the topic of wind energy through a discussion about renewable energy. It might be useful to distribute copies of the *Level 1 Wind energy information card* included in this pack. From this discussion students need to appreciate the following points.

- The primary source of the vast majority of the energy we consume is actually the sun.
- The sun's energy causes the wind by uneven heating of the earth's surface.
- The basic principles behind wind energy.
- The advantages and disadvantages of using wind energy.
- The UK is the windiest place in Europe and therefore has excellent wind energy potential. The construction of the wind turbine can then be introduced as an activity. Talk through and demonstrate the construction of the wind turbine.

For some classes, a general introduction to the issues surrounding renewable energy followed by the construction and testing of their wind turbine will be sufficient. This will allow them to develop a simple level of understanding of renewable energy issues.

Extension/Homework

The exercise could be extended by asking students to imagine that a wind farm was going to built close to their homes and for them to consider the plus and minus points associated with living near a wind farm.

More able students may like to add an ammeter to their test circuit. Readings can then be taken of the voltage and current generated at different wind speeds as created by a variable speed desktop fan. This could be extended into a second lesson where pupils build their own propellers out of card and test them to see which generates the most electrical energy at a fixed wind speed.

If the turbines are to be tested outside, each group will need a broom handle to place their turbine on for testing and a small plastic or cardboard box to hold the electrical circuit.

Note – fitting homemade propellers to the generator

Use a cork borer or similar to take a cylindrical section from a pencil eraser. Make a small hole in the cylindrical section of the eraser to fit onto the shaft of the motor. Use a hot glue gun to secure the propeller onto the other end of the piece of eraser.

Activity 5: Solar water heating

Curriculum Links

Ideas and evidence in science	E: Scientific enquiry Sc1: 1a,b
Investigative skills: planning; obtaining and presenting evidence; considering evidence; evaluating	E: Scientific enquiry Sc1: 2d-g,j-p S: Investigating: Preparing for, carrying out and reviewing and reporting on tasks W: Scientific enquiry 3.5-7, 3.9-10, 3.14-20
Energy resources	E: Physical processes Sc4: 5a-c, f S: Energy and forces: Properties and uses of energy; Conversion and transfer of energy W: Physical processes 5.1-3, 5.6

Key question

- How can we optimise the energy we get from the sun using solar water heaters?

Recommended age:

11–14 years

Number of lessons: 1

Assumes prior knowledge of the broad issues surrounding renewable energy

Materials and equipment required (per group)

- *Activity sheet 5.1*
- *Level 1 Solar energy information card*

The solar water heater kit (see *Activity sheet 5.1* for details)

- Shoebox or equivalent
- Various insulating materials
- Tinfoil
- Scissors
- Black water-colour paint
- Black permanent marker
- Black paper
- Polycarbonate/glass sheet/cling film big enough to cover the front of the shoe box
- Insulating tape
- 2 x boiling tubes and bungs with single hole (small enough to fit in the shoe box)
- Sticky tape
- 3 x thermometers or data logger with multiple temperature sensors
- Stopwatch

Lesson

Arrange students into pairs and introduce the topic of solar energy through a discussion. It may be useful to distribute copies of the *Level 1 Solar energy information card* included in this pack. From this discussion students need to appreciate the following points.

- The primary source of the vast majority of the energy we consume is actually the sun.
- The basic principles behind solar energy.
- The advantages and disadvantages of using solar energy. If appropriate to the group, this discussion can lead into a detailed description of how a solar water heater works, including the role played by long and short wavelength infra-red radiation.

Students can then move on to the activity that illustrates how a solar water heater works. To add a competitive edge, a prize could be offered for the pair whose water sample reaches the highest temperature. *Activity Sheet 5.1* shows the students how to assemble their water heater. It should be left to the students to decide which materials to use, based on their knowledge of how insulators work and how heat energy is transferred.

Once the water heaters are constructed, the activity is best conducted out of doors. The greatest temperature rises will be recorded on a sunny day, but even on a cloudy day when the sunlight is quite diffuse, noticeable temperature rises will be recorded. It will be useful if the supervising teacher records the ambient outdoor temperature. If possible, students should set up their experiments in the same location to ensure a fair test.

Thermometers can be used to measure the relevant temperatures but the use of data loggers allows an element of ICT to be introduced. Students should be asked to record the external temperature, the temperature inside the shoe box and the temperature in the water sample at regular intervals. This information can then be plotted on a graph.

Extension/Homework

Students can suggest improvements to the design of their water heaters and explain the scientific principles behind their designs. Older students could attempt to estimate how much hot water is used in their home each week and from this estimate how much it costs to heat this water each week.

Activity 6: Renewables at home

Curriculum links

Ideas and evidence in science	E: Scientific enquiry Sc1: 1a,b
Investigative skills: planning; obtaining and presenting evidence; considering evidence; evaluating	E: Scientific enquiry Sc1: 2a-c, k-m S: Investigating: Preparing for, carrying out and reviewing and reporting on tasks W: Scientific enquiry 3.1-3, 3.16- 17
Energy resources	E: Physical processes Sc4: 5a-g conservation of energy S: Energy and forces: Conversion and transfer of energy W: Physical processes 5.1-9

Key question

- How much of the electricity we use at home is generated from renewable energy? Could this figure be increased?

Recommended age:
13–14 years

Number of lessons:
2 to 4

Assumes prior knowledge of the broad issues surrounding renewable energy. Students will also need to understand the meaning and usage of kWh, kW and units (as used in electricity and gas bills).

Materials and equipment required

- *Activity sheet 6.1*
- *Introduction to renewable energy sheet*

Lesson

The purpose of this activity is to encourage students to look at their own energy consumption, the source of that energy and how it might be possible to use renewable energy sources to supply some of that energy.

The activity is research-based. Students will find out from their electric bills, in terms of kWh, how much energy they use in their home per week. Currently, the UK obtains just about three per cent of its electricity from renewable sources so, as a rough approximation, three per cent of the total energy can be subtracted from their bill as already being provided by renewable sources. The remaining 97 per cent comes from non-renewable sources, which are mainly fossil fuels.

The average UK household uses about 80–90kWh of electrical energy per week averaged over a year so their figures should be within this range.

To give some context to the amount of carbon produced, the average household in the UK creates around six tonnes of carbon dioxide every year (source: Energy Saving Trust, www.est.org.uk). An estimate in 1991 suggested annual man-made CO_2 emissions were more than 150 times the amount emitted by volcanoes on Earth (source: volcano.und.edu/vwdocs/Gases/man.html).

Their next task is to identify a renewable energy source or sources, which they could install in their home to provide as much of the 97 per cent as possible. The source they choose has to be practical so, for example, a 2MW wind turbine would more than cater for the energy needs of a single house but is not really a practical option for a standard 3-bed semi.

Most students will probably come back with the option of a combination of solar and wind energy, and possibly a geothermal element.

The exercise can be increased in complexity to take in the cost of installing the renewable sources against the savings in energy bills. This will involve some fairly detailed research but a huge amount of information on this subject is available on the internet.

Activity 7: Build a Cross-Wind Savonius turbine and generator

Curriculum links

Single science	
Ideas and evidence in science	E: Scientific enquiry Sc1: 1d
Investigative skills: planning; obtaining, presenting, considering and evaluating evidence	E: Scientific enquiry Sc1: 2c-s W: Scientific enquiry 3.2-22
Energy resources and energy transfer	E: Physical processes Sc4: 4b,d W: Physical processes 1.11
Double science/Physics	
Ideas and evidence in science	E: Scientific enquiry Sc1: 1d
Investigative skills: planning; obtaining, presenting, considering and evaluating evidence	E: Scientific enquiry Sc1: 2c-s W: Scientific enquiry 3.2-22
Electricity: circuits	E: Physical processes Sc4: 1f S: (National) Intermediate 1, Mains electricity 2.3.8 (Standard) Unit 2 Using Electricity 3.4 W: Physical processes 1.7
Energy resources and energy transfer	E: Physical processes Sc4: 5b,d-j S: (National) Intermediate 2, Momentum and energy 1.3.7, 1.3.11-12, Electromagnetism 2.3.2-3 (Standard) Unit 2 Using Electricity 6.4; Unit 6 Energy Matters 1.3, 3.1, 3.5, 3.7, 3.8, 3.10 W: Physical processes 1.7

Key question

- How does a wind turbine and generator work?

Recommended age:
15–16 years

Number of lessons:
2 to 3

Assumes prior knowledge of the broad issues surrounding renewable energy. Students will also need to know the theory behind how a simple generator works.

The schedule given below is based on two one-hour lessons, one for construction and one for testing. It may be necessary to use two lessons for construction, depending on the degree to which components have been pre-prepared.

Materials and equipment required (per group)

- *Activity sheets 7.1* and *7.2 (see reverse of sheet 4.2)*
- *Level 2 Wind energy information card*
- Cross-Wind Savonius wind turbine and generator kits (see below)
- Scissors, craft knife, anemometer (if available), access to a hot glue gun, variable speed desk fan, electrical jumper leads, low-voltage bulb and holder, a.c. voltmeter, a.c. ammeter

The Cross-Wind Savonius wind turbine and generator kit

- 1 x cylindrical section 2-litre drinks bottle
- A large, flat sheet of corrugated cardboard
- 35cm length of 6mm wooden dowel
- 100m of 24-gauge enamelled copper wire
- Small piece of mdf, 3cm wide
- 4 x rare earth magnets
- 4 x 5A cable connector blocks
- 2 x large drawing pins
- 50cm x 30cm mdf base board
- Sheet metal right-angle bracket approx 20cm high

Note

It is suggested that an exemplar model is made prior to the lesson so that students can see the finished article. Magnets and wire should be recycled for use in future lessons. To save time during the lesson, it is suggested that generator coils are wound beforehand.

Craft knives are necessary for parts of this activity. Appropriate precautions should be taken.

Lesson 1

Arrange students into pairs and introduce the topic of wind energy through a discussion about renewable energy. It might be useful to distribute copies of the *Level 2 Wind energy information sheet* included in this pack. From this discussion students need to appreciate the following points.

- The primary source of the vast majority of the energy we consume is actually the sun.
- The sun's energy causes the wind by uneven heating of the earth's surface.
- The basic principles behind wind energy.

- The advantages and disadvantages of using wind energy.
- The UK is the windiest place in Europe and therefore has excellent wind energy potential.

Explain that students are going to build their own wind turbine and a.c. generator and investigate how the electricity it produces varies with wind speed. Hand out *Activity Sheets 7.1* and *7.2 (on the back of sheet 4.2)* and talk through and demonstrate the construction process prior to the students beginning their own construction. This particular type of wind turbine is known as a ‘Cross-Wind Savonius’.

By the end of this lesson most students should have built their wind turbine and generator. It might be a good idea to check that students’ coils are arranged correctly on the stator before they fix them in position, because if they make a mistake their generator will not work and it will be very difficult to fix.

Lesson 2

Start with a recap of the previous lesson. Hand out *Activity sheet 7.2*. Students should now begin to test their wind generators. If correctly constructed, they should produce 1 or 2 volts at a moderate rotation speed.

Desk fans can be used to provide a small range of different wind speeds for testing. Anemometers can be used to quantify these wind speeds. If anemometers are not available, it is possible to use the ping-pong ball anemometers described in Activity 3 in these teachers’ notes and the associated wind speed conversion table given in *Activity sheet 3.1.*

The turbines and generators can also be tested out of doors at various locations around the school. At the end of the testing, students need to plot a graph of voltage generated against wind speed.

The activity could be further extended by providing a variety of rotor discs and stators, carrying different numbers of magnets and coils with different numbers of turns.

Extension/Homework

Students can consider what energy transfers are involved in the process and where the energy losses occur within the turbine and generator arrangement. They might also like to consider how the design could be improved.

If an oscilloscope is available, the experiment can be extended to look at the frequency of the electricity generated. Students can rotate the generator and examine the trace on the oscilloscope screen and measure basic properties like amplitude. They can also try to explain how each section of the waveform is generated.

Activity 8: Build a solar cooker

Curriculum Links

Single science	
Ideas and evidence in science	E: Scientific enquiry Sc1: 1d
Investigative skills: planning; obtaining, presenting, considering and evaluating evidence	E: Scientific enquiry Sc1: 2d-g,m W: Scientific enquiry 3.3-10, 3.16
Electromagnetic spectrum	E: Physical processes 2c,d W: Physical processes 3.7
Energy resources and energy transfer	E: Physical processes 4a,b W: Physical processes 5.4-5
Double science/Physics	
Ideas and evidence in science	E: Scientific enquiry Sc1: 1d
Investigative skills: planning; obtaining, presenting, considering and evaluating evidence	E: Scientific enquiry Sc1: 2d-g,m W: Scientific enquiry 3.3-10, 3.16
Electromagnetic spectrum	E: Physical processes Sc4: 3e,f S: (National) Intermediate 2, Waves 3.1.1 W: Physical processes 3.10
Energy transfer	E: Physical processes Sc4: 5a,b W: Physical processes 5.4-5

Key question

- Is it possible to cook food without fire, gas or electricity?

Recommended age:

14–16 years

Number of lessons: 1

Assumes prior knowledge of the broad issues surrounding renewable energy

Equipment and materials required (per group)

- *Activity sheet 8.1*

The solar cooker kit (see *Activity sheet 8.1* for details of construction)

- 1 suitable cardboard box (about the size of the boxes used for photocopy paper)
- Large sheets of corrugated cardboard
- A roll of tin foil
- PVA glue
- Duct tape
- A large aluminium foil baking container (15cm x 25cm or slightly smaller)
- Matt black metal paint
- A piece of toughened glass about 1cm wider and longer than the baking container
- Oven gloves
- Sun glasses
- Oven thermometer or data logger with temperature sensor

Note

This activity can be used to demonstrate how solar energy can be concentrated to perform useful work. It can also be used as an enjoyable end of term activity and students can use their solar cooker for heating cookies etc. For hygiene reasons, it is recommended that food is not actually cooked (although it is possible that cooking temperatures will be reached) in the solar cooker. Water is a good medium for checking the effectiveness of the cooker too.

The cooker should be taken through the cooking cycle several times before food is put in it to allow any impurities to be baked off.

Safety

Temperatures in excess of 100°C and even up to 200°C can be created in these solar cookers, and it is recommended that students wear oven gloves when using them. Sunglasses are also a useful precaution against glare from the reflective surfaces.

Lesson

Arrange students into pairs and introduce the topic of solar energy through a discussion about renewable energy. It might be useful to distribute copies of the *Level 2 Solar energy information card* included in this pack. From this discussion students need to appreciate the following points.

- The primary source of the vast majority of the energy we consume is actually the sun.
- The basic principles behind the different types of solar energy.
- The advantages and disadvantages of using solar energy.
- Although the UK isn't a particularly sunny place, in July the solar energy incident on a horizontal surface is between 4.5 and 5kWh per square metre per day. Five kilowatt-hours is enough energy to heat the water for a large hot bath. Distribute *Activity sheet 8.1.* Explain that students are going to build their own solar cooker. Talk through and demonstrate the construction technique.

It is important that students are cautioned about the temperatures their cooker can produce and the glare it can produce from its reflective surfaces.

An element of competition can be introduced to the activity by offering a prize for the cooker generating the highest temperature.

Extension/Homework

Students can be asked to research different designs of solar cooker and perhaps come up with one of their own.

Activity 9: Build a solar water heater

Curriculum Links

Single science	
Ideas and evidence in science	E: Scientific enquiry Sc1: 1d
Investigative skills: planning; obtaining and presenting evidence	E: Scientific enquiry Sc1: 2f W: Scientific enquiry 3.9
Electromagnetic spectrum	E: Physical processes Sc4: 2c,d W: Physical processes 3.7
Energy transfer	E: Physical processes 4a,b W: Physical processes 5.4-5
Double science/Physics	
Ideas and evidence in science	E: Scientific enquiry Sc1: 1d
Investigative skills: planning; obtaining and presenting evidence	E: Scientific enquiry Sc1: 2f W: Scientific enquiry 3.9
Electromagnetic spectrum	E: Physical processes Sc4: 3e,f S: (National) Intermediate 2, Waves 3.1.1 W: Physical processes 3.10
Energy transfer	E: Physical processes Sc4: 5a,b W: Physical processes 5.4-5

Design and Technology	
Developing, planning and communicating ideas	E: 1a,e WJEC: Resistant materials technology 5.1.1a,g
Working with tools, equipment, materials and components to produce quality products	E: 2a W: Resistant materials technology 5.1.2a
Evaluating processes and products	E: 3c,d W: Resistant materials technology 5.1.3c,d
Knowledge and understanding of materials and components	E: 4a,b W: Resistant materials technology 5.1.4a,b

Key question

- How can we heat water for our homes without fire, gas or electricity?

Recommended age:
14–16 years

Number of lessons/ time required:
4 to 8 hours, depending on the number of students involved

Equipment and materials required

See *Activity sheets 9.1* and *9.2* for instructions.

Guidance

This activity is designed to be undertaken by a small group of students under the direct supervision of a teacher. It is not specifically designed for carrying out during curriculum time as it is a fairly lengthy project.

The project is designed to produce a useable solar water heater from readily available materials. The design is based on use of a ‘Stelrad’ radiator as the collector element. These radiators are particularly suitable as they have tapped holes at all four corners so that the necessary diagonal flow of water is achieved easily.

All of the dimensions specified assume the use of a Stelrad radiator. If a different radiator type is used, the dimensions will have to be altered accordingly.

This project covers only the construction of the collector panel. It can be connected relatively easily to a hot water cylinder and pump for demonstration purposes, and information on how to do this is available in various publications available from the Centre for Alternative Technology (www.cat.org.uk). Based on material taken from Solar Water Heating: A DIY Guide © Centre for Alternative Technology Publications, a division of CAT Charity Ltd.

Activity 10: Renewables at school

Curriculum Links

Single science	
Ideas and evidence in science	E: Scientific enquiry Sc1: 1d
Investigative skills: planning; obtaining and presenting evidence	E: Scientific enquiry Sc1: 2d, j-o W: Scientific enquiry 3.3, 3.13-17
Mains electricity	E: Physical processes Sc4: 1g,h W: Physical processes 1.8-9
Electromagnetic spectrum	E: Physical processes Sc4: 2c,d W: Physical processes 3.7
Energy transfer and electromagnetic effects	E: Physical processes 4a,b,d W: Physical processes 5.4-5, 1.11
Double science/Physics	
Ideas and evidence in science	E: Scientific enquiry Sc1: 1d
Investigative skills: planning; obtaining and presenting evidence	E: Scientific enquiry Sc1: 2d, j-o W: Scientific enquiry 3.3, 3.6, 3.13-17
Electricity circuits	E: Physical processes Sc4: 1f S: (National) Intermediate 1, Mains electricity 2.3.8 (Standard) Unit 2 Using Electricity 3.4 W: Physical processes 1.7
Electromagnetic spectrum	E: Physical processes Sc4: 3e,f S: Intermediate 2, Waves 3.1.1 W: Physical processes 3.10
Energy transfer work, power and energy; electromagnetic effects	E: Physical processes Sc4: 5b,d-j S: (National) Intermediate 2, Momentum and energy 1.3.7, 1.3.11-12; Electromagnetism 2.3.2-2 (Standard) Unit 2 Using Electricity 6.4; Unit 6 Energy Matters 1.3, 3.1, 3.5, 3.7, 3.8, 3.10 W: Physical processes 5.5, 5.7-8, 1.15-19

Key question

- How much of our school's electricity is generated from renewable energy? How could we increase this figure?

Recommended age: 14–16 years

Number of lessons: 2 to 4

Assumes prior knowledge of the broad issues surrounding renewable energy and technologies available for generating renewable energy

Equipment required (per group)

Activity sheet 10.1

Activity description

Activity sheet 10.1 provides students with a basic guide to the project. The purpose of this activity is to encourage students to look at energy consumption around them, the source of that energy and how it might be possible to use renewable energy sources to supply some of that energy.

More specifically, the students have to examine the energy efficiency of their school and make a set of recommendations as to how this efficiency can be improved. They also need to make recommendations as to how a proportion of the school's energy needs might be met from renewable sources. The project can be developed further by including surveys of student (and staff) views on applying renewable energy to the school environment.

This activity will require the students to have access to information about the energy consumption of their school. For the purposes of convenience, it will be best if this information is collected for them and presented as baseline data for the project.

Information that will be useful includes the following.

- Total annual consumption of electricity.
- Total annual consumption of gas.
- Total annual consumption of oil.
- The specific uses that these energy sources are put to, e.g. gas for heating, electricity for lighting and general power.
- Any available breakdown of use of energy, e.g. by department.
- Unit cost of energy supplied.