Teaching Sustainability in High Schools:

Module 2 (Focus on Senior Physics)

Lessons 5-8

Electricity – Innovative Technologies towards Sustainable Development

Teacher Supplement

Developed by: The Natural Edge Project

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Student Supplement for Module 2:
Chemistry Innovations in Sustainable Development

Developed by: The Natural Edge Project

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In collaboration with the Sustainable Living Challenge

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Disclaimer

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Introduction – Using this Supplement

Overview

Are you a high school science, biology, chemistry, or physics teacher who wants to discover relevant and practical activities that engage students in sustainability in your classroom? This teacher supplement will help you address national curriculum requirements with regard to education for sustainability, and will also show how sustainability can provide context for STEM curriculum.

This Teacher Supplement provides teaching and assessment support for the *'Learning-by-Notes'* package for Senior Physics students, to support the use of these materials to address the requirement for education for sustainability in the national curriculum. It also aims to increase interest in Science, Engineering, Technology and Maths (i.e. STEM) through an interesting and current topic area. The teacher resource has been funded by Engineers Australia (QLD Division), as a companion to the existing 12 lessons (Grade 12, Senior Chemistry and Senior Physics) that have been previously developed with funding from the Port of Brisbane as part of the Sustainable Living Challenge.

As the second of three modules in this series, this module contains activity ideas, student handouts, and assessment ideas for four lessons on renewable energy systems.

– **Lesson 5A: Solar Energy** describes the key components of solar cells and the process used by solar cells to generate electricity from the sun's energy.

– **Lesson 5B: Wind Energy** describes the key components of wind turbines and the process used by wind turbines to generate electricity using the sun's energy.

– **Lesson 6: Steam** describes the key components of steam turbines and electric generators, and the processes used by these technologies to generate electricity using the sun's energy.

– **Lesson 7: Flowing Water** describes the key components of hydroelectric power plants and ocean power plants and the processes used by these technologies to generate electricity from flowing water.

– **Lesson 8: Fuel Cells** describes the key components of fuel cell systems and the process that fuel cells use to generate electricity from gas.

This curriculum draws on the text book: Hargroves, K. and Smith, M. (2006) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London. Teachers are encouraged to refer to this text for further explanation of related content, additional references and excerpts for use during training sessions. The text also has a supporting online companion at www.naturaledgeproject.net/NAON.aspx.

Structure of the Teacher Supplement

This 'Teacher Supplement' provides an activity pack for each of the four lessons described above. The content has been structured to enable a wide variety of teaching methods, from lesson-style teaching, to problem based learning. Teachers may choose to fully explore all of the material, or just take parts of the content as they support existing materials in the learning program. Each lesson supplement has the following structure to enable easy referencing and lesson preparation:

- **Educational Aim:** This text is the same as in the student materials, defining the educational objective for each lesson. The teacher may use this as an introduction to the class.
- **Alignment to National Curriculum:** This text provides a summary of how the lesson aligns with the stated objectives of the Australian National Curriculum.
- **Activity descriptions:** Here we provide 2 activities for each lesson, spanning exercises that require minimal resources or expenditure, to activities that may need some funds and/or preparation. Occasionally there are also pre-prepared student handouts that can be photo-copied or scanned, to assist with the lesson preparation.
- **Summary Activities and Homework Ideas:** Here we provide a number of ideas for assessment under three popular types including essay topics, mind map opportunities, and short answer questions. We also provide some sample answers to assist with marking.

Structure of the Student Materials

Each Lesson contains the following headings. It is intended that teachers can either use this structure directly, or be readily able to adapt it to their preferred class structure and format:

- **Educational Aims:** define the educational objective for each lesson. This text provides a snapshot of the key message.
- **Learning Points:** summarise key points to explain the message. This information can be transferred onto overhead or PowerPoint slides for teaching to the class. Alternatively, the points could be read out by students and discussed in a tutorial-style learning environment.
- **Brief Background Information:** This provides the teacher with a context within which to interpret the Learning Points. It also indicates the type of information contained in the recommended references and resources. This material often explains terminology in more depth, or provides background information to help further explain concepts in case students find the material difficult to understand. This additional information could also be used to prepare student handouts, or as additional reading for students. Note that the Brief Background Information should not be considered the only source of in-depth information. The teacher should refer to additional references such as *The Natural Advantage of Nations* for detailed information to support lesson delivery.
- **Key References:** This list is essential as a summary of where key information has been sourced from, and where more information on related topics can be found.
- **Key Words for Searching Online:** This list is intended to encourage students to explore online resources related to the topic of interest (both specific information and more general topics of interest). Specific pages are noted where appropriate, although at times only the home page is listed for general reading and navigation of the site. A search of these key words will also list the most current material available on the topic of interest.

Additional Support for Teaching Education for Sustainability

In addition to the extensive reference list provided for each part in the 'Student Supplement' the following is a list of key resources for which teachers can use to access further teaching material and potential class activities.

TeachSustainability.com.au (http://www.teachsustainability.com.au/): A primary resource for teachers is the *TeachSustainability.com.au* web resource. An initiative of the Sustainable Living Challenge, this website is a resource sharing database to support Australian teachers who are exploring issues of sustainability in their classrooms. This database allows the open and free sharing of resources that have been developed or sourced by school teachers and educators.

Teaching and Learning for a Sustainable Future (http://www.unesco.org/education/tlsf/): *Teaching and Learning for a Sustainable Future* web resource is an award winning internationally renowned training toolkit for those who want to educate for a sustainable future. It consists of over 100 hours (divided into 25 modules) of professional development for use in pre-service teacher courses, as well as the in-service education of teachers, curriculum developers, education policy makers and authors of educational materials.

Education for Sustainability Portal (http://www.aries.mq.edu.au/portal/index.htm): Developed by the Australian Research Institute in Education for Sustainability (ARIES), the *EFS Portal* is a central source of information on education for sustainability. The site is designed for use by those who want to use education and learning based strategies to stimulate change towards sustainability. This includes community groups, local councils, government agencies, industry, non-government organisations, schools, colleges and universities.

Federal Government Resources: DEWHA, DCC and ORER:

– The Australian Government Department of Environment Water, Heritage and the Arts (http://www.environment.gov.au/education/publications/index.html) provides a range of resources that seek to develop skills, knowledge, values and behaviours that support a sustainable environment.

– The Department of Climate Change website provides answers to frequently asked questions about Climate Change (http://www.greenhouse.gov.au/science/index.html).

– The Office of the Renewable Energy Regulator has been established to oversee the implementation of the Australian Government's mandatory renewable energy target. Their website has information on renewable energy options (http://www.orer.gov.au/index.html).

The Natural Edge Project – Engineering Sustainable Solutions Program (ESSP): Recognising that the engineering, scientific and design professions will play a significant part in moving society to a more sustainable way of life, together with the realisation that we have very little time to prepare, this program seeks to contribute open source peer reviewed education material to assist efforts globally to accelerate education for sustainable development in engineering and the built environment: All material is freely available, open-source and online, under a Creative Commons Attribute license: (http://www.naturaledgeproject.net/ESSP.aspx, see Curriculum & Course Content).

5A: Solar Energy: How do we make Electricity from Solar Cells?

Educational Aims:

The aim of this lesson is to describe the key components of solar cells and wind turbines. We also consider a variety of processes that are involved in generating electricity from the sun's energy, through solar and wind power.

Alignment with Existing Curriculum Requirements

The activities and information presented in this lesson aligns to the National Curriculum cross curriculum priority 'Sustainability' which is concerned with the ongoing capacity of the Earth to maintain life:[1]

Actions to improve sustainability aim to reduce our ecological footprint while simultaneously supporting a quality of life that is valued—the 'liveability' of our society. Sustainable patterns of living meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability is both an individual and a collective endeavour often shared across communities and nations necessitating a balanced but different approach to the ways humans have interacted with each other and with their biophysical environment. Sustainability learning draws on and relates learning across the curriculum. It leads to students developing an overall capacity to contribute to a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations.

These activities are aligned with the Queensland Studies Authority (QSA) Senior School Syllabus for Physics. Specifically, the activities and information presented in this manual align to the following parts of the Physics Senior Syllabus:[2]

Organiser 2 – Energy	
E1.1	Energy is the capacity to do work.
E1.2	Energy manifests itself in various forms, including: potential energy associated with gravitational, electric and magnetic fields; kinetic energy related to the motion of matter; and nuclear energy, which links to the concept of mass–energy equivalence.
E1.3	Energy can be described and measured in terms of an object's position and motion within gravitational, electric and magnetic fields.
E2.1	The total amount of energy within a closed system remains constant.
E2.2	Exchanges or transformations of energy do not change the total energy of the closed system
E2.3	When energy is converted from one form to another there is a reduction in the amount of useful energy available to do work
E2.4	The transference of energy between systems can be explained using the laws of thermodynamics

[1] http://www.australiancurriculum.edu.au

[2] http://www.qsa.qld.edu.au/downloads/senior/snr_chemistry_07_syll.pdf

E2.5	The laws of conservation of energy and momentum can be used to examine the interactions between objects in simple and complex situations
E3.1	Energy transformation and associated applications have social and environmental consequences
E3.2	Rational discussion of energy transformations in present day society requires an understanding of the underlying physics concepts and ideas
E3.3	Knowledge of underlying physics concepts and ideas can be used to provide reasoned argument about the viability of alternative energy transformation processes
E3.4	Energy has applications in medical, industrial and commercial fields eg radiation, electronics and alternative technologies
E3.5	Energy in solid state systems (e.g. semiconductors)

Activity 1 – Video Clip: Everything comes from the Sun!

In this activity, students will gain a systemic appreciation that all energy on the earth comes from the sun. Using technology (such as phone cameras and digital cameras), students will create a multi-media clip that highlights this important point.

Key Learning Point:

All the energy on the planet comes from the sun – not just solar energy!

Resources:

– Each group will need access to a recording device, which may be as simple as a mobile phone camera, a digital camera, or a video camera.

– Students may get examples for their project by viewing online examples.

– Brief Background Information, Lesson 5A 'Solar Cells' and Lesson 5B 'Wind Turbines'

– The website www.solarschools.net is an excellent solar resource.

Teacher Preparation:

– The teacher and students will need to be familiar with the materials in Lesson 5A and Lesson 5B.

– For teachers who are not familiar with using video creation for learning and assessment, please see for example 'School Tube' (www.schooltube.com)

Activity Description:

1. Ask students the following questions and answers to provide some context to this activity.

   a) How do we use the sun's energy?

      Many students will respond by saying 'solar energy' or perhaps 'solar panels'. Ask them to consider wind energy as an example. Wind is created because the earth is heated unevenly which creates areas of air with different densities. Warmer air rises and the cooler air moves to fill the space left behind, creating wind. So, the wind that turns huge wind turbines actually is created by the sun!

   b) What other forms of energy are created by the sun?

      Consider hydroelectric power from the sun driven water cycle, and biofuels from plant photosynthesis. The sun's energy is stored in fossil fuels because they are composed of the photosynthesis of plant and animal matter that has died, deposited, decomposed, buried, heated and compressed to undergo chemical reactions.

2. After a discussion on all the ways that energy comes from the sun, explain to students that their task is to make a brief film clip that demonstrates this in an exciting way. Perhaps they could write a short role play, or try to film different types of energies around the school. They could also write a documentary or a news clip.

3. Present the films to the class and discuss which ones conveyed the idea that all energy comes from the sun!

Student Handout – Everything comes from the Sun!

Use the following table to guide your enquiry into the source of different forms of energy. The facts you identify here will form the technical basis of your film clip on the sun.

For example, for 'Wind': Wind is created because the earth is heated unevenly which creates areas of air with different densities. The sun warms patches of air, which becomes lighter and rises so the cooler air moves to fill the space left behind, creating wind. So, the wind that turns huge wind turbines actually is created by the sun!

Energy Type	Sources
Wind	
Hydroelectric Power (from dams and spillways, such as the Snowy Mountain Scheme)	
Biofuels (such as sugar cane mulch)	
Fossil Fuels (oil and coal)	
Nuclear	(hint: think about all the suns in the universe)

Activity 2 – Experiment: Solar Efficiency

This activity allows students to investigate the efficiency of a typical solar cell by comparing the voltage produced from a solar cell in full sun to a known mass of water evaporated by the same amount of solar radiation. This activity has been adapted from Joe Wolfe's Physics experiments at the University of New South Wales.[3]

Key Learning Point:

Solar cells collect and store the sun's energy. The amount of energy lost in the conversion from solar radiation to electrical energy can be measured by the efficiency of a solar cell.

Resources:

- Materials (for one demonstration): A small solar panel (search for 'Small Solar Panel 6V 50mA' online)[4]; a resistor with a power rating at least as great as that of the panel (preferably greater so that it doesn't get hot); a voltmeter; a small, light, disposable, aluminium baking dish with a flat bottom and nearly vertical sides if possible; a can of black paint (eg in a spray can); a piece of cardboard as big as the base of the baking dish; a 30 cm ruler; a stick (or a pencil); a clock with a second hand; and a balance or scale.
- A sunny day!

Teacher Preparation:

- For this activity, students will need to understand the physics of photovoltaic cells (see Lesson 5A for information) and the science of solar radiation.
- The experiment requires an understanding of basic physical chemistry (latent heat of water and how to calculate the amount of energy required to evaporate a known mass of water).

Activity Description:

1. Paint the inside of the dish black and leave to dry.
2. Pour in a small, known mass 'm' of water (of known temperature — optional). The depth should be greater than the variation in depth of the bottom of the dish (that is, use a dish with a flat, smooth bottom)
3. Place the dish in direct sunlight, but protected from the wind. Put it on an insulator (such as a piece of cardboard) and keep it flat.
4. Measure the area, 'A_{panel}', of the solar panel. Arrange the solar panel, resistor (with resistance R) and voltmeter in series using alligator clips. Check to see if the circuit is properly set up by looking for a voltmeter reading, V.
5. Measure the angle 'θ' of the sun to the horizontal by measuring the length of shadow cast by a stick held vertically. Use the formula: $\theta = \tan^{-1}$(length shadow/height of stick).

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[3] http://www.phys.unsw.edu.au/~jw/I&Iexperiments.pdf

[4] For example, http://store.sundancesolar.com/minsolpan6v5.html - one available for under $25

6. Calculate the amount of solar radiation that is actually converted to useful electric energy 'e':

   If the water of mass m is all evaporated in time t, then the energy given to the water from the sun is approximately

   $$Energy = P_{dish} = L_v \times m$$

   where L_v is the latent heat of water (Lv = 2.3 MJ.kg-1, not a strong function of temperature). The heat capacity of the dish is negligible, as are conduction losses through the walls, provided there is no wind.

   The intensity of solar radiation is then estimated as

   $$I_{solar} = \frac{\text{power}}{\text{perpendicular area}} = \frac{P_{dish}}{A_{dish}} \approx \frac{L_v \times m}{A_{dish} \times t \times \sin\theta}$$

   Then, calculate the power delivered by the solar panel:

   $$P_{panel} = \frac{V^2}{R}$$

   Now the efficiency of the cell, e, can be calculated as

   $$e = \frac{\text{electrical power out}}{\text{solar power in}} = \frac{\frac{P_{panel}}{A_{panel}}}{\frac{P_{dish}}{A_{dish}}} = \frac{P_{panel}}{A_{panel}} \times \frac{1}{I_{solar}}$$

7. Discuss the implications of this number for the widespread use of solar panels.

Summary Activities and Homework Ideas

1. Essay

This essay question provides students with an opportunity to consider the criticisms of solar energy. In answering the questions posed below, students will be tested on their appreciation of the arguments, and their ability to write a well-structured essay within the word limit set by the teacher.

Essay Statement:

There are many critics of solar energy. It is often labelled inefficient (as seen in the solar efficiency experiment) and costly compared to non-renewable fossil fuels.

Write an essay that discusses these two major criticisms. In your argument, you may like to provide examples of technologies, case studies and predictions that support the development of solar energy.

Sample Answer:

Students may raise the following points about the two major criticisms:

- Inefficiency
  - Modern solar cells about 20% efficient – compared to fossil fuels which are about 35% efficient (but non renewable!)
  - With research and development solar can become much more efficient.
  - Rapidly running out of readily available stores of natural gas and oil.
- High Cost
  - Solar is expensive to implement but less so to run and maintain.
  - Carbon pricing and taxes will affect the price of fossil fuels.
  - Natural gas prices continue to rise.

2. Mind Map

This mind map exercise encourages students to recall the components of a solar cell, and the interconnections. In creating the mind map, students will be demonstrating their knowledge of the components, and their appreciation of their interconnectedness. This exercise could be undertaken individually or in a group.

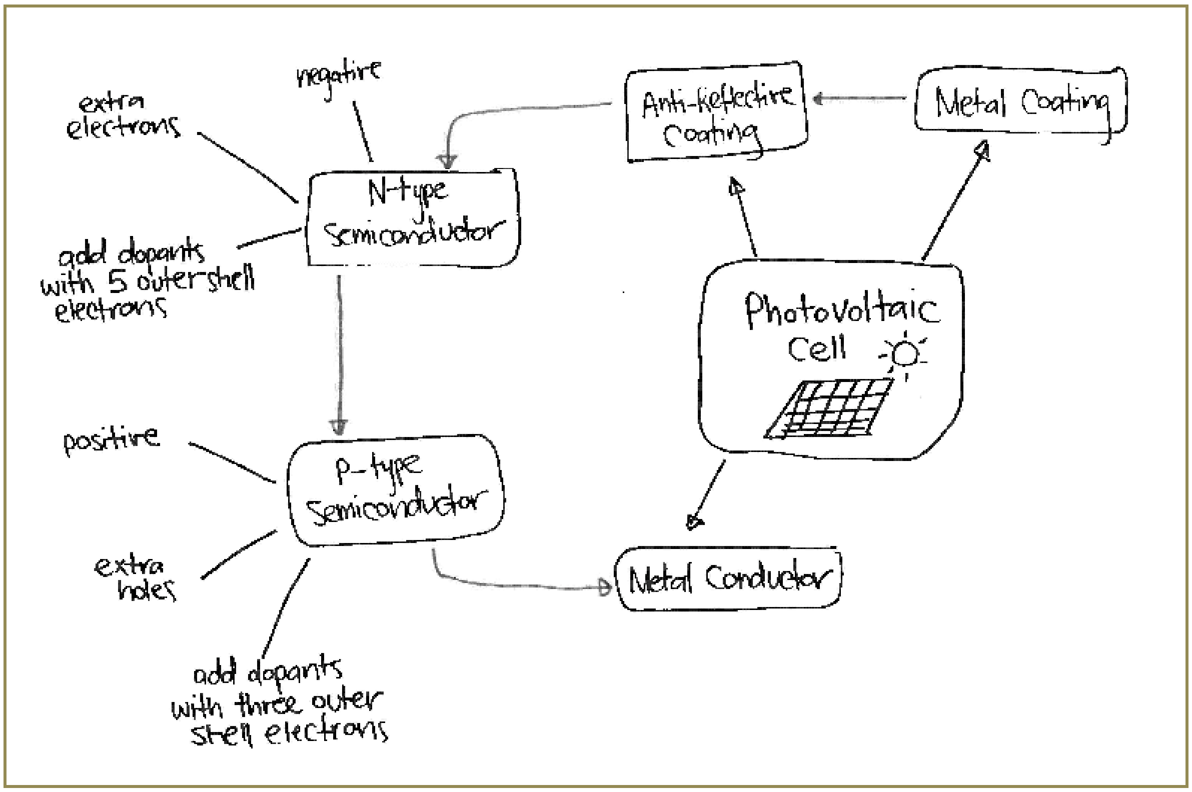
Mind Map Briefing:

Solar (Photovoltaic) Cells are made of many layers of materials. These include: a metal conductor; an anti-reflective coating; an N-type semiconductor; a P-type semiconductor; and a metal conductor.

Create a mind map that shows the role of each layer in creating a solar cell. In your diagram, indicate the interactions between each layer.

Sample Answer:

Key aspects of a mind map are noted here:



3. Short Response Questions

<u>Question 1:</u> Discuss why solar energy still experiences low conversion efficiency. Is this a barrier to a major uptake of solar cells for electricity production?

<u>Sample Answer:</u>

A key reason for relatively low conversion efficiency is that only about 30 percent of the sunlight is absorbed – the remainder is either reflected, passes through, or is stopped by the metal conductor on top of the cell which is in the shape of a grid and so shades a small area of the semiconductor. This is not a permanent barrier to the mainstreaming of solar cells for electricity production, as in summary, solar energy research and development is still in its early days. Already reflected light can already be reduced to less than 5 percent by placing an anti-reflective coating above the semiconductors. Power can also be maximised by using semiconductors that balance both electricity and voltage.

<u>Question 2:</u> Briefly describe key components of the embedded energy 'footprint' of a photovoltaic cell – that is, how much energy is required to manufacture, transport and run the cell over its lifetime.

<u>Sample Answer:</u>

There is no right or wrong answer here – students should be able to demonstrate an appreciation of the aspects of embedded energy, such as sourcing and transporting silicon, the support structure (steel/ aluminium etc) and transporting the finished structure to the buyer. The students may also be asked to comment on how this impacts on the 'sustainability' of current solar PV panels and what should be innovated in this area.

<u>Question 3:</u> Explain the photovoltaic effect. When and how was this discovered and how is it used in the production of electricity from solar cells?

<u>Sample Answer:</u>

The photovoltaic effect is the process by which electric current is generated by exposing the solar cell to sunlight, where photons from sunlight pass through the n-type semiconductor and strike the atoms in the p-type semiconductor near the junction. Photons with energy equal to at least a specific amount, called the band gap, are absorbed by the weakly-bound electrons in the dopants. These electrons now have enough energy to escape the dopants' hold.

Initially, the electrons are attracted to the positive n-type semiconductor but, once in the n-type semiconductor, the electrons encounter atoms that already have stable shells or extra electrons. The electrons are then attracted back to the holes in the p-type semiconductor but are unable to cross the junction due to the electric field's effect described above. Instead, the electrons take the following alternative path through the n-type semiconductor; through the metal conductor on the n-type semiconductor; through the load; through the metal conductor on the p-type semiconductor and finally back into the p-type semiconductor. The flow of electrons is electricity that can be used by the load.

5B: Wind Energy: How do we make Electricity from Wind Turbines?

Educational Aims:

The aim of this lesson is to describe the key components of solar cells and wind turbines. We also consider the processes used by these technologies to generate electricity from the sun's energy.

Alignment with Existing Curriculum Requirements

The activities and information presented in this lesson aligns to the National Curriculum cross curriculum priority 'Sustainability' which is concerned with the ongoing capacity of the Earth to maintain life:[5]

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E1.3	Energy can be described and measured in terms of an object's position and motion within gravitational, electric and magnetic fields.
E2.1	The total amount of energy within a closed system remains constant.
E2.2	Exchanges or transformations of energy do not change the total energy of the closed system
E2.3	When energy is converted from one form to another there is a reduction in the amount of useful energy available to do work
E2.4	The transference of energy between systems can be explained using the laws of thermodynamics

[5] http://www.australiancurriculum.edu.au

[6] http://www.qsa.qld.edu.au/downloads/senior/snr_chemistry_07_syll.pdf

E2.5	The laws of conservation of energy and momentum can be used to examine the interactions between objects in simple and complex situations
E3.1	Energy transformation and associated applications have social and environmental consequences
E3.2	Rational discussion of energy transformations in present day society requires an understanding of the underlying physics concepts and ideas
E3.3	Knowledge of underlying physics concepts and ideas can be used to provide reasoned argument about the viability of alternative energy transformation processes
E3.4	Energy has applications in medical, industrial and commercial fields eg radiation, electronics and alternative technologies
E3.5	Energy in solid state systems (e.g. semiconductors)

Activity 1 – Discussion: Vertical and Horizontal Wind Turbines

In this activity, teachers are able to teach students about the differences between horizontal and vertical wind turbines by creating large scale, labelled diagrams.

Key Learning Point:

There are two main kinds of wind turbines – horizontal and vertical. Both have advantages and disadvantages and can be used in different situations.

Resources:

– Materials (demonstration): a large drawing surface (whiteboard is good, large paper may be better for long lasting diagrams); and a range of colour pens.

Teacher Preparation:

– The teacher and students should have prior knowledge of wind energy, Bernoulli's Law, pressure and energy conversions.

– It would also be helpful (but not essential) for the teacher and students to have a good understanding of generators, gears and gear ratios.

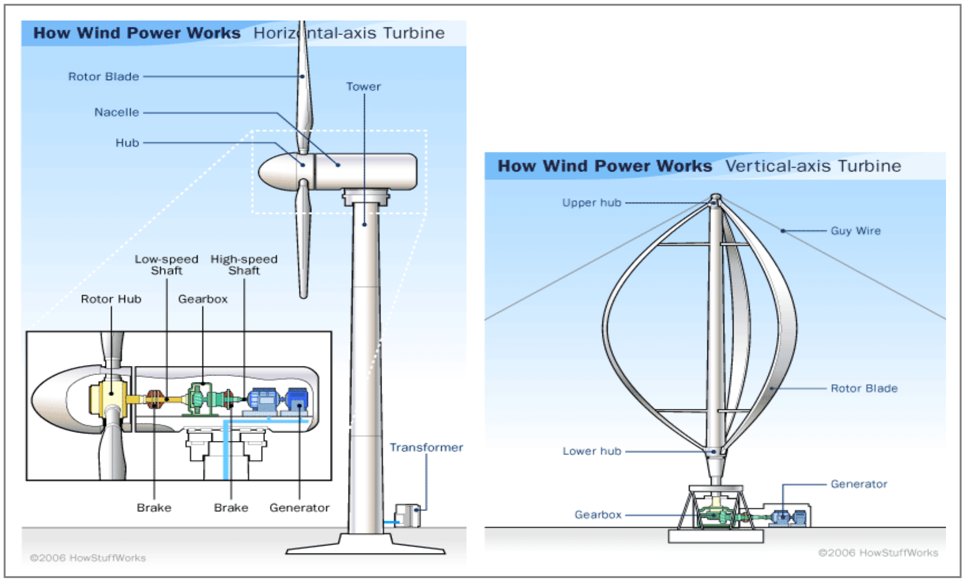
– Teachers may like to use Table 5.1 in the student materials to guide the discussion. A blank version of this table is provided in the student handout following this activity.

Activity Description:

1. Begin the lesson by asking students about their experience with wind turbines:
   a) Have they seen them?
   b) What kinds have they seen?
   c) Where were they placed?
   d) What else do they know about wind turbines?
2. Using Figure 5.8 from the student materials as a guide, draw two large scale wind turbines (i.e. horizontal and vertical) either on a white board or a large piece of paper. Alternatively, bring up a photo or diagram of the two types.
3. Ask students to identify differences between the two types and discuss physical reasons for the differences.

Student Handout – Vertical and Horizontal Wind Turbines

Example of model wind turbines:



(a) (b)

Figure 1. (a) Horizontal-Axis Turbine; and a (b) Vertical-Axis Turbine
Source: Layton, J. (n.d)[7]

As you complete the activity on vertical and horizontal wind turbines in class, keep a record of the differences you identify between the two kinds of wind turbines.

Table 1: Comparison of horizontal-axis wind turbines and vertical-axis wind turbines

Horizontal-axis wind turbines	Vertical-axis wind turbines

[7] Layton, J. (n.d) 'How Wind Power Works', *Howstuffworks*. Available at http://science.howstuffworks.com/wind-power.htm. Accessed 12 November 2007.

Activity 2 – Workshop: Making a Model Wind Turbine

This activity allows students to apply the knowledge they have learnt in the previous lesson or through individual research to make a model (non-working representation) of a vertical axis wind turbine. Students must justify their model and explain why it would be efficient and practical.

Key Learning Point:

Making a model of a wind turbine is an easy way to apply the physical concepts behind a wind turbine without requiring generators and other expensive equipment.

Resources:

- Making a working wind turbine can be a very resource intensive project, requiring generators to convert kinetic energy into electrical energy. Making a model (ie a non-working representation) is a practical way of encouraging students to apply the physical principle they know about wind turbines.
- Materials (for each student): cardboard, balsawood, string, scissors, soft drink bottles, matches or toothpicks etc.
- Alternatively, there are instructions for more detailed working wind turbines at www.instructables.com/id/Model-Wind-Turbine-KidWind-Project/
- Small model turbines can be purchased for demonstration and experiments. For example, one such model is the Model Power 1583 Wind Power Generator W/MOTOR (Building Kit N).

Teacher Preparation

- For this activity, students will need to understand the principles behind modern day wind turbines.
- Students will also need to understand how wind works and how it acts to turn the blades of a wind turbine (see *Lesson 5B: Wind Energy* for more information). They must then represent these concepts by designing and creating a working model of a turbine.

Activity Description:

1. Firstly, instruct students to design a model wind turbine (space for design provided in Student Handout). Their design must include material specification and sizing. Careful attention should be paid to the blade design to optimize the generation of power.
2. Now, ask students to create their designs. Encourage efficient use of materials and careful construction.
3. On a windy day, allow students to test their design, with regard to the workability of the blades.
4. Discuss, using the principles explained in Lesson 5, why some turbines might work better than others.

Student Handout – Making a Model Wind Turbine

Figure 1: An example of a model wind turbine[8]

A good design begins with a plan. Using your knowledge of current wind turbines and the physics of wind, create a design of a wind turbine below. Make sure you specify dimensions and materials. Remember, the best designs make good use of physics and are efficient with materials.

After you have tested and constructed your design, review it.

What worked well? What didn't work well? What should you have considered?

[8] http://www.ehow.com/how_5035549_make-easy-model-wind-turbine.html

Summary Activities and Homework Ideas

1. Essay

This essay question provides students with an opportunity to consider the major components of wind as a source of potential energy. In answering the questions posed below, students will be tested on their appreciation of the components of wind generation, and their ability to write a well-structured essay within the word limit set by the teacher.

Essay Statement:

An understanding of the physical principles behind wind helps to create better and more efficient wind turbines. Write an essay on the formation of wind. Remember to briefly explain any gas laws and energy relationships you use.

Sample Answer

The students' essays may include the following key points to discuss the process of Wind Formation:

- sun's heat energy is absorbed by land
  - radiation
  - solar absorption
  - heat
- land radiates heat into the atmosphere
  - radiation
  - physical properties of the earth
- hotter air rises while cooler air sinks
  - gas laws
  - fluid properties
  - molecular energy

2. Mind Map

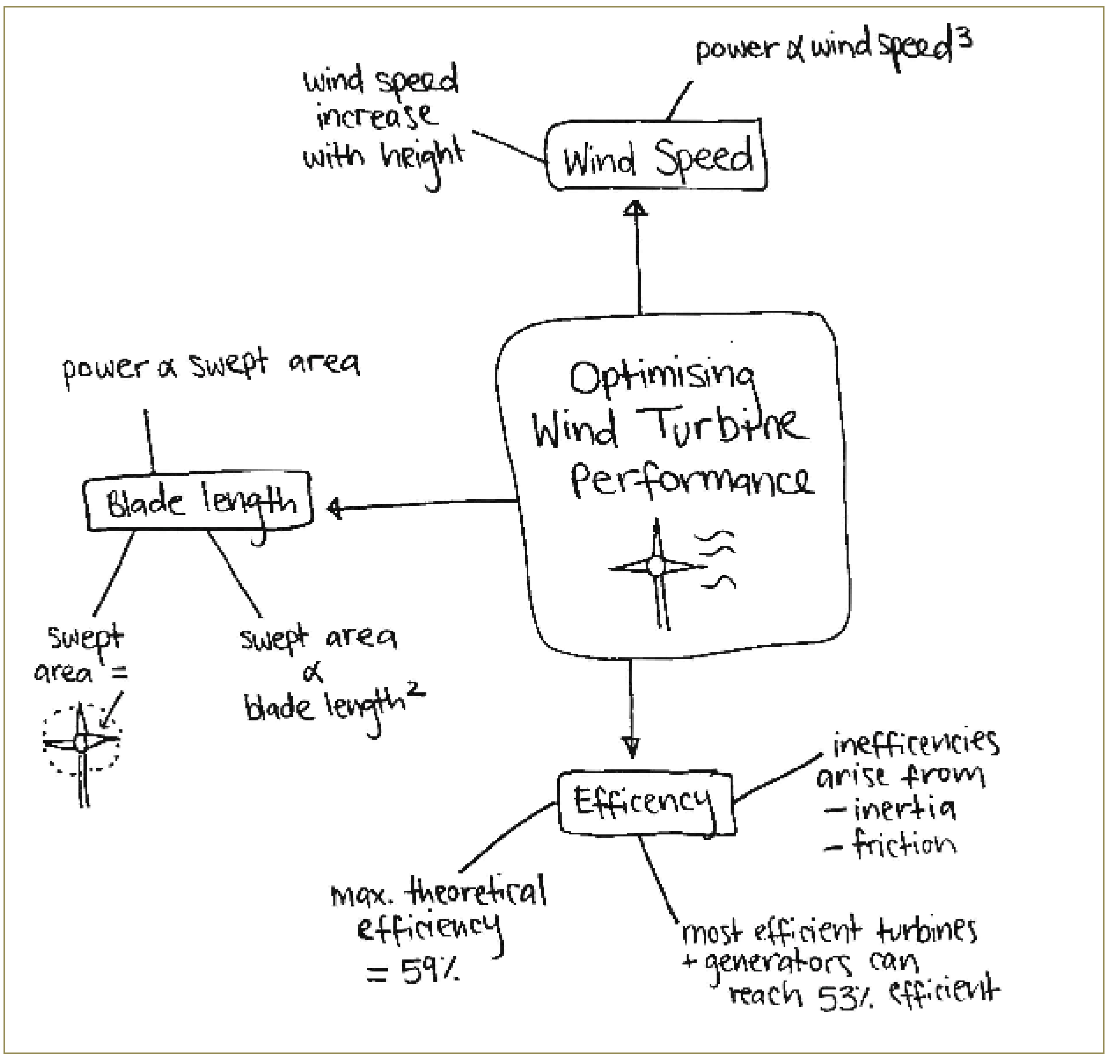
This mind map exercise encourages students to recall the components of a wind turbine, and the interconnections. In creating the mind map, students will be demonstrating their knowledge of the components, and their appreciation of their interconnectedness. This exercise could be undertaken individually or in a group.

Mind Map Briefing:

There are various way to improve, if not optimise wind turbine performance. Make a mind map of the various ways to achieve optimal performance. Include the fundamental physical concepts behind each method.

Sample Answer:

Key aspects of a mind map are noted here:



3. Short Response Questions

<u>Question 1:</u> What role does a gearbox play in a wind turbine?

<u>Sample Answer:</u>

The rotating blades cause the turbine shaft in the wind turbine to rotate with a rotational velocity of about 10-60 revolutions per minute, however, the electric generator requires a rotational velocity of about 1200-1800 revolutions per minute. The rotational velocity is increased by gearing up with a gearbox and a second shaft.

<u>Question 2:</u> Where are wind turbines most useful? Can wind turbines be used as the sole power source? In your response, use the following terms: base load power, peak power.

<u>Sample Answer:</u>

Wind turbines are most useful where there is a relatively constant and predictable supply of wind energy that approximately matches the demand for energy by the consumer.

Wind power can be used as the sole power source, when the consumer base demand for power (i.e. 'base load power') and the peak demand for power each day matches the constant supply of wind and the peak windy times during the day. Alternatively, turbines can also be used as a sole power source if it is attached to a battery that can store the generated energy. Such technology is rapidly becoming more of a reality for consumers.

<u>Question 3:</u> Why are wind farms often controversial? Describe two ways that these issues have been addressed over the last couple of decades.

<u>Sample Answer:</u>

Reasons for previous controversy are summarised below, together with innovations that have sought to address this:

- 'Wind turbines are unsightly': The evolution of wind turbines has resulted in more streamlined blades and towers, reducing the impact on the visual amenity.
- 'Wind turbines are noisy': Wind turbine technology innovations have also resulted in substantially more quite operations.
- 'Wind turbines will kill wildlife': A number of innovations have been developed in blade technology, form and with the height and positioning of the towers, such that bird kill has been substantially addressed.
- 'Wind turbines are erratic energy providers': As demonstrated in Lesson 5B, this is simply no longer the case, with many efficiency and storage innovations that make wind energy a viable mainstream form of electricity provision.

6. Steam: How do we make Electricity from Steam?

Educational Aims:

The aim of this lesson is to describe the key components of steam turbines and electric generators. We also consider the processes used by these technologies to generate electricity from steam.

Alignment with Existing Curriculum Requirements

The activities and information presented in this lesson aligns to the National Curriculum cross curriculum priority 'Sustainability' which is concerned with the ongoing capacity of the Earth to maintain life:[9]

Actions to improve sustainability aim to reduce our ecological footprint while simultaneously supporting a quality of life that is valued—the 'liveability' of our society. Sustainable patterns of living meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability is both an individual and a collective endeavour often shared across communities and nations necessitating a balanced but different approach to the ways humans have interacted with each other and with their biophysical environment. Sustainability learning draws on and relates learning across the curriculum. It leads to students developing an overall capacity to contribute to a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations.

These activities can be aligned to the Queensland Studies Authority (QSA) Senior School Syllabus for Physics. Specifically, the activities and information presented in this manual align to the following parts of the Physics Senior Syllabus:[10]

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E1.1	Energy is the capacity to do work.
E1.2	Energy manifests itself in various forms, including: potential energy associated with gravitational, electric and magnetic fields; kinetic energy related to the motion of matter; and nuclear energy, which links to the concept of mass–energy equivalence.
E1.3	Energy can be described and measured in terms of an object's position and motion within gravitational, electric and magnetic fields.
E2.1	The total amount of energy within a closed system remains constant.
E2.2	Exchanges or transformations of energy do not change the total energy of the closed system
E2.3	When energy is converted from one form to another there is a reduction in the amount of useful energy available to do work
E2.4	The transference of energy between systems can be explained using the laws of thermodynamics

[9] http://www.australiancurriculum.edu.au

[10] http://www.qsa.qld.edu.au/downloads/senior/snr_chemistry_07_syll.pdf

E2.5	The laws of conservation of energy and momentum can be used to examine the interactions between objects in simple and complex situations
E3.1	Energy transformation and associated applications have social and environmental consequences
E3.2	Rational discussion of energy transformations in present day society requires an understanding of the underlying physics concepts and ideas
E3.3	Knowledge of underlying physics concepts and ideas can be used to provide reasoned argument about the viability of alternative energy transformation processes
E3.4	Energy has applications in medical, industrial and commercial fields eg radiation, electronics and alternative technologies
E3.5	Energy in solid state systems (e.g. semiconductors)

Activity 1 – Discussion: Rewriting the Generator

In this activity, students will use their existing knowledge of generators to fill in missing pages of a generator manual. Guidance is given via a contents page. The student handout provides an example format for this activity.

Key Learning Point:

Generators are a vital component of electricity generation and convert kinetic energy into electricity, which is able to be easily moved and stored.

Resources:

- Copies of student handout (1 per student)
- Class time

Teacher Preparation:

- To complete this activity, students will require a fairly thorough knowledge of generators.
- For information to teach students about generators, refer to *Lesson 6: Steam.*

Activity Description:

1. Ask students to review Lesson 6 key learning points and background information.
2. After briefly discussing the topics of generators and electromagnetic induction, distribute copies of the student handout.
3. Provide students with time to fill out the handout.
4. Use the answers given in Lesson 6 to work through the headings as a class.

Student Handout – Rewriting the Generator

You are the head electrical engineer at a remote steam power plant. Your apprentice has just informed you that the manual for the generator was caught in a leak of steam and is badly water damaged. Only the contents page remains and you have a training session today with a new recruit!

Luckily, you have just completed a course in generator operation and feel that you will be able to explain it to the new recruit without too much trouble!

The salvaged contents page is given below. Using the headings, try to construct the manual.

Contents Page

Activity 2 – Demonstration: Steam Generation

This activity is an easy practical demonstration of two of the main processes involved in steam generation – firstly, the conversion of water to high pressure steam and secondly, using steam to rotate a turbine shaft (the third step is converting the kinetic energy to electrical energy, achieved with a generator, which was studied in the previous experiment).

Key Learning Point:

Making electricity from steam is three step process, firstly, the conversion of water to high pressure steam, secondly, using steam to rotate a turbine shaft and thirdly, converting the kinetic energy to electrical energy, achieved with a generator.

Resources:

- Materials: a portable hotplate; a saucepan; an aluminium pan that fits snugly over the saucepan; a plastic funnel; an oven mitt; and a toy pin wheel, available from dollar stores

Teacher Preparation:

- This demonstration could be performed as part of a general introduction to steam turbines.
- Caution! Steam can cause severe burns! Always wear the oven mitt and ensure students do not come too close.

Activity Description:

1. Take the aluminium pan and cut a strip out of the wall, the same width as the saucepan's handle.
2. Cut a hole in the centre of the base, ensuring it is smaller than the funnel opening.
3. Fill the saucepan with water and set it on the hotplate. Fit the aluminium pan over the top and place the funnel, top down, over the hole in the pan, as seen in this sketch:
4. Turn on the hotplate and wait for the water to boil.

5. When the water is boiling and steam is coming out of the top, put on the over mitt and hole the pin wheel horizontally over the steam. The pinwheel should rotate!
6. Make reference to the way this model demonstrates some key steps in steam electricity generation:
   - The hotplate and saucepan of water represents the conversion of water to steam;
   - the funnel restricts the volume of the steam and causes the pressure to rise (the Venturi effect).
   - The resulting high pressure steam turns the pinwheel, representing the rotation of a turbine shaft in a real steam generator.

Summary Activities and Homework Ideas

1. Essay

This essay question provides students with an opportunity to consider the major components of steam generation as a source of potential energy. In answering the questions posed below, students will be tested on their appreciation of the components of steam generation, and their ability to write a well-structured essay within the word limit set by the teacher.

Essay Statement:

Steam electricity generation is often used as part of a coal fired power plant, where the heat from burning coal is used to turn water to steam. How else can we turn water to steam?

Research and write an essay explaining how Australia could use steam generation and renewable energy sources to contribute to coal fired electricity generation. Identify the source of energy and the practicality of obtaining this energy.

Sample Answer

For example, in geothermal energy, students may mention the following:

- Geothermal energy is the heat energy in the ground near the earth's core
- Exploration of geothermal finding blocks of underground radioactive hot rock with fractures through which water can pass.
- This water would be injected, heated and returned to the surface to rotate a turbine shaft as steam.
- South Australia has huge amounts of these 'hot rocks'.

2. Mind Map

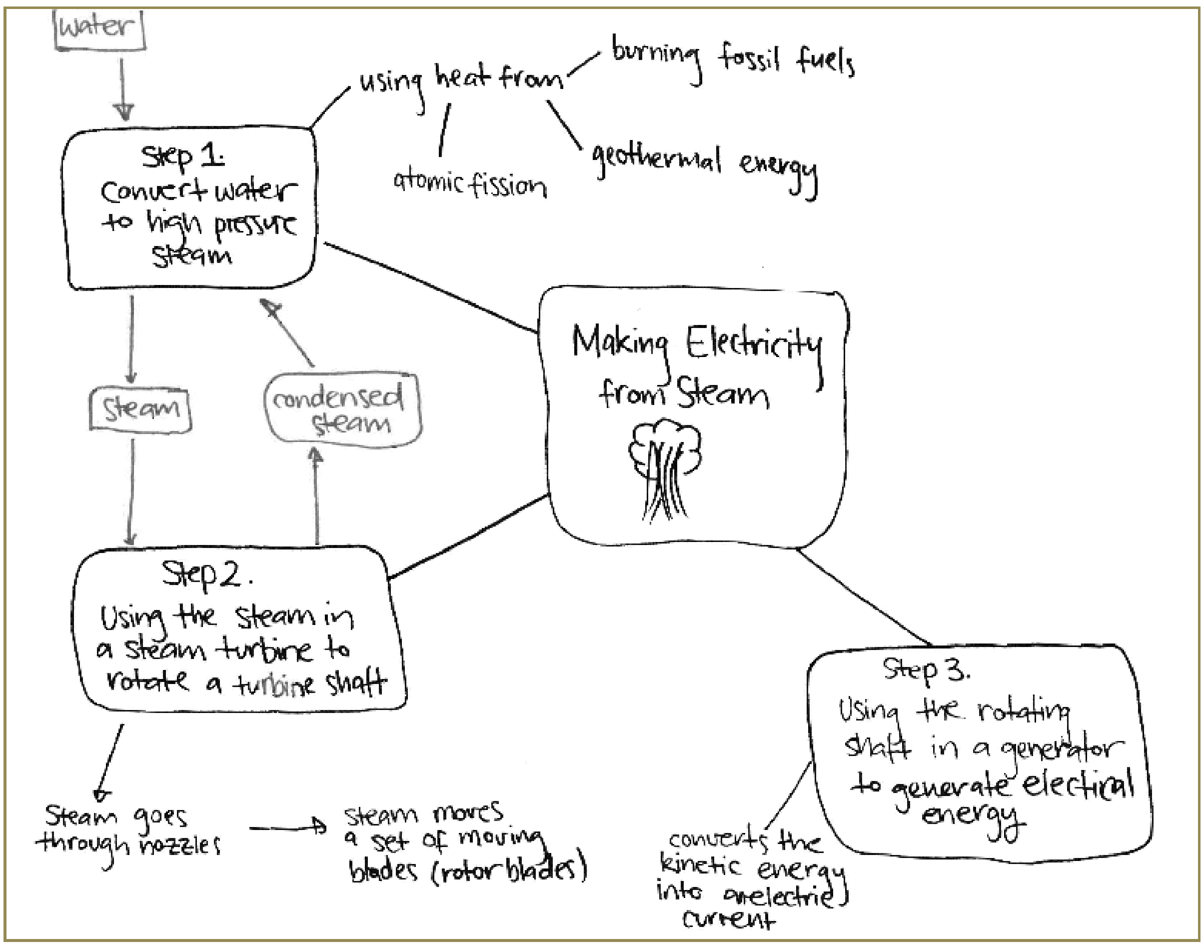
This mind map exercise encourages students to recall the components of steam generation, and the interconnections. In creating the mind map, students will be demonstrating their knowledge of the components, and their appreciation of their interconnectedness. This exercise could be undertaken individually or in a group.

Mind Map Briefing:

Create a mind map that shows the key steps in steam electricity generation. In each step of the process, identify the forms of energy involved. Also, map the path of the water throughout the process, indicating where it is able to be recycled.

Sample Response

Key aspects of a mind map are noted here:



3. Short Response Questions

Question 1: What is the difference between an Impulse Turbine and a Reaction Turbine?

Sample Answer:

The energy conversion as the steam flows through the blades depends on whether the turbine is an *impulse* turbine or a *reaction* turbine. The difference between these two types of turbines lies in their blade configurations:

- In an *impulse turbine*, the force that moves the blades is a result of the steam striking the blades. This force is known as an *impulse*. As the steam passes through the nozzle, all of its pressure potential energy is converted to linear kinetic energy. Then as the steam passes through the rotor blades, all of its linear kinetic energy is converted to rotational kinetic energy.
- In a *reaction turbine*, the force that moves the blades is a result of the blades changing the direction of the steam's flow. This force is known as a *reaction force*. As the steam passes through the nozzle, some of its pressure potential energy is converted to linear kinetic energy. Then as the steam passes through the rotor blades, all of its remaining pressure potential energy and all of its linear kinetic energy is converted to rotational kinetic energy.

Question 2: What are the sources of steam for a steam powered turbine? Why can steam electricity sometimes be considered a renewable energy source and sometimes not?

Sample Answer:

Three main sources of steam include:

- A *boiler*, which creates heat energy by burning fuels such as coal, oil, natural gas, wood or municipal waste;
- *Geothermal energy*, which is the heat energy in the ground near the Earth's core; and
- Atomic fission, which creates heat energy by splitting large atoms in to smaller atoms.

Through these examples it can be seen that atomic fission is not a renewable source. Geothermal is less clear, depending on whether the rocks from where the heat is being captured will eventually cool down, and at what rate. With regard to the boiler example, the 'sustainability' of this source of generated steam will depend on the source fuel, and the larger context of whether there are other reasons to be burning the fuels (i.e. where steam may be a beneficial by-product of another process.

Question 3: What is the physical principle underlying electric generators?

Sample Answer:

An electric generator works under the principle of electromagnetic induction, which means that if an electrical conductor, such as a wire, is moved through a magnetic field, then an electric current will be generated in the conductor.

7: Flowing Water: How do we make Electricity from Flowing Water?

Educational Aims:

The aim of this lesson is to describe the key components of hydroelectric power plants and ocean power plants. We also consider the processes used by these technologies to generate electricity from flowing water.

Alignment with Existing Curriculum Requirements

The activities and information presented in this lesson aligns to the National Curriculum cross curriculum priority 'Sustainability' which is concerned with the ongoing capacity of the Earth to maintain life:[11]

Actions to improve sustainability aim to reduce our ecological footprint while simultaneously supporting a quality of life that is valued—the 'liveability' of our society. Sustainable patterns of living meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability is both an individual and a collective endeavour often shared across communities and nations necessitating a balanced but different approach to the ways humans have interacted with each other and with their biophysical environment. Sustainability learning draws on and relates learning across the curriculum. It leads to students developing an overall capacity to contribute to a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations.

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[11] http://www.australiancurriculum.edu.au

[12] http://www.qsa.qld.edu.au/downloads/senior/snr_chemistry_07_syll.pdf

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Activity 1 – Discussion: Using Waterways for Energy

In this activity, students participate in a class discussion, following the structure below. They will use and share their prior knowledge of water and the power it creates to lead into learning about electricity from water.

Key Learning Point:

Water has a lot of stored energy. We can harness this energy to turn turbine shafts (making mechanical energy) which can be converted into electricity.

Teacher Preparation:

- The teacher may wish to study the student materials for 'Lesson 7: Flowing Water'.
- This lesson is intended as an introduction to the energy in water. As points are raised about various sources of water, encourage consideration of the forms of energy in the water and how this can be converted into useful electrical energy.

Activity Description:

Structure this discussion by asking the following questions (notes in italics):

1. How does water come to contain energy?

   Water has energy from the hydrological cycle, which gains energy from the sun. The sun warms water, causing evaporation and currents. Tides are formed by the movement of the moon around the earth

2. What forms of water have a lot of energy?

   The ocean (waves and tides). Rivers (waterfalls and rapids). Snow (avalaches, snowmelt). High pressure hoses.

3. How do you know there is energy in water?

   B*y feeling it (getting knocked over by waves at the beach, standing under a waterfall). By hearing it (roar of waves, rumble of an avalanche). By seeing it (movements, waves, turbulence)*

4. What kinds of energy are in these water forms?

   Kinetic – fast moving waves, rivers. Gravitational Potential – water at the top of a waterfall, snow on mountains. Sound – ocean, waterfalls

5. How can we harness this energy?

   Changing the water path – eg with dams and rivers to control the energy. Restricting the volume of the water – forcing it through tunnels and pipes.

6. How do we generate electricity from water?

   We need water turbines to convert water flow to mechanical rotation. The water rotates blades which converts the kinetic energy in water to rotational kinetic energy. There are various kinds of turbines, such as impulse or reaction turbines (see Lesson 7 for more details).

Activity 2 – Experiment: The Force of Water

This activity is an easy practical demonstration of the hydrostatic concept of 'head' or the energy associated with a certain water depth. This activity has been adapted from Energy Quest[13]

Key Learning Point:

The energy in water is related to the amount of water above it. Understanding the reasons why sources of water contains energy helps us to capture and convert the energy into useful electricity.

Resources:

- Materials (per group): 1 litre cardboard milk carton (empty and washed out); tap access; a single hole hole-punch or large, sharp nail; masking tape; a ruler; a whiteboard marker; and a pair of scissors.

Teacher Preparation:

- This activity is a general introduction to the concept of hydrostatic pressure. This is an important part of the hydroelectric power plant configuration. This experiment could be taught as part of an energy conversion lesson, demonstrating how hydrostatic pressure can be converted into kinetic energy.
- The experiment can be performed as a group demonstration or in small groups of students.

Activity Description:

1. Work through the construction of the device (as listed in the student handout)
2. As the student groups to consider the following questions:

   a) How far away did the streams of water fall from the carton?

   b) Was there a difference between the stream from the water from hole the bottom than at the top?

Sample Explanation

Water has weight. The closer to the bottom of the carton, the more water is above and the more weight is pressing down from above. The more weight, the more water pressure, and the more water pressure, the further away the stream will go and the faster it will go.

Hydroelectric facilities are built at the base of dams to take advantage of the high pressure of the water at the bottom of a reservoir. The water pressure is funnelled through a tunnel through the dam called a penstock. The water then is focussed on the blades of a turbine. Water pressure of the water turns the turbine, and the turbine turns a generator making electricity.

[13] Californian Energy Commission, 2010, http://www.energyquest.ca.gov/projects/index.html#hydro accessed 22 Dec 2010

Student Handout – The Force of Water

In this activity, you will build a device to investigate how hydroelectric facilities use the stored energy in bodies of water.

Materials:

1 litre cardboard milk carton (empty and washed out); tap access; a single hole hole-punch or large, sharp nail; masking tape; a ruler; a whiteboard marker; and a pair of scissors.

Steps:

1. Remove the top of the milk carton.
2. Measure 3cm from the bottom of the milk carton, and using the hole punch or the nail, punch a hole in the centre of the carton. Measure 6cm and punch another hole in the centre.
3. Measure 12cm up from the bottom and punch a third hole directly above the other two.
4. Measure 15cm up from the bottom and punch a final whole in the centre. Note that all holes must be the same size.
5. Take a long piece of tape and tape up all four of the holes.
6. Mark a line on the carton near the top - always refill the carton to this line.
7. Fill the carton and put it on the edge of the sink with the side with holes. Quickly remove the tape that is covering all four holes. Watch what happens. Measure how far away each of the streams hits the sink.
8. Let all the water empty out. Watch what happens as the water level drops. What happens to the streams of water?
9. Now tape up all holes. Put the carton back on the sink edge. Refill the carton and remove the bottom tape. Measure how far out the stream goes.
10. Retape the hole, and untape the next hole up; measure how far away the stream goes.
11. Retape the second hole and refill the carton with water. Then, untape the third hole; measure how far away the stream goes.
12. Retape the third hole and refill the carton with water to the same level as before. Then, untape the fourth hole; measure how far away the stream goes.

Inquiry Questions

How far away did the streams of water fall from the carton?

Was there a difference between the stream from the water from hole the bottom than at the top?

How can we use this energy to generate electricity?

Summary Activities and Homework Ideas

1. Essay

This essay question provides students with an opportunity to consider the major components of energy generation from flowing water. In answering the questions posed below, students will be tested on their appreciation of the components of using flowing water to generate energy, and their ability to write a well-structured essay within the word limit set by the teacher.

Essay Statement:

In class, we performed experiments that showed how water sources such as rivers and dams can be used to create electricity. Oceans (their currents and tides) are another source of energy. Write an essay:

- describing an experience you have had with the ocean's energy; and
- detailing some of your research into how scientists and engineers have managed to capture this energy.

Sample Response:

Student experiences may include:

- beach events such as freak waves, tsunamis and king tides
- tidal effects such as currents and rips
- flooding due to high tides combining with flood waters

Capturing this energy may be achieved by:

- Tidal power systems: a barrier that stretches across the estuary between a river and the ocean. A turbine is powered by the water flow or ebb that occurs with the change in tides
- Current power systems: tidals fences or mills use a fence like structure across a region of high current. The fence has several vertical axis turbine blades that are rotated by the current.
- Wave power systems: There are two general types of wave power systems: fixed and floating.

2. Mind Map

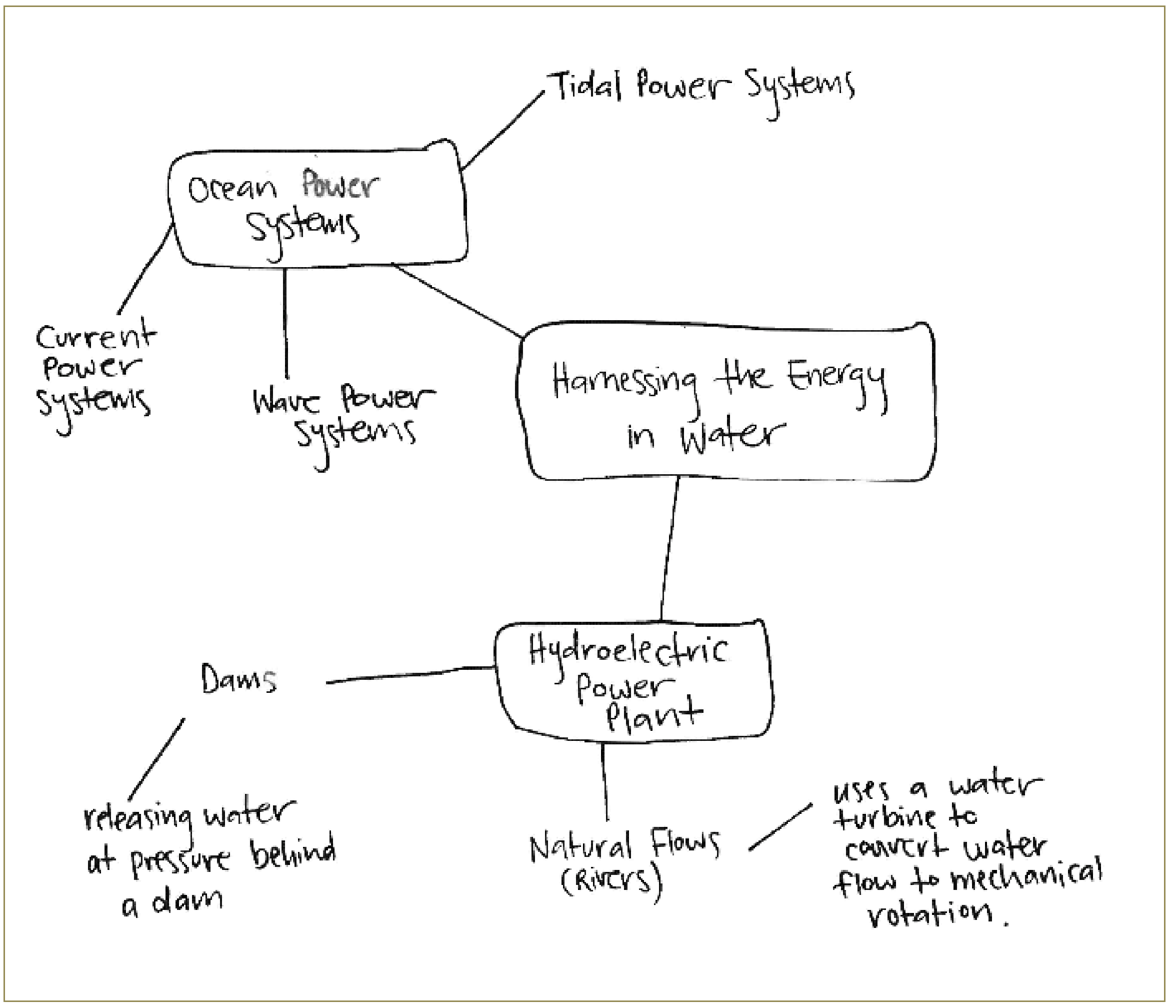
This mind map exercise encourages students to recall the components of steam generation, and the interconnections. In creating the mind map, students will be demonstrating their knowledge of the components, and their appreciation of their interconnectedness. This exercise could be undertaken individually or in a group.

Mind Map Briefing:

There are many different ways of harnessing the energy of water. Research some of the many kinds of hydroelectric schemes around the world. Arrange them into a mind map. Perhaps you could classify them based on the source of the water (ocean waves, ocean currents, rivers, dams, snow) or turbine and generator type.

Sample Answer:

Key aspects of a mind map are noted here:



3. Short Response Questions

Question 1: Describe how a hydroelectric power plant generates power.

Sample Answer:

Hydroelectric power plants generate electricity using the energy from flowing water, called ‘linear kinetic energy’, and energy from pressure, called ‘pressure potential energy’:

- The water flow may be natural in an existing waterway, created by what we refer to as a ‘Water Cycle’, or ‘Hydrologic Cycle’, driven by the Sun’s energy.
- The water flow may be created by releasing from water at pressure behind a dam. Dam walls are essentially barricades in waterways that slow or stop the water flow so that the water accumulates behind it, in a reservoir. Water flow is created by releasing water from the reservoir to a waterway, ocean or to another lower reservoir.

Question 2: List two environmental considerations need to be made when looking at the viability of introducing a hydroelectric water scheme?

Sample Answer:

These include environmental considerations with regard to any potential areas to be dammed or contained as part of the project and their environmental significance with regard to biodiversity and carbon capture, the greenhouse gases associated with construction and operation of the facility.

These include social considerations with regard to the potential occupation of the proposed area by communities, and a variety of impacts of their relocation.

These include economic considerations with regard to the economic cost of construction and maintenance of such a facility, and the alternative value of the area for other activities such as farming, sustainable forestry, tourism etc.

Question 3: What is the difference between an impulse and a reaction turbine?

Sample Answer:

A water turbines’ power output depends on two main factors: the energy of the water flow and the volume of water. Impulse turbines are typically used where the energy of the water flow is high and the volume of water is moderate to low. Reaction turbines are typically used where the energy of the water flow is moderate to low and the volume of water is high.

8: Fuel Cells: How do we make Electricity from Gas?

Educational Aims:

The aim of this lesson is to describe the key components of fuel cell systems and the process that fuel cell systems use to generate electricity from gas without combustion.

Alignment with Existing Curriculum Requirements

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E2.3	When energy is converted from one form to another there is a reduction in the amount of useful energy available to do work
E2.4	The transference of energy between systems can be explained using the laws of thermodynamics
E2.5	The laws of conservation of energy and momentum can be used to examine the interactions

[14] http://www.australiancurriculum.edu.au

[15] http://www.qsa.qld.edu.au/downloads/senior/snr_chemistry_07_syll.pdf

	between objects in simple and complex situations
E3.1	Energy transformation and associated applications have social and environmental consequences
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Activity 1 – Experiment: Splitting Hydrogen

In this activity, students learn about the process of electrolysis and will be able to split hydrogen and oxygen using pencils, a battery and a beaker of water. This activity has been adapted from Energy Quest.[16]

Key Learning Point:

Most fuel cells use hydrogen as a fuel. Hydrogen makes up 90% of the universe however it is usually bound with other atoms in a molecule so fuel processing is required. Electrolysis is one possible fuel processing technique.

Resources:

- Materials: A 9 volt battery; two regular number 2 pencils (remove eraser and metal part on the ends); salt; thin cardboard; electrical wire; a small glass; and tap water.

Teacher Preparation:

- Students should also be familiar with the terms anode, cathode, electrolyte and catalyst before performing this simple experiment.
- Students should understand that hydrogen rarely exists alone and is usually bound with other atoms in a molecule. Explain that electrolysis is a fuel processing technique that is generally used in regenerative fuel cells.

Activity Description:

1. Sharpen each pencil at both ends. Cut the cardboard into a strip slightly longer than the diameter of the glass. Push the two pencils into the cardboard, about 3cm apart.
2. Dissolve about a teaspoon of salt into the warm water and let sit for a while. The salt acts as a catalyst helps conduct the electricity better in the water.
3. Using one piece of the electrical wire, connect one end on the positive side of the battery and the other to the black graphite (the "lead" of the pencil) at the top of the sharpened pencil. Do the same for the negative side connecting it to the second pencil top.
4. Place the other two ends of the pencil into the salted water, as shown in Figure 1, and observe what happens

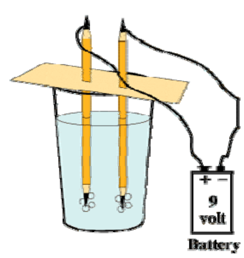


Figure 1. Diagram of the electrolysis set up[17]

[16] Californian Energy Commission, 2010, http://www.energyquest.ca.gov/projects/index.html#hydro

Explanation for the class:[18]

As the electricity from the battery passes through and between the electrodes (the pencils), the water splits into hydrogen and chlorine gas, which collect as very tiny bubbles around each pencil tip. Hydrogen collects around the cathode and the chlorine gas collects around the anode.

How can you get chlorine from H_2O? Good question! Sometimes in experiments, a secondary reaction takes place. This is what happens in this experiment. Oxygen is not given off in this experiment. That's because the oxygen atoms from the water combine in the liquid with the salt to form hydroxyl ions. Salt's chemical formula is NaCl - sodium chloride. The chlorine gas is from the chloride in the salt. The oxygen in the hydroxl ions stay in the solution. So, what is released in this reaction is not oxygen but is chlorine gas that collects around the pencil tip. Around the other pencil is hydrogen gas.

In real electrolysis systems, a different solution is used, and higher levels of electricity help to split the water molecules into hydrogen and oxygen without this secondary reaction.

[17] Californian Energy Commission, 2010, http://www.energyquest.ca.gov/projects/split_h2o.html

[18] Californian Energy Commission, 2010, http://www.energyquest.ca.gov/projects/index.html#hydro

Activity 2 – Multi-media: 'Fuelm' Clips!

This activity requires students to apply their knowledge of fuels cells to creating a short film clip on a certain type of fuel cell.

Key Learning Point

There are six main types of fuel cells. The main difference between them is the type of electrolyte used.

Resources:

– Each group will need access to a recording device, which may be as simple as a mobile phone camera, a digital camera, or a video camera.

– Students may get examples for their project by viewing online examples.

– Brief Background Information, Lesson 7 'Electricity from Gas'

Teacher Preparation:

Students should understand the theory behind fuel cells, such as fuel processors, anodes, cathodes, electrolytes and catalysts. They should also know that there are various kinds of fuel cells.

Activity Description:

1. Create groups of 2-3 students.
2. Distribute copies of the student handout or write up the six different kinds of fuels cells on the board.
3. Explain to students that in teams they are to create a short 2 minute film clip detailing the important characteristics of one of the six fuel cells (this could be allocated by the teacher):

   1. Alkaline fuel cell (AFC); 2.Proton exchange membrane fuel cell or polymer electrolyte membrane fuel cell (PEMFC); 3.Direct alcohol fuel cell (DAFC), also known as direct methanol (DMFC) or direct ethanol (DEFC) fuel cell, depending on the fuel used; 4.Phosphoric acid fuel cell (PAFC); 5.Molten carbonate fuel cell (MCFC); and 6.Solid oxide fuel cell (SOFC).

4. Ask the students to include the following information in their clip:
   – Electrolyte
   – Anode Reaction
   – Cathode Reaction
   – Overall Reaction
   – Temperature (if applicable)
   – Efficiency
   – Application
5. As a class, watch the clips and then discuss the presentations with regard to each of the six fuel cells.

Summary Activities and Homework Ideas

1. Essay

This essay question provides students with an opportunity to consider the major components of energy generation from gas, namely hydrogen. In answering the questions posed below, students will be tested on their appreciation of the components of using hydrogen fuel cells to generate energy, and their ability to write a well-structured essay within the word limit set by the teacher.

Essay Statement:

Hydrogen fuel cells have many potential uses such as transport (cars, buses, trains, planes and boats), off-grid power supply, emergency power supply and long term charging for notebook computers and smart phones.

Write an essay explaining how hydrogen fuel cells could be used in one of the above technologies. You should include current fuel technologies, costs to upgrade, barriers to implementation and benefits.

Sample Answer

For the example of hydrogen cars, the student response may include the following:

- Hydrogen fuel cells in cars could replace traditional combustion engines, which emit dangerous levels of greenhouse gases and use non-renewable fuels.
- Fuel cell vehicles run on hydrogen gas rather than gasoline and emit no tailpipe emissions.
- These vehicles are in the early stages of development, and several challenges must be overcome before these vehicles will be competitive with conventional vehicles. However, the potential benefits of this technology are substantial.
- Costs include research and development into hydrogen cars, retrofitting fueling stations, upgrading technologies and disposal of existing vehicles.

2. Mind Map

This mind map exercise encourages students to recall the components of gas energy generation, and the interconnections. In creating the mind map, students will be demonstrating their knowledge of the components, and their appreciation of their interconnectedness. This exercise could be undertaken individually or in a group.

Mind Map Briefing:

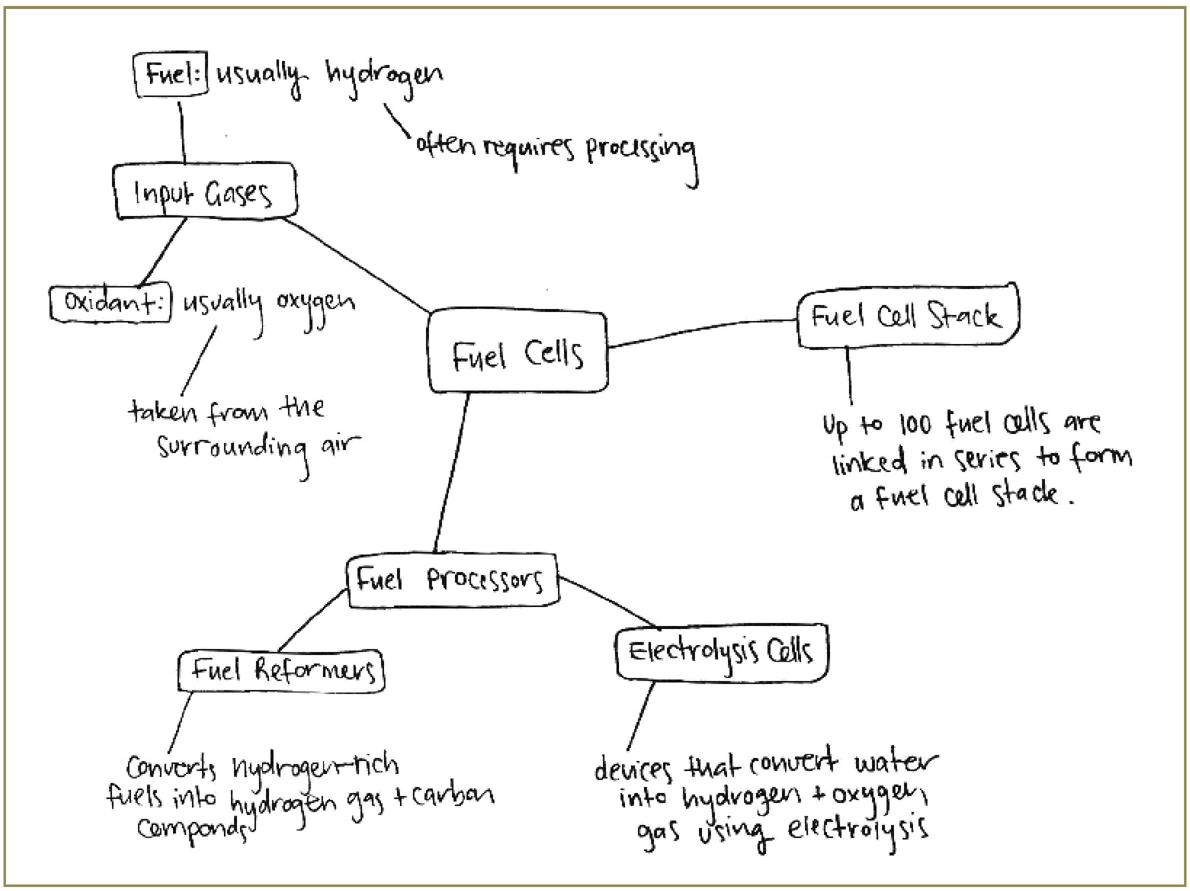
Fuel cells are devices that convert gases into electricity without combustion. They generally comprise of three main components:

- Input gases: a fuel and an oxidant
- A fuel processor
- A fuel cell stack

Create a mind map (including diagrams) that details the physical processes involved in each step of the device.

Sample Answer:

Key aspects of a mind map are noted here:



3. Short Response Questions

Question 1: Briefly describe a typical fuel cell system.

Sample Answer:

Fuel cells are devices that convert gases into electricity without combustion. They generally comprise of three main components.

- Input gases: a fuel and an oxidant
- A fuel processor
- A fuel cell stack

Question 2: Why is a catalyst so important in fuel cell production?

Sample Answer:

In a typical fuel cell, hydrogen fuel or hydrogen-rich fuel and oxygen oxidant are combined in the presence of a catalyst to generate electricity, heat and pure water vapour via a particular type of electrochemical process called an oxidation-reduction reaction. An oxidation-reduction reaction involves an oxidation half-reaction at the anode and reaction half-reaction at the cathode, and the specific half-reactions vary between the types of fuel cells.

Question 3: What role does electrolysis cells play in sustainable fuel cell technology?

Sample Answer:

Electrolysis cells are devices that convert water into hydrogen gas and oxygen gas using a process called electrolysis. Electrolysis is the reverse of the process that fuel cells use. In conventional electrolysis cells, the chemical potential energy in the resulting hydrogen gas is 50-70 percent of the electrical energy applied.

Of course, there is no extra energy value in using conventionally-generated electricity to create hydrogen and then reversing the process to use that hydrogen to generate the same quantity of electricity! However, there is an application for this arrangement in regenerative fuel cells. Regenerative fuel cells are valuable when electricity is required for 24 hours per day but only available for part of the day. For example, in remote areas where only solar-generated electricity is available, electrolysis can be used to create hydrogen gas and oxygen gas during the day and a fuel cell can be used to generate electricity at night.