TEACHER BOOKLET

STELR

RENEWABLE ENERGY

TEACHER RESOURCE


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STELR

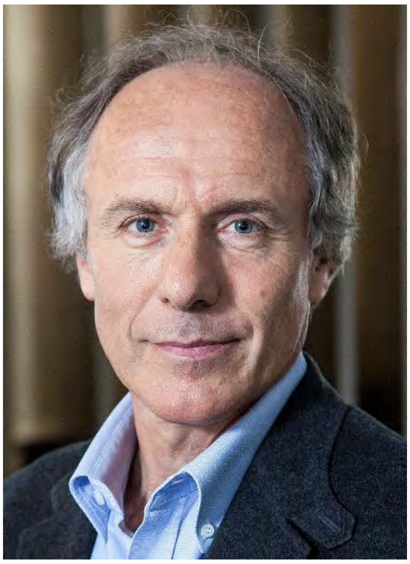
RENEWABLE ENERGY

TEACHER MANUAL

4th Edition

CONTENTS

FOREWORD



In 2007, I had just been elected a Fellow of ATSE. Bright eyed and bushy tailed, I attended an Education Committee meeting. In front of us was a stack of papers describing 200 or so extracurricular science and technology programs for Australian schools.

The problem? Performance and participation rates in school science were down; too few teachers had science degrees; students saw no job security in science careers; and the science curriculum did not engage many of our brightest students.

The challenge? A contribution by ATSE, perhaps to back some of the existing programs.

With the naivety of a new recruit and Silicon Valley brashness (I'd just left my role as a CEO there) I asked, what's the point? If these activities have not helped so far, we need something different.

'So smarty pants, what would you do?' was the appropriate response. Stuck for an answer – but not one to shy away from a schoolyard dare – I spent the weekend researching.

The key, I discovered, was relevance. Our kids are growing up in a wealthy, comfortable society – complacency is knocking at the door.

Wondering what was on their minds, I found the 2006 Australian Childhood Foundation survey. After personal issues, global warming ranked third – young people are extremely concerned about the future of their planet.

After perusing many reports and long discussions, I proposed a co-curricular activity based on renewable energy – not only because it complemented the science curriculum but also because it is a significant weapon in the fight against global warming.

The program would have two goals: capture the interest of students who might consider science or engineering careers, but also introduce *all* students to real-world science and technology, giving them an appreciation of the power of science.

We agreed that to truly engage students it needed a hands-on component – a kit of equipment for every school. And finally, we knew that teachers are central, so we had to provide professional development.

By 2008 Peter Pentland was in his stride as the program manager. I stayed deeply involved for several more years and then happily withdrew. I am delighted that there are now approximately 750 Australian STELR schools (nearly a quarter of all secondary schools in Australia) and nearly 40 international STELR schools.

Science teaching needs relevance. And so it was, and so it is, and so it will be.

Dr Alan Finkel AO FAA FTSE

Dr Finkel, President of ATSE 2013–2015, initiated and championed the STELR project.

STELR

STELR is a set of in-curriculum STEM teaching modules for secondary schools, developed by the Australian Academy of Technology and Engineering (ATSE). ATSE is a learned academy of scientists and engineers who have made notable contributions in their fields.

Note: STELR is an acronym for Science and Technology Education Leveraging Relevance*. STEM refers to science, technology, engineering and mathematics.*

OUR VISION

In Australia, science participation rates in the senior years of secondary school have been flat or declining for some decades. Despite the manifest importance of science and technology in their lives, secondary school students largely do not perceive science or mathematics as relevant to them.

STELR aims to increase senior school science participation by inspiring younger secondary school students with relevant, engaging STEM lessons. It leads them to an appreciation of the role that science, technology and mathematics have in the world, which, it is hoped, will inspire many of them towards careers in these fields. Beyond this, it uses evidence-based scientific inquiry as a means to develop students' scientific literacy and their general capacity for critical thinking.

THE KEY COMPONENTS

In order to meet its vision, STELR builds a number of key elements into its modules, explained below.

Relevance

STELR modules are built around issues that students consider relevant to their lives, giving them a fundamental reason to engage with the lessons. Research shows that global warming and sustainability rank highly in students' concerns, so these provide the underlying theme to most of the modules.

Related to this, student activities within the modules are designed to be *authentic* – incorporating projects, plans, and presentations that mirror what students will be required to do in their careers.

Inquiry-based, equipment-based

A large body of evidence shows that students learn best when they develop their own questions about a topic that engages them, and follow their own path of inquiry to answer those questions. While pure applications of this methodology are beyond the resources of most schools, STELR incorporates inquiry-based learning as a significant component of its modules. The robust, purpose-built equipment used in the modules actively promotes inquiry-based learning. In using the equipment, students engage with it and questions naturally arise. Students can make and test hypotheses in order to answer their questions.

Independent & collaborative

Evidence shows that students learn well in collaboration with one another. They also need to develop their capacity to concentrate and focus in independent work. The STELR modules provide opportunities for both.

Scientific method

The large number of experiments in the modules give students good practice at forming experimental aims and hypotheses, identifying variables, gathering and manipulating results data, and reflecting on their procedures and results. These are all key scientific inquiry skills that are applicable in much broader contexts.

STEM & society

Inquiry-led learning is not defined by traditional subject areas. While STELR modules primarily focus on the underlying science, they are genuinely inter-disciplinary with mathematics, technology and engineering deeply embedded. For example, students gather and manipulate numerical data to see how scientific principles apply in technological contexts.

STELR's focus on real-world engineering and technology leads naturally into questions about the roles of these disciplines within society. The STELR modules include such issues as an integral part of the lessons.

In-curriculum

STELR operates within the curriculum so that all students participate, and teachers do not have to find time for it beside other, curriculum-mandated topics.

The three science curriculum strands of the Australian Curriculum – Science Inquiry Skills, Science as a Human Endeavour and Science Understanding – as well as cross-curriculum elements are interwoven.

The program actively works to support participation by girls and other groups traditionally under-represented in STEM programs.

Teacher support

STELR inspires and empowers teachers. It incorporates contemporary teaching and learning practices and includes teacher professional learning and ongoing teacher support. Teacher's notes provide additional information, advice, and suggestions, and the STELR web site provides additional backup and resources. Answers are provided.

STELR HISTORY

Following initial planning, the first module of STELR, *Renewable Energy*, was first trialled in a small number of schools across Australia in 2008 and 2009, including metropolitan and rural government, Catholic and independent schools. Evaluations showed that teachers believed the program had an overall positive effect on students' engagement in science and on their perception of the relevance of science. There also was evidence of change in teachers' practice and knowledge and application of contemporary teaching approaches.

Following these trials, with the support of the Australian Government and other sponsors, in 2010 the program was re-developed for implementation of the *STELR Stage One Project* in 183 schools across Australia. Numbers of recommendations were adopted, but most notably this stage saw the introduction of robust, student-friendly equipment.

The student resources were written primarily for Year 10 level, but a range of activities able to be adapted for Year 9 were also provided.

In addition to receiving lesson content and equipment, two teachers from each STELR school took part in a professional learning program, and schools were supported by professional mentors.

In 2011, based on feedback from the 2010 trials, recommendations from the national steering committee (headed by Professor Russell Tytler) and recommendations from an evaluation study by Professor Leonie Rennie, the STELR resources underwent further significant changes. At this time, 185 Australian schools were running the program.

STELR continues to evolve and grow, including updates to existing resources to stay aligned to the Australian Curriculum. Some of the new resources are listed below.

Two mathematics modules supplement the *Renewable Energy* module:

- *Maths of Solar Panels*
- *Maths of Wind Turbines*

New equipment packs and curriculum materials have been developed as modifications of the original STELR *Renewable Energy* program:

- *Wind Energy* (a cut-down version of *Renewable Energy*)
- *Electricity and Energy* (a modification of *Renewable Energy* suitable for Years 5 and 6)
- *Solar Cars*

STELR has also published a number of curriculum resources that use the STELR teaching and learning principles but do not have specialised equipment packs, for example:

- *Climate Change and Oceans*
- *Earth Moon and Sun*
- *Future Health*
- *Car Safety*
- *Water in the 21st Century*
- *Carbon Dioxide – Friend or Foe?*

Acknowledgements

The ATSE STELR Project gratefully acknowledges the many teachers, mentors and education and industry experts who have contributed their ideas, advice, sample materials and other resources as the STELR program has evolved. Their contribution has been crucial to the success of the program and is greatly appreciated.

CONTACT

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THE RENEWABLE ENERGY MODULE

Renewable Energy is the flagship module of the STELR project. It covers energy and electricity in the context of renewable energy technologies.

OVERVIEW

Renewable Energy is an introduction to energy designed primarily for Year 8 (Australia) students. It makes extensive use of the STELR Renewable Energy equipment kit for demonstrations and experiments.

The module integrates mathematics, technology and engineering, and societal issues. It takes an inquiry-led approach and offers many opportunities for discussion and group work. It includes practical demonstrations, a research project, and career profiles. There are many experiments, with varying degrees of guidance. In these, students reflect on the scientific methodologies they use as well as endeavouring to get results that demonstrate the scientific principles they are learning. There are extensive notes for teachers.

The course begins with a general explanation of global warming and describes how fossil fuels are the principal cause of this. For this reason, the world is transitioning to renewable energy resources, most of which are used to produce electricity. In this way the exploration of energy in general, and electricity in particular, is placed within a meaningful context and given relevance to students' lives.

The module is a complete unit of work, building up and reinforcing concepts as it progresses. As such, it can be used from start to finish, however teachers can easily extract sections and adapt these for their classes, including for other year levels.

Even students familiar with the concepts taught in the module are likely to benefit by carrying out the demonstrations and experiments it includes, providing hands-on experience that will reinforce the concepts.

The module includes a short pre-test, to help you gauge students' current understanding, and a comprehensive final test.

MODULE STRUCTURE

The *Renewable Energy* module has eight units: *Global Warming*, *Energy*, *Energy Resources and Electricity*, *Batteries*, *Wind Energy*, *Solar Panels*, *Open Inquiry* and *STEM at Work*.

Within these units, individual sections are identified as *lessons*, *demos*, *pracs*, *projects* or *tests*. Most can be completed within one class period, but you should always preview and plan to confirm this.

- *Lessons* often include group discussions and interactive activities, but focus primarily on the teaching of key concepts.
- *Demos* are informal hands-on demonstrations, used to stimulate interest and raise questions.
- *Pracs* are experiments. These vary in their degree of guidance.
- *Prac/Lessons* integrate hands-on activities with teaching of content.
- *Project* – there is one project, to research and present on a specific energy resource. It is a good idea to give this to students early in the module to give them time to work on it.
- *Test* – there is one pre-test of 15 multiple-choice questions, and a post-test of 25 multiple-choice and nine long-answer questions.

MODULE RESOURCES

This STELR Renewable Energy teacher Guide is designed to be used in conjunction with the STELR Renewable Energy Student Book and the STELR Renewable Energy class sets of equipment. There is information about all the Module resources on the STELR website where all the written resources and videos van be downloaded free of charge:

STELR
https://stelr.org.au/stelr-modules/renewable-energy/

STELR Renewable Energy Teacher Manual

This teacher manual is available online.

STELR Renewable Energy
https://stelr.org.au/stelr-modules/renewable-energy/#curriculum-materials

It contains all the lesson content included in the student book as well as notes and suggestions for teachers. It has sample answers to questions. The manual also contains answers to the pre- and post- tests for students. The tests are not in the student book, but are supplied on the STELR Renewable Energy USB stick.

STELR Renewable Energy Student Book

STELR Renewable Energy Student Books are also available on-line at the STELR website in both Word and PDF formats. The online resources can be modified to suit the needs of your students. The files can be shared on internal school hard drives to provide access to teachers and/or students within the school.

Bound hard copies of the STELR Renewable Energy Student Books can also be purchased by schools or added to your class booklist for students to purchase. Please contact the STELR Administrative Officer at STELR.Admin@atse.org.au for further details about how to purchase the books.

STELR Renewable Energy USB

When you purchase a class set of STELR Renewable Energy equipment, you will be sent a STELR Renewable Energy USB. It contains the following:

- copies of the teacher and student books
- student tests
- additional resources including *Circuit Training, Rebound Efficiency*, *Maths of Solar Panels* and *Chemistry of Climate Change*
- STELR background information
- supplementary PDFs
- additional pracs
- case studies

We strongly recommend that the contents are uploaded to the school network to provide a back-up copy in case the USB is misplaces. Additional Renewable Energy USBs can be ordered from using a form on the STELR website here:

STELR Renewable Energy
https://stelr.org.au/stelr-modules/renewable-energy/#curriculum-materials

STELR Renewable Energy Equipment

It is assumed that you are using this book because you have already purchased STELR Renewable Energy equipment for use in your school. To purchase additional kits or spare parts please download an order form from the STELR website here:

STELR Renewable Energy
https://stelr.org.au/stelr-modules/renewable-energy/#equipment-kits

Videos

A number of videos are included in the lessons within the module. They are indicated by this symbol.

The videos referred to in this module can be accessed in a number of ways.

- They have been downloaded to the STELR Renewable Energy USB
- All the videos referred to in this module are available on the STELR YouTube Channel here: https://www.youtube.com/c/STELRProject
- Those that were produced by the STELR team specifically for the STELR Modules have also been uploaded to the STELR page at Australia's Science Channel here: https://australiascience.tv/department/stelr/
  This provides alternative way to access the videos for schools who prefer not to use or block access to YouTube.

Please note that not all of the suggested videos are on Australia's Science Channel and can only be accessed through YouTube. You will see that some of the video symbols have two links. If only one link is supplied, this means it is not available through Australia's Science Channel.

STELR Website

Scroll to the bottom of the STELR Renewable Energy page to find additional resources for this module. They include:

Renewable Energy Curriculum links
https://stelr.org.au/stelr-modules/renewable-energy/renewable-energy-curriculum-links/

Solar Cells Theory
https://stelr.org.au/additional-info/solar-cells-theory/

Solar Energy – additional resources
https://stelr.org.au/additional-info/solar-energy/

Wind Energy Theory
https://stelr.org.au/additional-info/wind-energy-theory/

Wind Energy Additional resources
https://stelr.org.au/additional-info/wind-energy/

Other types of renewable energy
https://stelr.org.au/additional-info/renewable-energy/

Climate Change
https://stelr.org.au/additional-info/climate-change/

Career Profiles in Renewable Energy
https://stelr.org.au/stem-at-work/career-profiles-renewable-energy/

You can also check out the STELR NEWS and EVENTS buttons at the top of the STELR web pages.

Other web sites

Some activities in the student book rely on real time data (such as wind maps or solar radiation maps) provided by external websites. They are indicated by this symbol with the URL.

External websites are checked regularly to ensure they are active and relevant.

DIAGRAMMATIC OVERVIEW

Content	Renewable Energy Module	Activities
	Unit 1: Global Warming	
Group brainstorm to elicit current knowledge about global warming	1.1 Getting started	
15 multi-choice questions	1.2 Pre-test	
Greenhouse effect; fossil fuels; CO_2; renewables	1.3 Lesson: Global Warming	
	Unit 2: Energy	
Motion or potential for motion; types of energy; potential vs. kinetic; joules	2.1 Lesson: What is Energy?	
	2.2 Prac: Energy Toys	Cotton-reel racer, jumping cups & flik flak: informal demo of transformations
Transformation & transfer; electricity from coal & hydro, word formulas; turbines, generators	2.3 Lesson: Trnsfmtns & Transfers	
	2.4 Prac: Trnsfmtns & Transfers	6 stations demonstrating different types of energy transformation – uses the STELR kits & wind-up toys
Energy transforms into >1 type at once; heat & sound; unwanted energy, flow diagrams	2.5 Lesson: Branching Trnsfmtns	
Optional: energy never lost or gained	2.6 Lesson: Energy Conservation	
Calculating efficiency, Sankey diagrams	2.7 Lesson: Energy Efficiency	
	Unit 3: Energy Resources and Electricity	
Students revisit their understanding of fossil fuels, greenhouse gases and renewability.	3.1 Lesson: Fuels and Greenhous Gases	
Why is electricity so useful? Production & usage	3.2 Lesson: Importance of Electricity	
Students weigh up the pros and cons of different energy resources.	3.3 Lesson: Energy Resources	
	3.4 Project: Energy Resources	Students research an energy resource and present their findings

Content	Renewable Energy Module	Activities
	Unit 4: Batteries	
Students brainstorm the advantages and disadvantages of non-rechargeable and rechargeable batteries as an energy source	4.1 Lesson: Why Use Batteries?	
	4.2 Prac: Connecting Batteries	Students become familiar with the STELR battery, multimeter and test rig. They explore connecting batteries in series and parallel.
Students think about changing battery technology and design.	4.3 Lesson: Battery Technology	
	Unit 5: Wind Energy	
How they work; where to put them; advantages & disadvantages	5.1 Lesson: Wind Turbines	
Students become familiar with the wind energy equipment and hypothesise on the best design.	5.2 Lesson: Wind Turbine Design	
	5.3 Prac: Wind Turbine Blade Angle	This prac uses the STELR wind turbine to find optimum blade angle.
	5.4 Prac: Number of Blades	This prac uses the STELR wind turbine to find optimum no. of blades.
	Unit 6: Solar Panels	
How they're made; how they work; where best to locate them	6.1 Lesson: How Solar Panels Work	
	6.2 Prac: Exploring Solar Panels	Students become familiar with the solar panel and connect the cells in series.
	6.3 Prac: Angle to the Light	This prac investigates the effect of light angle on electricity generation.
	Unit 7: Open Inquiry	Students investigate their own question with the wind turbine or solar panel
Two STEM careers: role in society; students' likes & skills	**Unit 8: STEM at Work**	
Test for entire module: 25 multiple choice & 9 long-answer questions	**Post-test**	

CURRICULUM COVERAGE

Renewable Energy covers the three strands of the science component of the Australian Curriculum: science understanding (SU), science as a human endeavour (SHE), and science inquiry skills (SIS). The inquiry strand is strongly supported by equipment kits and experiments.

This summary describes coverage of the Australian Curriculum. In Australia, most schools follow either the Australian Curriculum or a state curriculum which, in most cases, overlaps significantly with the Australian Curriculum. Teachers from other countries are likely to find the following information useful in identifying elements in their own curricula covered by the module.

The module is targeted primarily at Year 8 students but includes content covering curriculum elements from **Years 6 to 10**. Teachers may find parts of the module suitable for any classes within this range. Some teachers also find these activities useful as a basis for open-ended investigations in **senior Physics** classes.

Although some content in the module aligns with Years 9 and 10 curriculum, the concepts presented and their treatment within the module make them accessible to Year 8 students.

Further details of curriculum coverage within each of the strands is provided below.

Science Understanding

The core science understanding elements covered in the module relate to energy and electricity.

Energy

- What energy is, types of energy, kinetic vs. potential energy, heat and energy transfers and transformations all match to Year 8 physics, SU155.
- Conservation of energy and energy efficiency match to Year 10 physics, SU190.

Electricity

- A basic introduction to electricity and electrical circuits, such as is provided in the module, relates to Year 6 physics SU097. Many secondary school teachers repeat this content in Year 8 as there can be significant differences in its coverage at Year 6 and many students won’t have had the opportunity to demonstrate the concepts with good equipment.
- The investigation of energy in circuits relates to Year 9 SU182 on the transfer of energy.

These and other science understanding matches are shown in the diagram below.

Renewable Energy Module	**Science Understanding**
Unit 1: Global Warming 1.1 Getting started 1.2 Pre-test 1.3 Lesson: Global Warming	**SU189 (Yr 10) Earth & Space Sciences:** Global systems - how human activity affects global systems - the causes & effects of the greenhouse effect - the effect of climate change on sea levels & biodiversity **SU179 (Yr 9) Chemistry:** Chemical reactions - products of combustion affect the environment
Unit 2: Energy 2.1 Lesson: What is Energy? 2.2 Prac: Energy Toys 2.3 Lesson: Trnsfmtns & Transfers 2.4 Prac: Trnsfmtns & Transfers 2.5 Lesson: Branching Trnsfmtns	**SU155 (Yr 8) Physics:** Energy appears in different forms, including movement (kinetic energy), heat and potential energy…energy transformations and transfers… - potential energy is stored energy, such as gravitational, chemical and elastic energy - different forms of energy in terms of their effects - heat as a by-product of energy transfer - flow diagrams **2.3 & 2.4 SU097 (Yr 6) Physics:** Electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources - air & water turn turbines to generate electricity - investigating the use of solar panels
2.6 Lesson: Energy Conservation 2.7 Lesson: Energy Efficiency	**SU190 (Yr 10) Physics:** Energy conservation in a system can be explained by describing energy transfers and transformations - the Law of Conservation of Energy - in energy transfer and transformation…usable energy is reduced…not 100% efficient
Unit 3: Energy Resources and Electricity 3.1 Lesson: Fuels and Greenhous Gases 3.2 Lesson: Importance of Electricity 3.3 Lesson: Energy Resources 3.4 Project: Energy Resources	**SU182 (Yr 9) Physics:** Energy transfer through different mediums… - factors that affect the transfer of energy through an electric circuit **3.5 SU177 (Yr 9) Chemistry:** All matter is made of atoms that are composed of protons, neutrons and electrons… - charge of electrons, protons, neutrons

Renewable Energy Module	**Science Understanding**
Unit 4: Batteries 4.1 Lesson: Why Use Batteries? 4.2 Prac: Connecting Batteries 4.3 Lesson: Battery Technology	**SU097 (Yr 6) Physics:** Electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources - recognising the need for a complete circuit to allow the flow of electricity - exploring the features of electrical devices such as switches and light globes - circuit components
Unit 5: Wind Energy 5.1 Lesson: Wind Turbines 5.2 Lesson: Wind Turbine Design 5.3 Prac: Wind Turbine Blade Angle 5.4 Prac: Number of Blades **Unit 6: Solar Panels** 6.1 Lesson: How Solar Panels Work 6.2 Prac: Exploring Solar Panels 6.3 Prac: Angle to the Light	**SU097 (Yr 6) Physics:** Electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources - moving air and water can turn turbines to generate electricity - investigating the use of solar panels - considering whether an energy source is sustainable **4.1 & 4.2 SU116 (Yr 7) Earth & space sciences:** Some of Earth's resources are renewable... but others are non-renewable - what is meant by the term 'renewable'? - comparing renewable and non-renewable energy sources
Unit 7: Open Inquiry	
Unit 8: STEM at Work	
Post-test	

Science Inquiry Skills

All of the Australian Curriculum science inquiry skills for Years 7 to 10 are covered to some degree within the module, in the eight formal experiments (based on given inquiry questions), one open experiment, and numerous demonstrations and opportunities for informal experimentation. The formal experiments are presented with different degrees of guidance – some model good scientific practice while others give students freedom to make their own decisions about how to run their investigations and present the results. Teachers should assess the experiments against their students' abilities and modify accordingly if they think students need more or less guidance. In particular, teachers delivering the module via the online platform can modify experiment directions as they see fit.

Students do all experiments collaboratively.

Some particular points with respect to inquiry skill items for Years 7 and 8 are noted below:

- SIS124/139 *Questioning and predicting: Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge.*
    - Section *7 Open Inquiry* is an open experiment where students collaboratively select their own investigation to undertake.
    - All the formal experiments in the module, and many of the informal pracs, ask students to make and explain hypotheses before they proceed.
    - Elaboration: *recognising that the solution of some questions and problems requires consideration of social, cultural, economic or moral aspects rather than or as well as scientific investigation*, is central to the module project, *4.2 Project: Energy Resources*.
- SIS125/140 *Planning and conducting: Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed*.
    - Students collaboratively plan investigations in *2.8 Prac: Rebound Efficiency* and *4.8 Prac: Open Inquiry*.
    - Students are required to identify potential safety hazards and suitable preventative actions for all experiments.
- SIS126/141 *Planning and conducting: Measure and control variables, select equipment appropriate to the task and collect data with accuracy.*
    - Students are asked to identify the variables in all the experiments.
    - There is good opportunity to use cameras to record accurate results in the Energy Conservation and Energy Efficiency pracs.
- SIS 129/144 *Processing and analysing data and information: Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships in data using digital technologies as appropriate.*
    - Students present experiment results in graphs. Information is presented to them in graphs of different types, in *3.1 Fossil Fuels And Greenhouse Gases*
- SIS 130/145 *Processing and analysing data and information: Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions based on evidence*.
    - Elaboration: *comparing and contrasting data from a number of sources in order to create a summary of collected data* – in experiments *5.4 Prac:*

Number of Blades and *6.3 Angle to Light* students share and average results and address reasons for doing this. They consider how to deal with divergent results.

- SIS 131/146 *Evaluating: Reflect on scientific investigations including evaluating the quality of the data collected, and identifying improvements.*
  - Questions require students to reflect on all their experiments, assessing them and noting how they could improve them.
- SIS 132/234 *Evaluating: Use scientific knowledge and findings from investigations to evaluate claims based on evidence*.
  - For all experiments students discuss how well their data support a conclusion.
- SIS 133/148 *Communicating: Communicate ideas, findings and evidence based solutions to problems using scientific language, and representations, using digital technologies as appropriate*.
  - Students communicate their results throughout the module, but *4.2 Project: Energy Resources* in particular provides strong opportunity for this. Students using the online version can use digital media in their projects.

Science as a Human Endeavour

In *Renewable Energy*, fundamental energy and electricity themes are placed within the context of global warming. In this respect, the module focuses on science and technology as they impact an issue with significant societal consequences. Some specific links the module has to the curriculum are noted below. Teachers may choose to build on these connections.

- SHE 119/134 (Years 7/8) *Nature and development of science: Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available*.
  - The danger of burning fossil fuels was not recognised for many years.
- SHE 157/191 (Years 9/10) *Nature and development of science: Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community*.
  - There is good linkage to the Year 10 elaboration: *considering the role of science in identifying and explaining the causes of climate change*.
- SHE 158/192 (Years 9/10) *Nature and development of science: Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries*.
  - Solar panels and wind turbines are good examples of this. Other good examples can be developed from *3.1*
  - The module provides scope for development of the Year 10 elaboration: *considering how computer modelling has improved knowledge and predictability of phenomena such as climate change and atmospheric pollution*.
- SHE 120/135 (Years 7/8) *Use and influence of science: Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations*.
  - As above, solutions to global warming affect society generally, with ethical and political implications. There are particularly strong impacts on ecosystems.

- SHE 121/136 (Years 7/8) *Use and influence of science: People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity*.
    - *Unit 8 STEM at Work* focuses directly on occupations within the STEM sector.
    - The global warming aspect of the module offers the possibility of expanding on the Year 8 elaboration: *recognising the role of knowledge of the environment and ecosystems in* a *number of occupations*.
    - The lesson and prac on energy efficiency (*2.7 Lesson: Energy Efficiency*) offer the possibility of expanding on the Year 8 elaboration: *considering how engineers improve energy efficiency of a range of processes*.
- SHE 160/194 (Years 9/10) *Use and influence of science: People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities*.
    - There are many links to this item within the module with respect to students assessing claims about global warming and the advantages and disadvantages of different energy resources. There is a particular link to the Year 10 elaboration: *considering the scientific knowledge used in discussions relating to climate change*.
    - The module relates well to Year 10 elaboration: *recognising that scientific developments in areas such as sustainable transport and low-emissions electrical generation require people working in a range of fields of science, engineering and technology*.
    - *Unit 8 STEM at Work* focuses directly on occupations within the STEM sector.
- SHE 228/230 (Years 9/10) *Use and influence of science: Values and needs of contemporary society can influence the focus of scientific research*.
    - The theme of responses to global warming connects with the Year 9 elaborations: *investigating how scientific and technological advances have been applied to minimising pollution from industry*, and *considering how choices related to the use of fuels are influenced by environmental consideration*s.
    - There is scope for further development of the Year 10 elaboration: *investigating technologies associated with the reduction of carbon pollution, such as carbon capture*.
    - There is scope for further development of the Year 10 elaboration: *considering innovative energy transfer devices, including those used in transport and communication*.

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1 GLOBAL WARMING

One effect of global warming is an increased number of bushfires.
Credit: CSIRO science image

1 Global Warming creates context and relevance by looking at global warming and how the use of renewable energy resources will reduce this. It begins with a group exercise to organise key terms related to global warming, to start students thinking about the topic and for you to assess their current knowledge.

A pre-test of 15 multiple-choice questions will provide an overview of student knowledge of all the content covered in the course. Optionally do this first.

In *1.2 Lesson: Global Warming*, a video is used to present the key concepts of global warming. The lesson reinforces understanding of the greenhouse effect and how fossil fuel use has enhanced this. Renewable energy resources allow us to meet our energy requirements without contributing to the greenhouse effect, thus providing the central contextual focus of the course.

Earth's climate is changing, and quickly. We need to act to protect people, ecosystems, and economies. We know what's causing the changes, and it's mostly to do with how we get energy.

1.1 GETTING STARTED

Overview

1.1 Getting Started introduces the issue of global warming. Studies have shown that students are concerned about this topic, hence we use it to engage them in a unit primarily about energy.

Getting Started consists of one activity designed to stimulate discussion. It will start students thinking about global warming and give you the opportunity to gauge their current knowledge.

Some students may have strong political views on the topic. We suggest that you acknowledge this if it comes up but avoid debate – at least to begin – taking an approach along the lines of 'let's see what the issues are first'.

Curriculum

Global warming is covered in Year 10 in the Australian Curriculum, as part of earth systems. We present just the main elements necessary for a basic understanding of the problem, sufficient for students to see that replacing fossil fuels with renewable energy will reduce the problem.

Global warming: core ideas and terminology

- *Global warming* is the increase in Earth's average air temperature due to the enhanced greenhouse effect. *Climate change* is the change in climatic conditions arising from this. Changes in climate are different at different locations – for example some places might become colder, wetter, dryer etc. as average global temperatures increase. Strictly speaking, global warming is the *cause* of climate change, however the terms are commonly used synonymously. In these lessons we typically do not distinguish between them.
- The *greenhouse effect* is the natural effect due to a small proportion (<1%) of atmospheric gases that capture heat emitted from the Earth (which would otherwise go into space) keeping it on the planet for longer. It brings about Earth's comparatively warm average temperature of 16°C. If there were no greenhouse gases the average temperature would be closer to −20°C.
- *The enhanced greenhouse effect* is the same physical process as the greenhouse effect, but higher concentrations of greenhouse gases – due to human activities – cause higher temperatures than are due to the natural greenhouse effect alone.
- The main *greenhouse gases* (gases that cause the greenhouse effect) are carbon dioxide, methane, nitrous oxide and water. The various refrigerant gases currently in use are also powerful greenhouse gases, although present in only small quantities. Carbon dioxide is the main contributor to the enhanced greenhouse effect, and most of it comes from burning fossil fuels, although land clearing and industry are also significant contributors. In this unit we focus primarily on CO_2 and fossil fuels, which provide the link to energy.
- *Fossil fuels* refers primarily to coal, oil and natural gas. Coal is mostly carbon, so when burned produces carbon dioxide. Oil and natural gas are hydrocarbons, burning to produce carbon dioxide and water. Water is a greenhouse gas but water vapour produced as a direct result of

burning is not a significant contributor to the enhanced greenhouse effect, because water cycles through the atmosphere quickly. More significant is the positive feedback loop that, as the average air temperature rises, the atmosphere can hold greater amounts of water vapour.

Brainstorm exercise

We suggest that students work in small groups for 10 mins then come together as a class to compare. There is no correct answer to the exercise, and few students are likely to be able to explain how all the terms presented fit in.

Some ideas might be:

- *natural gas* and *coal* are fossil fuels that we use to supply us with *energy*, and they produce *carbon dioxide* when they're burned;

carbon dioxide and *methane* are greenhouse gases – i.e. they contribute to the *greenhouse effect* which stops some *heat* leaving Earth;

increased amounts of greenhouse gases leads to the *enhanced greenhouse effect*, which increases the Earth's average *temperature*;

the effects of an increased global temperature include *climate change*, e.g. *flooding* and *drought*, and rising *sea level*. Some of these changes are likely to lead to climate *refugees*:

one of the ways we learn about global warming is from the air trapped in *ice cores* (scientists can directly measure the proportions of greenhouse gases in air from the last 800,000 years, and the proportions of heavy isotopes also indicate average temperatures at those times);

ozone, and the hole in the ozone layer, don't really have anything to do with global warming – this is a common misconception so we included the word in order for you to make this clear to students.

Setup

You may want to prepare cards or post-it notes with the terms below before class. Each group of students will need a large sheet of paper (we suggest A3 or larger) or a white board.

One of the really big issues facing the world at the moment is global warming...or people often call it climate change. So, how much do you know about it?

Share your ideas with your classmates to see what you know and what you're not sure about.

Question 1

In groups of three or four, brainstorm what you know about global warming.

- Copy the terms below onto small cards or post-it notes.
- On a large sheet of paper or white-board write the title *Global warming*.
- Group the terms that you think belong together and use pens to draw lines and write headings, comments or other words, to show how you think the terms fit together.
- Mark an area with a question mark in it. Put terms that you don’t know, or you’re not sure how they relate to global warming, in it.

The terms for the brainstorm are:

- sea level
- energy
- temperature
- flooding
- greenhouse effect
- carbon dioxide
- ice cores
- enhanced greenhouse effect
- heat
- coal
- refugees
- natural gas
- heatwave
- climate change
- ozone
- drought
- methane

PRE-TEST

This test is designed to give you an indication of your students' current understanding. However, it is very difficult to get an accurate picture of a class's understandings with a short multiple choice test. To improve the quality of information that you get from it:

- encourage students to mark 'I'm not sure' if that is how they feel...you don't want them to guess
- you may want to choose some questions for brief class discussion – this should provide more depth of information about students' grasp of the concepts.

Students do not have the pre-test in their books. PDF copies of the test are on the Renewable Energy USB key.

How much do you know about global warming, energy and electricity now?

Here's a quick test to give your teacher an idea before you get started. Don't worry if you don't know the answers, and don't spend time trying to think of them – just click 'I'm not sure'. If you have to click 'I'm not sure' all the way through, that's fine.

GLOBAL WARMING

Question 1

Earth's average air temperature has been rising over the last 100 years. This is called global warming. The main cause is:

- ☑ the use of coal, oil and natural gas because they release carbon dioxide when burned
- ☐ pollution of Earth's land and oceans
- ☐ the use of coal, oil and natural gas because they release heat when burned
- ☐ the sun has increased in temperature
- ☐ a hole in the ozone layer that surrounds the Earth
- ☐ I'm not sure

Question 2

Which is the best description of the global greenhouse effect?

- ☐ Some gases burn with a green light
- ☐ Areas enclosed with glass, such as greenhouses, become hotter
- ☑ Some gases in the Earth's atmosphere cause its temperature to increase
- ☐ A hole in the ozone layer causes the Earth's atmosphere to warm
- ☐ Ice at the North and South Poles and in glaciers is melting
- ☐ I'm not sure

ENERGY

Question 3

Which of the following statements about energy is/are true?

- ☐ If something has energy it must be moving, for example a cheetah running
- ☐ Pushes, pulls and twists are all forms of energy
- ☑ Energy has many different forms, such as can be found in food, electricity, and moving machinery
- ☐ Electric batteries don't have energy themselves, but can give other things energy
- ☐ If you train hard you will build up your energy
- ☐ I'm not sure

Question 4

Which of the following are examples of objects increasing in energy?

- ☑ A cooking pot: when it's heating up
- ☐ Thoughts: when someone thinks deeply about something
- ☑ A stone: when increasing speed after being dropped
- ☑ A stone: while being carried to the top of tower on a conveyor belt
- ☑ A rubber band: when it's being stretched
- ☐ I'm not sure

Question 5

Kinetic energy is:

- ☐ the energy inside atoms
- ☐ another name for electromagnetic energy
- ☐ stored energy
- ☑ the energy that something has due to its motion
- ☐ I'm not sure

Question 6

Which of the following are examples of things with potential energy?

- ☑ Water behind a dam at a hydroelectric power plant
- ☐ A wind turbine turning
- ☐ Light beaming out from the sun
- ☑ A cheese sandwich
- ☑ A piece of coal
- ☐ I'm not sure

Question 7

Electric heaters run on electricity and produce heat.

Which is the best description of how they do this?

- ☐ Electricity isn't energy, but heaters use it to create energy in the form of heat.
- ☑ Heaters take in energy in one form – electricity – and turn it into another form – heat.
- ☐ Heaters destroy the energy present in electricity to create heat.
- ☐ I'm not sure

Question 8

When we say that the energy efficiency of a coal-fired power station is 40% we mean:

- [ ] it runs 40% of the time
- [ ] it is run at 40% of its full capacity, feeding it with 40% of the coal that it could handle
- [x] 40% of the energy in the coal is converted into electricity
- [ ] the power station is 40% smaller in physical size than other power stations with similar power output
- [ ] I'm not sure

Question 9

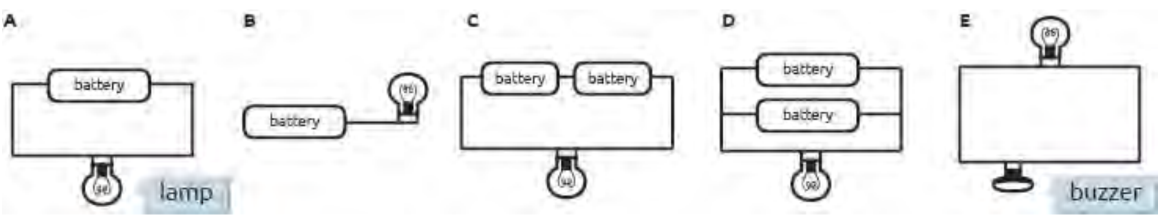
Joe's motorbike, like all motorbikes, heats up when he rides, and it makes a lot of noise.

Which of the following are true?

- [x] The heat that the bike produces is waste energy
- [x] The noise, heat and motion of the bike all come from chemical energy in the fuel
- [ ] All of the energy in the fuel is used up making the bike move
- [ ] Not all of the energy in the fuel is used to move the bike – some is destroyed in the motor
- [ ] I'm not sure

ELECTRICITY

The next four questions relate to the electrical circuit diagrams below.



Question 10

In which of the circuits would the lamp light up?

- ☑ A
- ☐ B
- ☑ C
- ☑ D
- ☐ E
- ☐ I'm not sure

Question 11

Compare circuits A and B. The lamp:

- ☐ in A will not light up, because the energy from the battery is returned to the battery
- ☑ in A will light up, because it has a complete circuit for electricity to flow
- ☑ in B will not light up, because there is no path for electricity to flow back to the battery
- ☐ in B will light up, because it is connected to a power source
- ☐ I'm not sure

Question 12

Compare circuits A, C and D. How bright would the lamp be?

- ☐ The lamps would shine equally in each circuit
- ☐ The lamps in C and D would be equally bright, brighter than in A
- ☑ The lamp would shine brighter in circuit C than in A or D
- ☐ The lamp would shine brighter in circuit D than in A or C
- ☐ I'm not sure

Question 13

______ is a series circuit and ______ a parallel circuit.

- ☐ A, B
- ☐ B, E
- ☑ C, D
- ☐ D, A
- ☐ I'm not sure

ENERGY RESOURCES

Question 14

Gravitational potential energy → kinetic energy → mechanical energy → electricity.

Which electricity production method does this best represent?

- ☐ Coal-fired power station
- ☐ Solar panel
- ☐ Wind turbine
- ☑ Hydro-electric power plant
- ☐ I'm not sure

Question 15

Why are renewable energy resources suggested as part of the solution for global warming?

(*select one answer*)

- ☐ They don't involve mining
- ☑ They don't produce carbon dioxide when they generate electricity
- ☐ The primary energy resources they use are replaced quickly
- ☐ They produce fewer pollutants than fossil fuels
- ☐ I'm not sure

1.2 LESSON: GLOBAL WARMING

This lesson explains what global warming is, what causes it, and how we can help reduce it. It uses a video called *Global Warming: Cold Facts Hot Science* which was specifically produced for this STELR module. The video is now several years old. Teachers could also discuss with students more recent events attributed to global warming.
It's important that students understand the link between global warming and energy:

1. humans use fossil fuels for most of their energy
2. use of fossil fuels releases CO_2 into the atmosphere
3. CO_2 is a greenhouse gas, which means that it traps radiation escaping from the Earth and warms the atmosphere
4. increased amounts of CO_2 are increasing temperatures beyond the normal range – this is global warming
5. if we can replace fossil fuels with energy sources that don't produce CO_2 then we remove a major cause of global warming.

KEY QUESTIONS

- What is global warming, and what are its causes and effects?
- What can we do about global warming?

Watch this video.

VIDEO Global Warming: Cold Facts Hot Science
https://youtu.be/CKzxdly7DpY

https://australiascience.tv/episode/global-warming-cold-facts-hot-science/

Take notes for the video below.

Students can take notes.

There's a lot of information in the video. The questions below will help you to get the main messages.

Each question has the time in the video where you can get the answer.

Question 1

Burning fossil fuels – coal, oil and natural gas – produces carbon dioxide. [3:38]

- [x] true
- [ ] false

Question 2

Carbon dioxide is a greenhouse gas. [3:38]

- [x] true
- [ ] false

Question 3

Greenhouse gases are gases that keep heat that is escaping from Earth into space in the atmosphere longer. [1:42]

- [x] true
- [ ] false

Question 4

Increasing the proportion of greenhouse gases in the atmosphere increases the Earth’s average air temperature. [1:47]

- [x] true
- [ ] false

Important note about the effects of global warming

It is important that students understand that specific weather events – for example particular storms, heatwaves or heavy rainfall – are not caused in a straightforward way by global warming. There have always been storms, heatwaves and heavy rainfall. However, global warming makes extreme weather events *more likely*. It also increases the likelihood that they are *more severe*.

Note: Currently there is no clear evidence that global warming increases the number of cyclones (also known as hurricanes or typhoons), but it does suggest that it increases their severity.

Question 5

The greenhouse effect: [2:03 to 3:03]

(select all the options that are true)

- ☐ began on Earth around 200 years ago
- ☐ is caused by how close the Earth is to the Sun
- ☑ has occurred for so long on Earth that life has evolved for it
- ☑ is caused by some of the gases in the atmosphere
- ☐ protects the Earth's surface from dangerous radiation from the Sun

Question 6

Which of the following are effects of global warming that are shown or mentioned in the video?

[0:12 to 0:28 and 7:08 to 8:30]

- ☐ hole in the ozone layer
- ☑ rising sea levels
- ☑ environmental refugees
- ☑ fires
- ☑ health effects

For the question below, the video does not state explicitly what extreme weather events are, however this is suggested by the opening footage: heatwaves and/or drought, leading to fires, and heavy rain, leading to floods. Storms, resulting in high rainfall, damaging winds and storm surges might also be mentioned (although, as noted above, evidence currently does not suggest global warming causes more cyclones, but that it makes them stronger).

Question 7

In the video, Sean talks about 'extreme weather events'. Give two examples of the sorts of events you think he's talking about.

1. Torrential rainfall, which can cause flash flooding and mudslides.

2. Heatwaves, which can cause fires and lead to increased deaths directly.

As Sean points out, the greenhouse effect makes Earth much warmer than it would otherwise be, and life here has evolved to live in these warmer temperatures. But an increase in the proportion of greenhouse gases in the atmosphere in the last 200 years means we're getting too much of a good thing, and Earth's average temperature is rising.

This *increased* greenhouse effect is called the **enhanced greenhouse effect**.

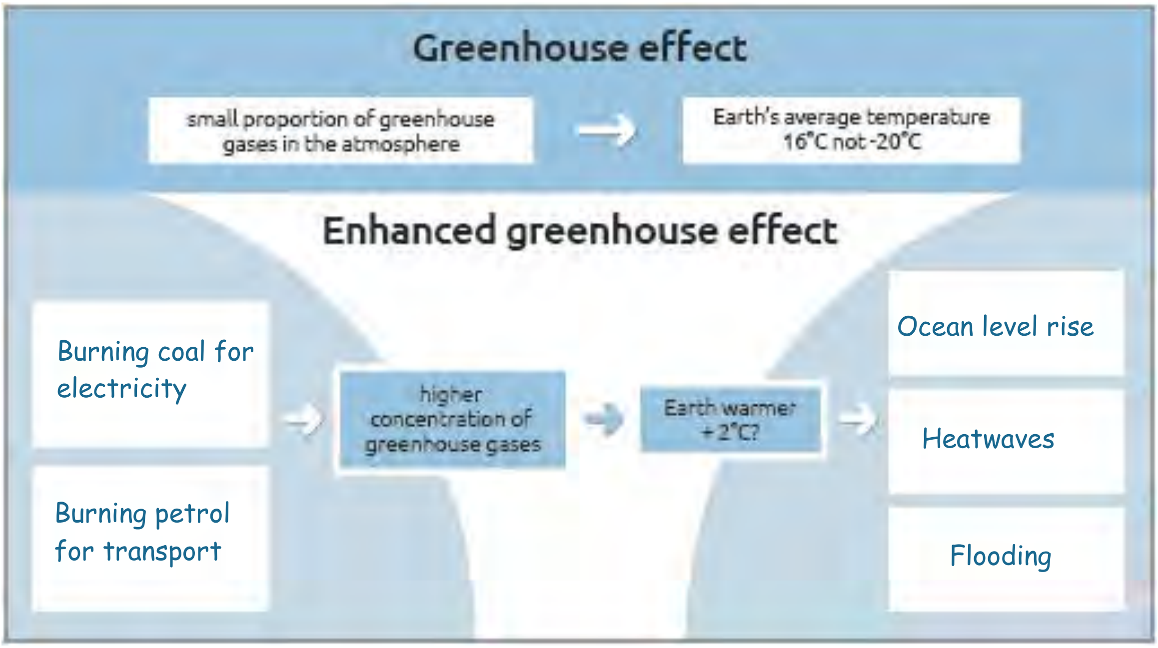
Question 8

The diagram below compares the *normal* greenhouse effect with the *enhanced* greenhouse effect. Complete the diagram by filling in the boxes in the bottom section:

- two causes of the enhanced effect, on the left hand side, and

three effects of the enhanced effect, on the right.

[3:14 to 4:30]



Question 9

We know that for the last couple of hundred years, as population has increased, we've been burning more and more coal, gas and oil. We might expect that this would lead to higher concentrations of carbon dioxide in the atmosphere, but what evidence is there for this?
[5:17 to 6:22]

There is evidence in samples of air captured and stored in bubbles in snow and ice at the poles. The air bubbles form a continuous record that goes back 800,000 years. Scientists can directly measure the levels of carbon dioxide in these samples, and these show that after being steady for thousands of years CO_2 levels have been steadily increasing since about 200 years ago.

Question 10

At 8:50 in the video, Sean talks about how we can turn global warming around. He lists, among other things:

- solar energy
- wind energy
- hydro power
- nuclear energy
- hydrogen for transport
- electric cars

What do these all have in common that will help us stop global warming? Explain.

None of these energy resources produce carbon dioxide, so they provide ways that we can have the energy we need without adding to global warming.

WRAP-UP

Have you learned what you set out to in this lesson?

Question 11

Which is the best description of global warming?

- [x] the heating of Earth's atmosphere due to increased proportions of greenhouse gases in the atmosphere
- [ ] the heating of the Earth due to a rise in temperature of the molten rock under the surface
- [ ] the heating of Earth's atmosphere due to holes in the ozone layer
- [ ] the heating of Earth's atmosphere due to increased energy output from the Sun

Question 12

Which options below list some of the effects of global warming?

(Select one or more)

- [ ] increased human population and increased use of fossil fuels
- [ ] increased levels of carbon dioxide and methane in the atmosphere
- [x] increased number of droughts, heatwaves and heavy rainfall
- [x] migration of people, rising sea level, rising ocean temperature

Question 13

Which of the following are possible ways that we could reduce global warming?

Important: Note the reasons given as well.

- [x] Use nuclear power stations, because they do not produce greenhouse gases
- [ ] Use renewable energy technologies like solar and wind, because these energy sources will never run out
- [x] Use renewable energy technologies like solar and wind, because these energy sources do not produce greenhouse gases
- [ ] Don't use plastic bags and containers
- [x] Use electric-powered cars, with electricity from renewable sources

Question 14

What was the biggest thing you learned about global warming doing this lesson?

Various answers.

Question 15

What's the biggest question you still have about global warming?

Various answers.

2 ENERGY

We need energy to hold up a phone, and energy to charge it...what have these things got in common?

In this section we step back from renewable energy technologies to build up a basic understanding of energy itself. Students investigate using the STELR equipment and carry out an experiment on ball rebound efficiency.

2.1 Lesson: What is Energy? Building from students' current understanding, the first lesson looks at definitions of energy in the context of there being many different types. All of these involve motion or the potential for motion. The joule is introduced as the unit of energy.

2.2 Prac: Toys Students play with the jumping cups, cotton-reel racer, and/or flik flak and observe energy transformations.

2.3 Lesson: Transformations and Transfers Energy transformations and transfers are explained and energy transformation word formulas, i.e. [energy type 1] → [energy type 2], introduced. A simple overview of the transformations from kinetic to electrical energy in turbines and generators is given.

2.4 Prac: Transformations and Transfers A round-robin practical activity uses the STELR equipment for students to observe a wide variety of energy transformations.

2.5 Lesson: Branching Transformations Introduces branching transformations, which often have unwanted heat as one of the products. Branching transformations can be represented with flow charts.

2.6 Lesson: Energy Conservation Optional (conservation of energy is introduced in the Australian Curriculum in Year 10). However, the lesson is not difficult and could be used with Year 8s if you have time.

2.7 Lesson: Energy Efficiency Introduces Sankey diagrams and explains how to calculate energy efficiencies. Energy efficiency is also a Year 10 topic within the Australian Curriculum but we recommend this lesson as it is necessary in order to carry out the following pracs, measuring ball rebound efficiencies. These give students good experience organising themselves and producing, managing, and mathematically manipulating data. The results that they derive are easy to understand intuitively, i.e. high rebound efficiency percentages correspond to good rebounds, and low percentages to weak rebounds.

It's hard to pin down exactly what energy is.

In this section you use the STELR equipment to get onto its trail.

2.1 LESSON: WHAT IS ENERGY?

2.1 Lesson: What is Energy? aims to give a general understanding of energy and the fact that there are many different types, but all measured using the same unit. It does not attempt comprehensive coverage of energy types, but introduces a lot of examples.

Outline

1. Students are asked to find examples of energy in some pictures and then attempt a definition.
2. Two videos provide definitions and discuss different types of energy.
3. Energy is possessed either as movement (kinetic) or the potential to create movement.

Types of energy

Classification of energy types is vague, with overlapping categories, e.g. mechanical energy is simply kinetic energy in the case of machinery.
The issue is made more difficult because all forms of energy fall into one of two categories: kinetic or potential. This means that *kinetic* can be used to refer to a type of energy – the motion of objects – or an entire category, including heat, sound and electromagnetism. Further, both heat and sound are strictly just kinetic energy in the first sense – the motion of *small* objects (molecules).
Since these problems arise from accepted usage we have not attempted to solve them. Neither have we attempted to explain the difficulties to students. Rather, we have tried to be clear in every instance what our meaning is. Nevertheless*, it would be good to make the point to students that often more than one term can be correctly used to describe a type of energy*.
As a reference for you, the types of energy mentioned in these lessons are:
Kinetic types:

- *kinetic:* anything moving, but typically medium to large-sized objects
- *mechanical:* moving machinery
- *sound:* wavelike movement of particles, especially in a gas or liquid
- *heat (thermal):* random molecular motion
- *electromagnetic radiation:* waves of alternating electric and magnetic fields, in a great range of wavelengths
- *heat (infra-red radiation):* infra-red electromagnetic radiation
- *light:* electromagnetic radiation visible to the human eye, though sometimes used to mean all wavelengths

Potential types:

- *chemical:* energy in the bonds between atoms within molecules and lattices
- *nuclear:* energy inside atoms
- *gravitational:* energy in the attraction of matter to matter
- *electrical:* energy of separated electrically charged particles (can be transferred through an electric circuit)
- *elastic:* stretched or compressed objects, e.g. rubber or springs, also compressed gas

Common misconceptions

We don't explicitly address misconceptions in the lesson – depending on your students you may want to do this yourself.

- students often confuse energy and force – it may be good to remind them that a force is a push, pull or twist. Energy is related to forces, but not the same thing.
    - suggestion: to make the energy-force distinction, use the diagram describing the joule later in this lesson – you have to apply a force to the tomato to raise it up against the force of gravity. It takes energy to move the tomato against gravity.
    - a strict definition distinguishing energy from force refers to work: work is done when a force moves an object over a distance, which always involves energy being transformed from one form to another.
- students sometimes confuse energy with motion – moving things have kinetic energy, but not all forms of energy involve motion, e.g. all the potential forms of energy
- students often talk about power and energy as the same thing – power is the rate of energy transformation, so this is strictly incorrect. However, the terms are frequently used synonymously in common usage, so it's not unreasonable for students to conflate the two. You can tell students what power is, but at this stage of the unit they only need to understand that they are different.

KEY QUESTIONS

- What is energy?
- What are some different types of energy, and what do they have in common?
- What has energy got to do with global warming?

The biggest cause of global warming is the carbon dioxide that we've released into the atmosphere over the last 200 years. And by far the biggest source of that carbon dioxide is from the burning of fossil fuels – oil, coal and gas.

Oil, from in the Earth, is refined and shipped around the world. Almost all of it is burned, chemically changing to carbon dioxide and water vapour, which are released into the atmosphere. *Credits: Oil rig, Stephen (danrandom) from UK; car, Steevven1(both Wikimedia Commons)*

Why do we burn so much oil, coal, and gas? The answer is, of course, for **energy**.

But what exactly is energy? It's not an easy question...

Question 1

Draw your ideas of what energy is.

This is an opportunity for students to express their own ideas about what energy is.

The question below is intended to be quite loose and open. Although we think that there are some reasonably obvious answers, different answers may be justifiable and could be a good basis for discussion.

Question 2

All of the pictures above have something to do with energy – often more than one type. With a partner, see how many types you can identify.

	Energy type 1	Energy type 2	Energy type 3
Skier	chemical		
Wind turbines	electricity		
Sun	chemical	kinetic	
Dog on trampoline	electricity	sound	
Petrol pump	chemical		
Energy drink	elastic	gravitational	kinetic
Radio	chemical		
Cow	light	heat	
High jumper	kinetic	mechanical	electricity
Power pylons	kinetic	gravitational	
Fire	chemical	heat	light

Note: Don't worry if you're not sure – this is to see what you know now, and you'll get a chance to come back for another go later.

Question 3

Now, after discussing with your partner, have a go at saying what energy is.

[The question is difficult and students will offer a range of responses…the important thing is that they make an attempt.]

The text below provides a very quick account of energy as movement or potential for movement, and lists some examples of each. It moves past a great deal of content with very little explanation. Students may or may not have learned about the individual energy types (e.g. heat as movement of atoms, in particle theory), but the main point is simply to give them a working list of energy types. You may choose to offer more explanation.
Note: Nuclear energy is intentionally left out as it is covered in a following question.

Energy is about **moving** – either something *actually moving* or with the *potential* to move. Here are some examples.

Actually moving

- Anything that moves has **kinetic energy.**
- If it's a machine that's moving the kinetic energy is often called **mechanical energy.**
- **Light**, and all electromagnetic waves, move...they're a form of kinetic energy.
- **Heat** is the movement of the atoms that something is made up of, so it's a type of kinetic energy.
- **Sound** is the movement of atoms or molecules – also a type of kinetic energy.

Potentially moving

- Something above the ground has the potential to fall –that is, move – so it has **gravitational potential energy.**
- Anything that burns or is eaten as food contains **chemical potential energy.**
- **Electricity** can be used to make light, heat and sound, and to make things move – it is a form of potential energy.
- A spring, compressed or extended, will move when it's let go – it has **elastic potential energy.**

Question 4

When something is moving it has: *(choose the best answer)*

☐ potential energy

☐ electrical energy

☐ chemical energy

☐ mechanical energy

☑ kinetic energy

Question 5

Which of the following are types of potential energy? *(select one or more)*

- [x] elastic energy
- [x] gravitational energy
- [ ] sound energy
- [ ] kinetic energy
- [x] chemical energy

Question 6

We classify heat as a type of ____________ energy because ____________ .
(Choose the best answer)

- [ ] kinetic; it can move from one object to another
- [x] kinetic; the atoms in hot things move faster than in cold things
- [ ] potential; we store it in objects when they get hotter and hotter
- [ ] potential; though it doesn’t involve movement itself, it can make things move, like a hot air balloon

Question 7

Nuclear energy is energy contained *inside* atoms. It's different from chemical energy, which is the energy *between* atoms. Nuclear energy is only released if atoms are heated to extremely high temperatures, such as in stars.

Is nuclear energy a type of kinetic or potential energy?

- ☐ kinetic
- ☑ potential
- ☐ neither kinetic nor potential energy

WRAP-UP

How have you gone in this lesson? These questions will check if you've understood the main points.

Question 8

Which is the best description of energy?

- [x] what moving things have, and what can make them move
- [ ] how active you feel
- [ ] what anything made of atoms has
- [ ] how fast something is going, or how hot it is

Question 9

All the different types of energy...

- [ ] are in or come from living things
- [ ] are basically different – we call them all energy but in physics they're different things
- [ ] always involve objects that are moving, or have moving parts
- [x] involve either things moving, or the potential to make things move

2.2 PRAC: ENERGY TOYS

This page has two small, fun, pracs involving energy transformations and transfers. With students aware of different types of energy from the previous lesson, it should be clear to them that energy is changing form, sometimes several times, with these.

Note: We don't formally introduce the terms energy transformation *or* energy transfer *in this demo – this is done in the next lesson – however there is no harm using the terms.*

- For both demonstrations the main transformation is **elastic** → **kinetic**. The final question asks them to identify similarities and differences between the examples.
- For each demonstration the students are asked to write an 'energy story', essentially the sequence of energy types. We suggest that they discuss with a peer first. We also suggest that they draw diagrams. This will help reinforce understanding but will take longer and you may choose to skip this (or require it).
- For the jumping cups we extend the transformation chain to include the kinetic → gravitational potential → kinetic transformations of the jump. You may want to extend the chain backwards, too, to the food energy used for muscles to wind up or stretch the toys, and possibly beyond.
- Most of the energy in these examples will end up as heat. You may want to mention this, but it is covered more fully later, in *Branching Transformations*.
- Encourage students if they note that the elastic-to-kinetic transformations all have some sound (and heat) transformations occurring as well, but again note that this will be dealt with later. For the mean time concentrate on the 'main' transformations.

Play

The main focus of this demo is to demonstrate simple transformations of one energy form to another, however we recommend allowing students to play trying out different things – for example, setting the jumping cups on different surfaces – in order to make the demo fun and raise other questions about what is going on.

Note: We use the jumping cups again, later in the course, to observe that the elastic energy transforms into more than one new energy type.

An 'additional challenge' asks students to make the cotton-reel racers go faster or further. This is to introduce the ideas of variables and fair comparisons. It can be used as a quick exercise, a mini project, or omitted completely. See the teaching note before the challenge for further discussion.

KEY QUESTION

- What happens to the energy in these toys?

Energy stories

If you watch something for a while, you can generally tell an *energy story* about it. That is, you can say what it does, or what happens to it, paying particular attention to its energy.

You know how to identify quite a few types of energy now, so you should have no trouble telling energy stories for the devices in these demonstrations.

COTTON-REEL RACER

Set up the cotton-reel racer and get it going. You may have to play around a bit before you get it to run smoothly.(watch the video below if you need).

How to use the cotton-reel racer
https://youtu.be/qrAqzPIPaF0

https://australiascience.tv/episode/stelr-cotton-reel-racer/

Question 1

Discuss with a classmate and then write the energy story of the racer.

See if you can include the following in your story:

- Is any potential energy involved?

Is any kinetic energy involved?

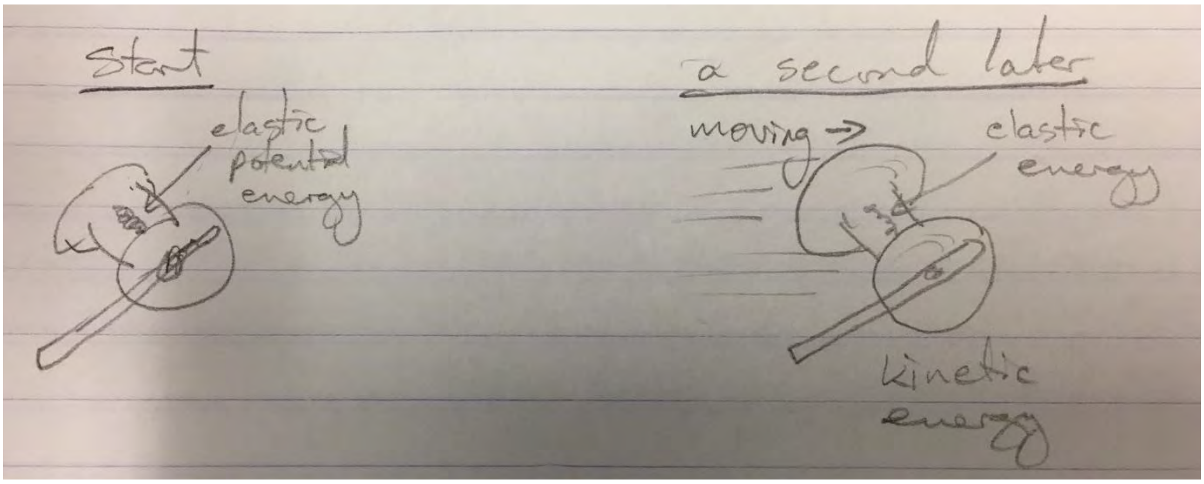
Does energy change location?

Note: It will help your story a lot if you include diagrams.

For example…

I have chemical energy in me from food. This makes my muscles move, which is kinetic energy, and I used this to wind up the rubber band, which was giving it elastic energy. Elastic energy is a form of potential energy. When I let the racer go it ran across the bench. That's movement so it was kinetic energy.

When the rubber band was half unwound it still had some elastic energy left, but the racer had moved, so that's an example of elastic energy moving.



Question 2

When the racer is moving along it seems to be using up one form of energy and turning it into another form.

Write what the energy types are in the boxes.

elastic → kinetic

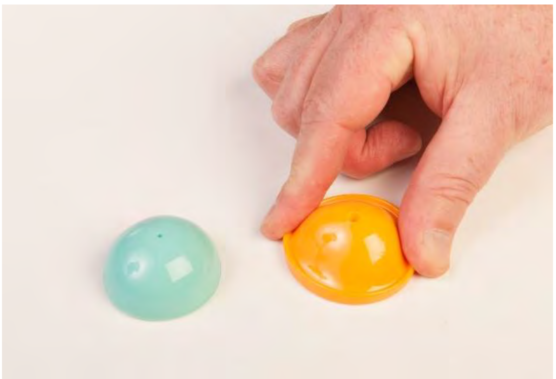
JUMPING CUPS

Instruction video if you need ….

https://www.youtube.com/watch?v=J7Km6DhYs0Y

https://australiascience.tv/episode/stelr-jumping-cups/

Fold a jumping cup inside out and place it on a tabletop. Let go and stand clear...



Question 3

Discuss with a classmate and then write the energy story of a jumping cup.

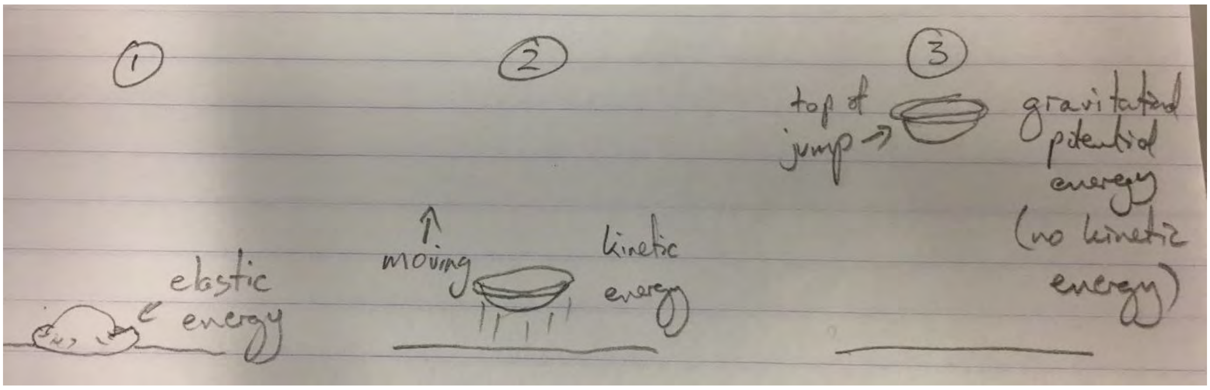
See if you can include the following:

- Is any potential energy involved?

Is any kinetic energy involved?

Note: As before, consider using diagrams to illustrate your story.

My muscles used chemical energy from my food to twist the jumping cup. That was kinetic energy from my muscles giving the jumping cup elastic energy, which is a form of potential energy. Then the jumping cup sat for a bit without moving. It was just sitting there holding on to its elastic energy. Then, pop! it took off. It had quite a bit of kinetic energy to start as it jumped up, but it lost this as it got higher. It lost its kinetic energy as it got more gravitational potential energy. Then it got as high as it would go. It had no kinetic energy very briefly, but it was at its highest so it had its most gravitational energy. As it came down it lost gravitational energy and picked up speed again...kinetic energy.



Question 4

Consider a jumping cup from the time that you let it go until when it falls back to the table top again (just before it hits the table).

Identify the main types of energy that the cup has in this time and write them in order, using arrows to show the changes.

elastic → kinetic → gravitational → kinetic

WRAP-UP

The wrap-up question is intended for students make explicit the general notion that energy can change form, also possibly that it does so easily and often, in different combinations.

- All the demonstrations have an **elastic** → **kinetic** transformation as the main event

Students might note differences in the different types of elasticity (twisting, distorting, extending) and the different kinetic motions (rolling along horizontally, jumping upwards).

Question 5

Compare the two demonstrations and your energy stories for them.

- In terms of the energy involved, both the demonstrations had something in common. What?
  Hint: This should be evident from the energy changes that you identified in Question 2, and Question 4.

Describe two differences in this common feature in the two demonstrations.

[sample answer below…students may make other observations, for example in each case the elastic potential energy came from kinetic energy in our hands, from our muscles.]

All of the demonstrations have a change from elastic energy, which is potential, to kinetic energy. The elastic energy seems to be 'used up' as it creates the kinetic energy.

Two differences are:

1. In the cotton reel racer the elastic energy was stored by a stretchy material being twisted around and around, whereas in the jumping cups there was also a stretchy material (although not as stretchy) that was pushed inside out.

2. The kinetic motion in the cotton reel racer was rotational, which resulted in the racer moving along horizontally. In the jumping cup the kinetic energy in the cup was in one direction, up.

The extra challenge below is intended as a way to introduce students to the concepts of variables and fair comparisons. To see the effects of the changes they make they have to keep all variables constant except one.
The exercise is fairly open...at your discretion students can play with the racer and quickly answer what changes they made, or develop ideas with the questions

provided. These offer the possibility of students quantifying input and output variables, recording data in tables and graphing it.
The simplest variables we can think of are:

- increasing the number of rotations on the rubber band
- increasing the number of rubber bands
- changing the rubber band's length or thickness
- starting the racer from a small ramp

EXTRA CHALLENGE

Can you make the cotton reel racer go faster or further?

Decide which you want to aim for – speed or distance – and see what you can do to improve the racer's performance. Compete with others to see who does best.

Then answer one or more of the questions below...

Question 6

Choose from the questions below. Students could provide a written report of their answers or they could use video, photos, diagrams, graphs or tables to answer.

- What did you do to make your racer go faster or further? How much difference did it make?
- How do you know that it was the change that you made that made the racer go faster or further, rather than something else?
- Can you find two things to change to make the racer go faster or further? If so, which one has the greatest effect? Explain.
- Can you quantify what you changed (this means, can you measure or count it)? If so, can you measure how much faster or further your racer goes for each extra unit of the change you make?
- Do changes that increase a racer's speed also increase the distance it travels, and vice versa? Explain.

2.3 LESSON: TRANSFORMATIONS AND TRANSFERS

Having demonstrated energy transformations and transfers with the cotton-reel racer, jumping cups, this lesson introduces the terms formally and reinforces the principles.

- Energy transformation is introduced in the context of uses of fossil fuels, to maintain the link to global warming.
- Transformations are represented with word formulas: [energy type 1] → [energy type 2]
- The chain of transformations that occur in a hydro-electric power station is explained, introducing *turbines* and *generators*. This will help students understand other electricity-generating methods, e.g. wind turbines and coal-fired power stations, later.
- Energy transfer is explained with examples and students asked to find further examples.

Engagement

Consider using this music video, featuring an exceptional Rube Goldberg machine, as stimulus.

KEY QUESTIONS

- What is energy transformation and how can we represent it?
- What is energy transfer?

ENERGY TRANSFORMATION

Fossil fuels such as coal, oil and natural gas contain chemical energy. But when we use them, it's not chemical energy that we want. We want:

- kinetic energy, for example using petrol to power cars;
- heat, for example in a gas home-heating system;
- electrical energy, for example in coal-fired power stations.

We start with energy in one form, and then **transform** it into another.

We can represent energy transformations with word formulas, using arrows. For example, for a car using petrol the transformation is:

chemical energy → kinetic energy

Burning gas for heat it's:

chemical energy → heat

and in a coal-fired power station it's:

chemical energy → electrical energy

Question 1

Like all coal-fired power stations, Eraring in New South Wales is designed to carry out a particular type of energy transformation. In this photo you can see coal, electrical poles and wires, and structures where the transformation takes place.

> If possible, give students three small paper stickers for this question. They stick these on the picture over the coal, the substation, and the plant itself, and label them appropriately.

Put stickers on the photo where the chemical energy is, where the electrical energy is, and where the energy transformation takes place. Write 'chemical energy' and 'electrical energy' on the appropriate stickers, and draw an arrow in the right direction for the transformation. (Write on the photo if you don't have stickers).

Credit: CSIRO science image

Question 2

The poster to the left was issued in the United States during the First World War.

- Explain the message it is conveying.

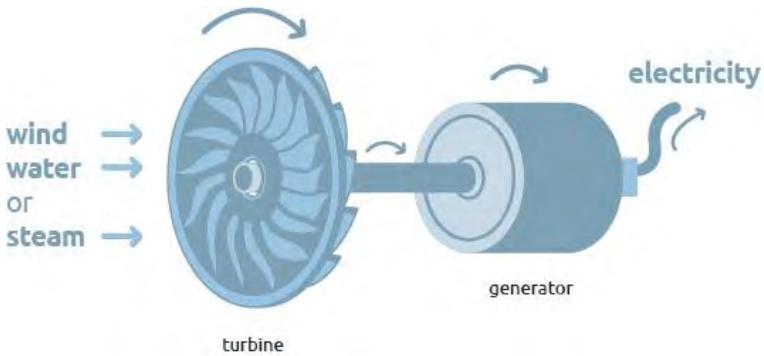
Do you think that 'consumes' is a good word to use here? What would be a more scientific way of saying 'light consumes coal'?

1. It is saying that the light that comes from light bulbs in buildings and streets etc. comes from coal, which has to be burned to get the energy. So by turning off lights people will use less coal.

2. Students may or may not defend the use of the word 'consumes'. A more scientific way of putting this would be 'chemical energy in coal is transformed into light energy'.

Turbines and generators

Coal-fired power stations do not transform coal's chemical energy into electricity directly – there is a chain of transformations in between.



In a coal-fired power station, the coal fires heat up water to make high-pressure steam to turn a *turbine* – a mechanism that spins The turbine, in turn, spins a *generator* – a mechanism that turns mechanical energy into electricity (by spinning a magnet inside wiring, but you don't have to remember this). Hydro-electric power stations use falling water to turn the turbine and wind turbines use moving air.

Question 3

Turbines are moved by wind, water or steam. Which of the following best describes the energy transformations when a turbine is connected to a generator to create electricity?

- [x] kinetic → mechanical → electricity
- [ ] mechanical → gravitational → electricity
- [ ] kinetic → chemical → electricity
- [ ] elastic → kinetic → electricity
- [ ] light → elastic → electricity

Hydro-electric power

Two hydro-electric plants in Tasmania. Left. Wilmot power station, 32 MW. Water flows down the pipe to the turbine in the building at the bottom. Right: The Gordon Dam, 450 MW. Three underground turbines are fed from an 80 m vertical channel from the bottom of the lake. Credit: Hydro Tasmania

In hydro-electric power stations, turbines are moved by water. The water comes from dams above the turbines, where it has gravitational potential energy relative to the turbines.

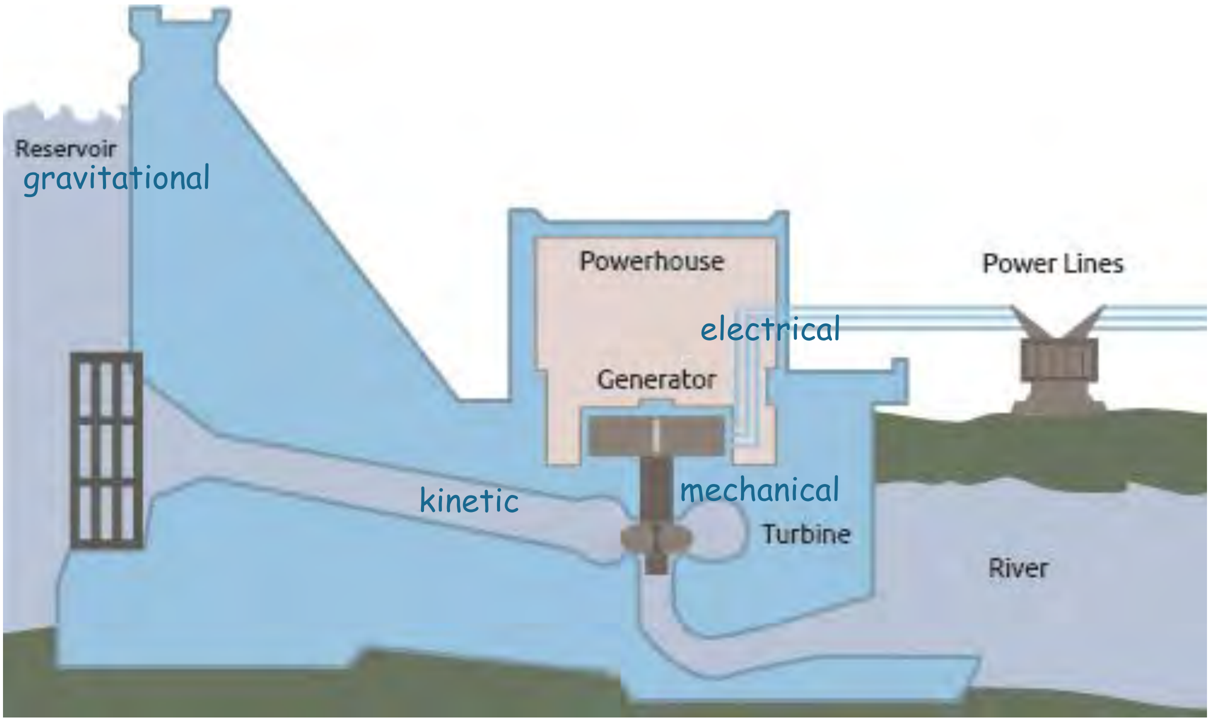
Water is piped to the turbines from the bottoms of the dams. Sometimes the turbines are at the base of the dam and sometimes they are further downhill (or even underground, as at the Gordon dam) to maximise the height of the water above them.

Question 4

Below is a diagram of a hydro-electric power station.

User stickers or a contrasting coloured pen to label where the following types of energy are:

1. electrical
2. mechanical
3. gravitational
4. kinetic



Question 5

Create a word formula for the three energy transformations that occur in a hydro-electric power station. Write the four energy types in the boxes below.

gravitational → kinetic → mechanical → electrical

ENERGY TRANSFER

Energy **transfer** is when energy stays in the same form, but moves from one place to another. Here are two examples:

- **Turbine spinning a generator**
  In a power station the turbine is connected to the generator by a shaft – a long metal rod. The mechanical energy of the turbine is transferred along the shaft and becomes mechanical energy in the generator.
- **Power lines**
  Electrical energy generated in power stations is transferred *via* power lines to houses and businesses where it is used.

Some examples for the question below:

- kinetic – kicking a ball
- light – from Sun to Earth
- sound – from speaker to ear
- heat – from base of pot to handle of pot

Question 6

Describe two other examples of energy transfer.

Energy type	Transfer example
kinetic	An bowling ball hits the pins…some of the kinetic energy of the ball is transferred to the pins, which start to move
sound	A whale call can travel thousands of kilometres in the ocean

WRAP-UP

Are you on top of what energy transfers and transformations are?

Question 7

Which is the best description of what energy transformation is?

- ☐ when something gets more energy
- ☐ when energy in a particular form moves from one place to another
- ☐ when energy changes into matter
- ☑ when energy changes from one form into another

Question 8

Which is the best description of what energy transfer is?

- ☐ when something gets more energy
- ☑ when energy in a particular form moves from one place to another
- ☐ when energy changes into matter
- ☐ when energy changes from one form into another

2.4 PRAC: TRANSFORMATIONS AND TRANSFERS

This prac has six stations that students rotate around in small groups (5–7 mins/station). They operate simple equipment and observe a variety of energy transformations and transfers. A summary section prompts them to bring together what they have learned from the different stations.

- There's no need to set up all the stations if this is inconvenient or if you want to save time.
- You need to prepare all the stations before the class starts.
  Note: You need to make your own small collection of toys for the first station (see the teacher's note below for further information).
- Test each station to make sure it works as expected.

Goals

- Students see that energy transformations and transfers are common and occur in many different combinations (many are useful, taken advantage of with technology that we use)
- Students get a simple and friendly introduction to electrical circuits and the STELR equipment.

Two sub-themes

Additional questions for some of the demonstrations introduce two subsidiary themes:

- the more energy that goes into an energy transformation, the more comes out, and
- the flow of electricity is directional.

These themes are not developed in detail but are intended to seed the ideas of energy conservation and electrical circuits. Students are asked to consider the examples they have observed on the prac summary page, where they should be able to generalise to state the two themes. Skip these questions if you do not want to include these elements.

KEY QUESTION

- How many energy transformations and transfers can you identify?

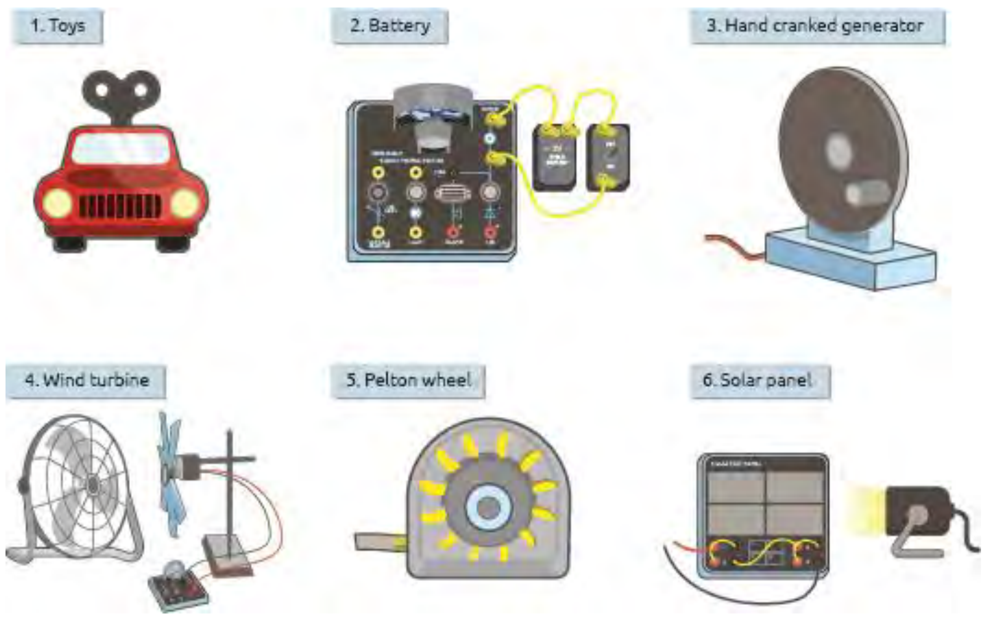
In this prac you get to observe more energy transformations, most of them with electricity as one of the energy forms. Look out for energy transfers as well.

There are six stations. In groups, move around to explore the energy transfers and transformations that can be carried out on the equipment at each one.

Each station should be ready for you when you get to it, which means:

leave each station as you found it!

The numbers and names of the stations are...



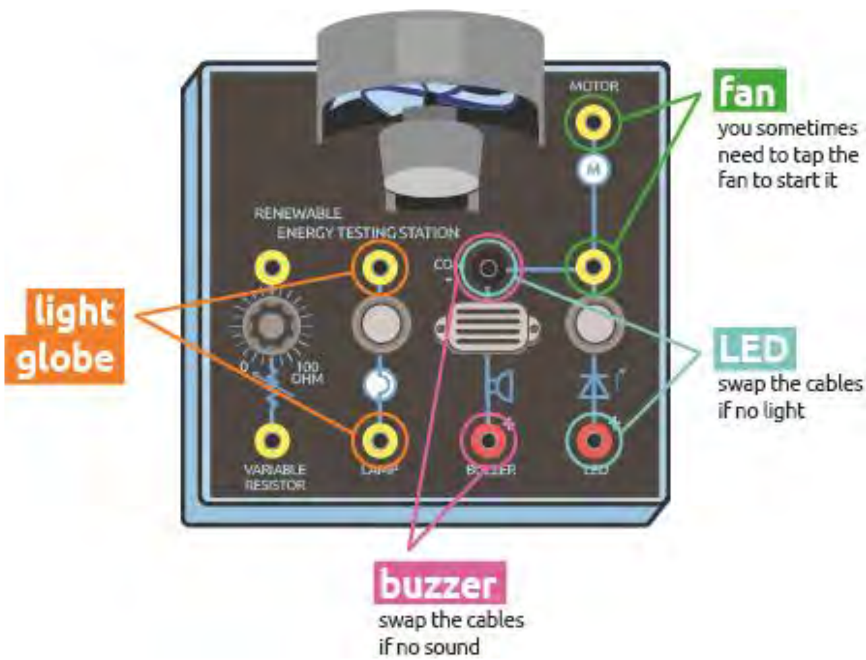
Your teacher will give you directions for each station and tables to record your observations.

Additional questions

For some of the stations there are a few additional questions, after you've noted the transfers and transformations.

Fan, buzzer and lamp

At stations 2 to 6 you'll use the fan, buzzer or lamp on the STELR testing station. See the diagram below for the connections to use and a couple of hints.



2.4.1 STATION 1: TOYS

You need a small collection of suitable toys for this exercise – three or four would be good but two is sufficient. Any toy that stores potential energy and releases it when it runs will do, e.g. music boxes, pull-back cars, battery-powered toys and any type of wind-up toy.

This station has a number of different wind-up or battery-powered toys.

WHAT TO DO

Examine the toys and make them work.

Think about the starting energy in each toy and how it might be *transferred* from one place to the next, or how it is *transformed* into another form of energy.

Question 1

Toy 1: Give a brief description of the toy and a quick explanation of how you think it works.

Depends on the toy…e.g. wind-up toys take energy from our muscles to wind up a spring (elastic energy) which is then released as kinetic energy and sound in the toy.

Question 2

Toy 2: Give a brief description of the toy and a quick explanation of how you think it works.

As above.

Question 3

Identify energy transformations and transfers in the toys.

Toy no.	Energy transformations	Energy transfers
1	(for example) kinetic of muscles to elastic of wound spring	sound from the toy to your ear
2	Chemical (from battery) to mechanical	One mechanical part make another part move

2.4.2 STATION 2: BATTERY

This station connects the battery to the fan and buzzer, so has transformations:

- chemical → electrical → kinetic
- chemical → electrical → sound

In case students are not sure that a battery has potential chemical energy there is a diagram of an electric cell, labelled with 'chemical A' and 'chemical B' to act as a hint.
Energy transfers occur in the cabling and in the shaft of the motor/fan.

Setup

As in diagram A below.

Additional questions

Students reverse the current for both circuits:

- the fan goes in the opposite direction
- the buzzer doesn't work

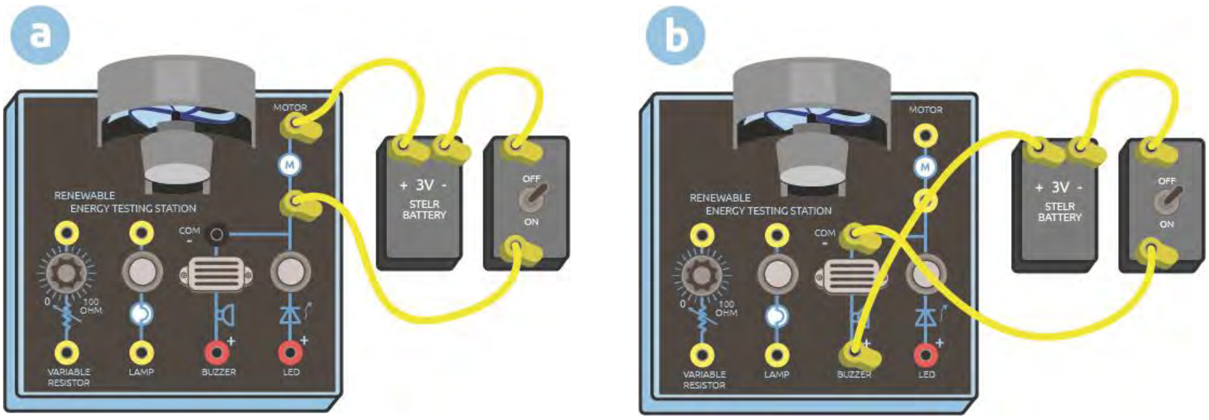
A video showing the features of the STELR testing station can be found here:

https://www.youtube.com/watch?v=pQ6oKjOtXrs

or here:

https://australiascience.tv/episode/stelr-testing-station/

This station has the STELR battery connected to the fan and then the buzzer on the testing station.



WHAT TO DO

- With the equipment set up as in A above, turn on the switch and observe what happens.
- Turn off the switch and reconnect as in B:

  a. **red +** on the battery → **red + BUZZER** on the testing station

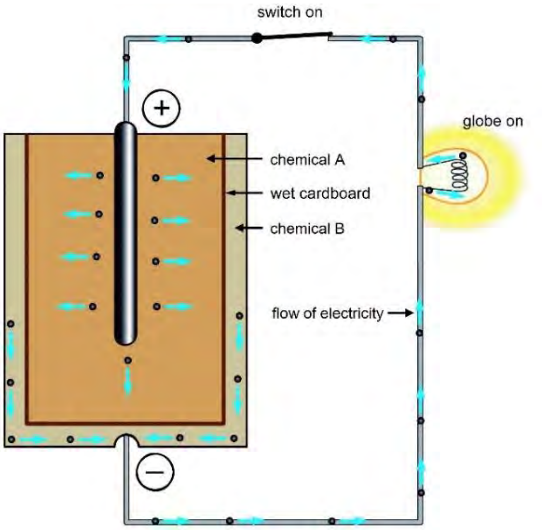
b. switch connector → **black COM –** on the testing station
Turn on the switch and observe.

Question 4

Identify energy transformations and transfers in the two setups.

	Energy transformations	Energy transfers
Fan	(for example) electrical to mechanical	kinetic, from the motor shaft to the fan blades
Buzzer	electrical to sound	electrical, from one part of the circuit to another

If you're not sure about the type of energy in a battery, the diagram to the right should give you a clue.



ADDITIONAL QUESTIONS

For both setups, swap the connections to the testing station.

Question 5

Did you observe any changes when you reversed the cables to the fan? If so, describe them. *Hint: Look closely...there is a difference.*

The fan rotated in the opposite direction.

Question 6

Did you observe any changes when you reversed the cables to the buzzer? If so, describe them.

The buzzer didn't work with the cables reversed.

When you're finished leave the equipment as in diagram A, with the switch off.

2.4.3 STATION 3: HAND-CRANKED GENERATOR

This station connects the hand-cranked generator to the fan and lamp, so has transformations:

- kinetic (hand) → mechanical (hand-crank) → electrical (generator) → kinetic (fan)
- kinetic (hand) → mechanical (hand-crank) → electrical (generator) → light (lamp)

Energy transfers occur between the hand and crank and the crank and the generator, in the electrical wires and in the shaft of the motor/fan. Light coming from the lamp to the eye is another example.
Note: The hand turning the crank can be described either as a transfer of kinetic energy or a transformation from kinetic energy (in the hand) to mechanical energy (in the crank). This illustrates some of the vagueness about the terminology here.

Setup

As in the photo below, with the hand-cranked generator connected to the fan. It doesn't matter which connection points are used.

Additional questions

Students reverse the direction of crank and speed of crank for both circuits:

- the fan goes in the opposite direction and speeds up and slows down
- the lamp works the same for both directions and glows brighter and softer

A video showing how to use the STELR hand-cranked generator can be found here:

https://www.youtube.com/watch?v=LybgdVoUzgY

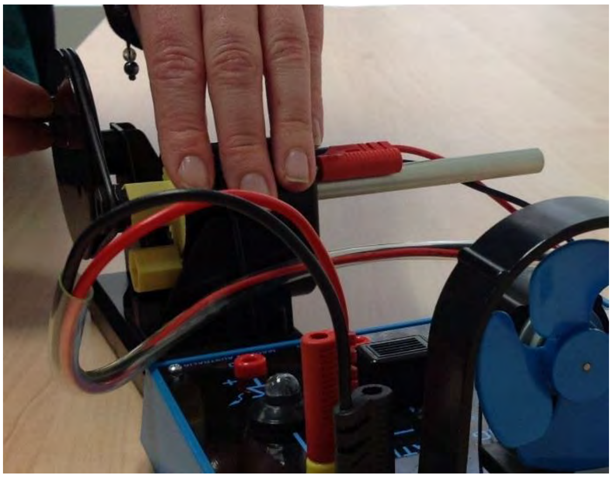
Or here:

https://australiascience.tv/episode/stelr-hand-cranked-generator/

This station has the STELR hand-cranked generator connected to the fan and then the lamp on the testing station.

WHAT TO DO

- With the hand-cranked generator connected to the MOTOR connections, turn the handle of the generator. Observe.
- Move the cables on the testing station to the two yellow LAMP connections.
- Turn the generator handle and observe.



Question 7

Identify energy transformations and transfers in the two setups.

	Energy transformations	Energy transfers
Fan	(for example) mechanical (of fan) to kinetic (of air)	sound of fan from the fan to your ear
Lamp	electrical to light	light transfers from the lamp to your eye

ADDITIONAL OBSERVATIONS

With the generator connected to the fan:

- turn the handle each way. Does it make any difference?
- change the speed as you turn the handle. Does it make any difference?

With the generator connected to the lamp:

- turn the handle each way. Does it make any difference?
- change the speed as you turn the handle. Does it make any difference?

Question 8

What did you observe with the fan:

- when you changed the direction that you cranked?
- when you changed the speed that you cranked?

1. The direction the fan rotated reversed when the generator was cranked the other way.

2. When we cranked faster the fan spun faster, and when we cranked more slowly the fan slowed down.

Question 9

What did you observe with the lamp:

- when you changed the direction that you cranked?
- when you changed the speed that you cranked?

1. There was no difference to the lamp when we changed the direction we cranked.

2. When we cranked faster the lamp glowed more brightly. When we cranked slowly the lamp glowed dimly.

When you're finished leave the generator connected to the fan.

2.4.4 STATION 4: WIND TURBINE

This station connects the wind turbine to the buzzer and lamp, so has transformations:

- kinetic (wind) → mechanical (turbine) → electrical (generator) → sound (buzzer)
- kinetic (wind) → mechanical (turbine) → electrical (generator) → light (lamp)

Energy transfers occur for the wind between the fan and turbine, in the shaft between the turbine and the generator, in the electrical cabling, for sound coming from the buzzer to the ear and the light coming from the lamp to the eye.
Note: The wind turning the turbine can be described either as a transfer of kinetic energy or a transformation from kinetic energy (in the wind) to mechanical energy (in the turbine).

Setup

As in the picture below, with the turbine connected to the buzzer. Check to make sure the circuit is connected so the buzzer works – if not swap connections. The fan should be about 50 cm in front of the turbine.

Additional questions

Students change the fan settings:

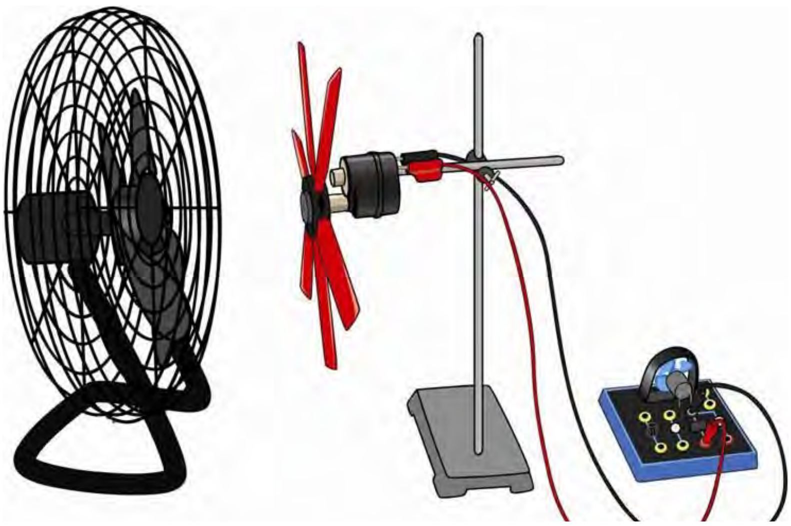
- there is slight variation in the volume of the buzzer but not much – it reaches a threshold and stays there
- the lamp gets brighter and dimmer

A video showing how to set up the STELR wind turbine can be found here:

https://www.youtube.com/watch?v=BYsvJ0ReMiE

Or here: https://australiascience.tv/episode/stelr-wind-turbine/

This station has the wind turbine connected to the buzzer and then the lamp on the testing station.



Initial setup with the wind turbine connected to the buzzer.

WHAT TO DO

- Turn the fan on medium and listen.
- Move the cables to the two yellow LAMP connections on the testing station.
- Observe.
- Turn off the fan.

Question 10

Identify energy transformations and transfers in the two setups.

	Energy transformations	Energy transfers
Buzzer	(for example) kinetic (of air) to mechanical (of wind turbine)	electrical, from the wind turbine to the buzzer
Lamp	mechanical (of turbine) to electrical	electrical, from the wind turbine to the lamp

ADDITIONAL OBSERVATIONS

With the turbine connected to the buzzer and, after that, to the lamp, change the fan setting between low, medium and high.

Question 11

Did you notice any changes with the buzzer when you changed the fan setting? If so, describe them.

The buzzer buzzed louder when the fan was higher, (but this may be subtle, and the wind turbine may not turn at the lower fan settings).

Question 12

Did you notice any changes with the lamp when you changed the fan setting? If so, describe them.

The lamp glowed more brightly when the fan was higher, (but this may be subtle, and the wind turbine may not turn at the lower fan settings).

When you're finished leave the turbine connected to the buzzer (so it will sound). Turn off the fan.

2.4.5 STATION 5: PELTON WHEEL

This station connects the Pelton wheel to the lamp and LED, so has transformations:

- kinetic (water) → mechanical (Pelton wheel) → electrical (generator) → light (LED)
- kinetic (water) → mechanical (Pelton wheel) → electrical (generator) → light (LED)

Energy transfers occur for the water between the tap and turbine, from the turbine to the generator, in the electrical cabling, and for the light coming from the lamp and LED to the eye.

Setup

With the Pelton wheel connected to the lamp on the testing station. See video for setup instructions.

Additional questions

Students alter the flow of water with the tap and reverse the connections to the lamp and LED:

- the lamp gets brighter and dimmer as water flow increases and decreases; it lights up however it is connected
- there is some variability in the brightness of the LED, but it reaches a maximum threshold fairly quickly; it only works when connected one way

They also disconnect the circuit and listen for any difference in speed in the Pelton wheel:

- the wheel speeds up when the circuit is disconnected

A video showing how to use the STELR Pelton wheel can be found here: https://www.youtube.com/watch?v=GDQSGVlsF7E

Or here: https://australiascience.tv/episode/how-to-use-the-stelr-pelton-wheel/

This station has the STELR Pelton wheel connected first to the lamp and then the LED on the testing station.

Pelton wheels are a type of water turbine. Traditional water wheels feed water to the top of the wheel and the water's weight turns the wheel. Pelton wheels use the force of the running water striking the 'buckets' around the wheel.

A Pelton wheel from the Walchensee Power Plant, Germany. Credit: Wikimedia Commons

WHAT TO DO

- Make sure that the hose is firmly connected to the tap and Pelton wheel, and that the water coming out of the wheel will flow into the sink.
- Turn on the tap to get the Pelton wheel spinning and observe.
- Move the cables to the red **+ LED** and black **COM –** connections on the testing station. If the LED doesn't light up, swap the connections.
- Observe.
- Turn off the tap.

Question 13

Identify energy transformations and transfers in the two setups.

Setup	Energy transformations	Energy transfers
Lamp	(for example) kinetic (of water) to mechanical of Pelton wheel	kinetic of water, from tap to Pelton wheel
LED	mechanical of Pelton wheel to electrical	light from LED to your eye

ADDITIONAL OBSERVATIONS

- Turn the tap handle to change the water flow from the tap for both the lamp and LED.
  CAREFUL! Don't twist the tap onto full rapidly!

Reverse the connections for the lamp and LED.

Question 14

What did you observe with the lamp when you changed the water flow and swapped connections?

1. The stronger the flow of water the brighter the lamp glowed.
2. There was no observable difference when the connections to the lamp were reversed.

Question 15

What did you observe with the LED when you changed the water flow and swapped connections?

1. There was not much change in the brightness of the LED, but it went off at low water flow.
2. When we swapped connections the LED didn't glow at all.

Now set the tap so that the lamp or LED is glowing. Listening carefully, pull out a cable connector from the testing station.

> Students may need quiet for the following test. When they disconnect the lamp or LED they should be able to hear the Pelton wheel speed up.

Question 16

Did you hear anything when the cable connector was pulled out of the testing station? Describe what you heard.

We could hear the Pelton wheel speed up.

When you're finished, leave the Pelton wheel connected to the lamp, with the tap turned off.

2.4.6 STATION 6: SOLAR PANEL

This station connects the STELR solar panel to the fan and LED, so has transformations:

- light (or electromagnetic radiation) → electrical → kinetic (fan)
- light (or electromagnetic radiation) → electrical → light (LED)

Energy transfers occur for the light between the halogen lamps and solar panel, in the electrical cabling, in the shaft of the motor/fan and for light coming from the LED to the eye.

Setup

As in the picture below with the halogen lamps and power supply, and the solar panel connected to the fan on the testing station,
OR
if it is a sunny day with direct sunlight coming through a window, put the station there and use the sunlight.

- If using the halogen lamps, connect them to the power supply and plug it into a wall socket – use the wall switch to turn the lights on and off.
WARN STUDENTS THAT THE HALOGEN LAMPS GET HOT

use the longer red and black cables to connect the panel to the testing station...this will allow students to move the panel more freely than with the short yellow cables

Connect the cells on the panel in series, i.e. connect negative to positive for cells 1 to 2, 2 to 3 and 3 to 4. We suggest putting the cables at the back of the panel – that is, use the same connection points as in the diagram below but from the back of the panel. Use the positive connector on cell 1 and negative on cell 4 to connect to the testing station.

Additional questions

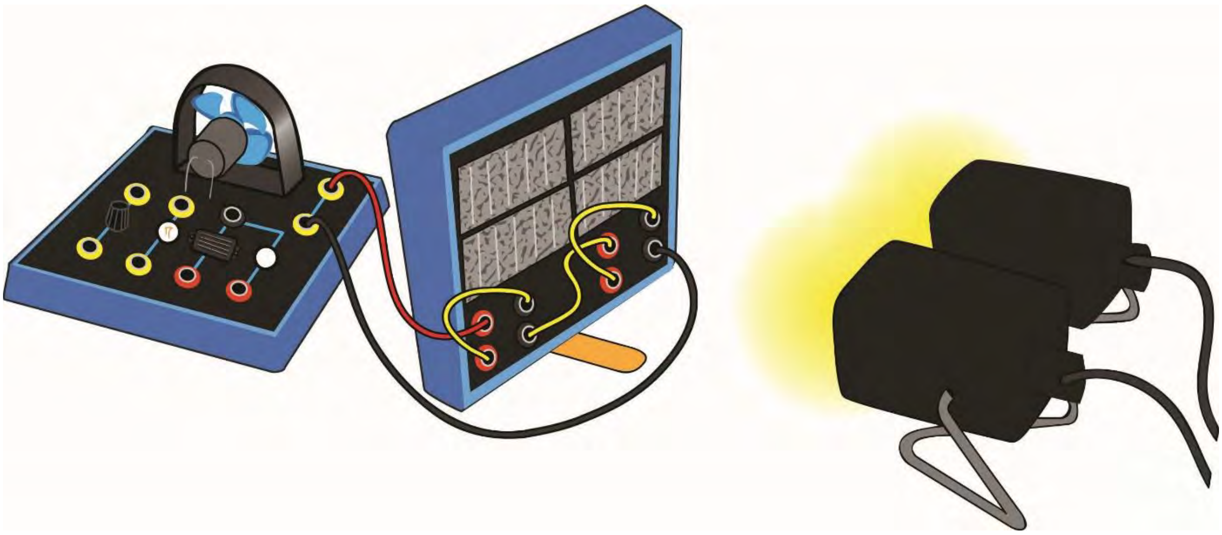
Students change the distance of the halogen lamps from the panels. If using sunlight they can move the panel out of direct sunlight or use their hands or other objects to shade them. They also swap connections on the testing station:

- they should be able to see the fan going at different speeds as the panel gets more or less light. When they swap connections the fan rotates in the opposite direction
- they may see some variation in the brightness of the LED but it quickly reaches a threshold and then doesn't get brighter. It only works connected in one direction

A video showing how to use the STELR solar panel can be found here:
https://www.youtube.com/watch?v=UttPMAlFnWA

Or here: https://australiascience.tv/episode/how-to-use-the-stelr-solar-cells/

This station has the STELR solar panel connected first to the fan and then to the LED on the testing station.



The STELR solar panel connected to the fan.

WHAT TO DO

- If using halogen lamps as a light source, turn them on at the wall and adjust if necessary to point them at the solar panel.
  If using sunlight, move the panel into direct light.
- Observe.
- Move the cables to the red **+ LED** and black **COM –** connections on the testing station. If the LED doesn't light up, swap the connections.
- Observe.
- Turn off the halogen lights or move the panel out of direct sunlight.

Question 17

Identify energy transformations and transfers in the two setups.

Setup	Energy transformations	Energy transfers
Fan	(for example) light to electricity	light, from the halogen lamps to the solar panel
LED	electricity to light	electrical from the solar panel to the LED

ADDITIONAL OBSERVATIONS

- For both the fan and LED, change the amount of light falling on the solar panel by moving the halogen lamps or moving the panel between direct light and shade. **CAREFUL!** The halogen lamps get hot!

Reverse the connections for the lamp and LED.

Question 18

What did you observe with the fan:

- when you changed the amount of light falling on the solar panel?

when you swapped connections?

The fan slowed down or stopped when the solar panel was shaded.

When the connections were swapped the fan rotated in the opposite direction.

Question 19

What did you observe with the LED:

- when you changed the amount of light falling on the solar panel?

when you swapped connections?

There was some but not a lot of variation in the brightness the LED glowed. If the solar panel was shaded too much the LED went out.

The LED didn't work at all when the connections were swapped.

When you're finished, leave the solar panel connected to the fan.
Turn off the halogen lights.

2.4.7 PRAC SUMMARY

The goal of this section is to consolidate concepts hopefully raised in students' minds with the demonstrations at the six stations. Specifically, the questions aim to reinforce the ideas that energy transformations:

- are common, and occur in all sorts of combinations between different energy types,

are used by humans often and in many different ways, and

that it may be that energy in any form can be transformed into any other form, indirectly if not directly. This idea isn't developed, but it's good if students start to wonder about this.

Energy transfers are given less focus, but can still be important in explaining how things happen. Transfer is important in the way we use energy as well.

Additional questions

Two questions consolidate two sub-themes introduced in some of the demonstrations:

- in an energy transformation, the more energy there is in the starting form then the more there is in the transformed form (leading towards the idea of energy conservation), and

direction is important for electricity, at least in some cases (leading towards the idea of current).

Be creative

Students benefit greatly when they represent the same concepts in different ways. The final question asks students to represent an energy transformation in a creative way.

It's time to consider what all the different station setups tell us about energy.

Answer the questions below to help build up an overview.

Question 1

Identify two stations where the starting energy was kinetic energy.

What was similar and what was different about the two examples?

The hand-cranked generator and the Pelton wheel. In both cases something was moving, forcing a mechanism to go round. The difference is that in one case it was a hand moving, and in the other it was water.

Question 2

How many different forms of energy were produced from electrical energy? What were they?

At least three: light, sound mechanical. (But students may know that heat was also produced, and they may count the fan as producing kinetic energy, either in the fan itself or the air).

Question 3

Was there an example of energy transformation **kinetic** → **electrical** → **kinetic**? What was it?

Can you think of another, real-world example, where a train of transformations like this occurs?

If you start and finish with kinetic energy, what is the advantage of such a chain?

Yes, the hand-cranked generator had kinetic energy in the hand, transformed to electrical energy, which then was transformed back to kinetic energy in the fan.

An example of this is a hydro power station transforming kinetic energy of water to electrical energy, then transforming the electrical energy back to kinetic energy in, say, a drill. The advantage is that it is quite easy to transfer electrical energy (once you have power lines set up).

Question 4

Give an example from the prac showing that one type of energy can be produced from different types of energy.

Electrical energy can be produced from light energy (the solar panel) and from kinetic energy (the wind turbine, the Pelton wheel, and the hand-cranked generator).

Question 5

Name some common devices in which the following energy *transformations* take place:

	Transformation	**Example of device**
1	Electrical energy to sound and light energy	**Television, computer**
2	Electrical energy to heat energy	**Toaster, electrical heater, hair dryer**
3	Chemical energy to mechanical energy	**Car engine**
4	Kinetic energy to mechanical energy	**Wind turbine, bicycle**
5	Electrical energy to mechanical energy	**Electric fan**

The following question is intended to push students to think beyond what they've observed in the prac. As such, there is no expectation that they will give any particular answer.

- Some students may know that we hear because sound makes our ear drums vibrate. This could be seen as a transformation from sound to kinetic energy, or a transfer of kinetic energy from air to ear drum.
- If students don't think of this or any other example where sound energy is transformed, they might argue that they expect it can be transformed because most other energy forms seem to be transformable, or they might offer reasons why sound is difficult to transform. What's important is just that they give reasons and look for evidence to support their position.

Question 6

There is no example in the prac of *sound* being transformed into another type of energy.

Do you think that this is because sound is a type of energy that cannot be transformed? Explain.

Various answers acceptable…see teacher note above.

ADDITIONAL QUESTIONS

It could be good to suggest students discuss the following two questions, which are fairly open in form.
We would hope that students will conclude that:

- in an energy transformation, the more energy there is in the first form, the more there will be in the second form. So, for example, the faster you crank the generator, the faster the fan will go, or the brighter the lamp will glow.
- the second question is perhaps more difficult, but ideally students will conclude that electricity moves in a direction, though sometimes this doesn't matter. For example, it makes a big difference for the buzzer and LED, which only work in one direction. The fan works in both directions but itself changes the direction it rotates. For the lamp there is no difference.

Question 7

In the prac you were asked to:

- vary the speed that you turned the hand-cranked generator,
- move the fan different distances from the wind turbine,
- change the amount of water flow in the Pelton wheel, and
- change the amount of light striking the solar panels.

What happened in each case?

Donna, a student, thinks that these examples tell us something about the *amounts* of energy involved in transformations. What could it be? Do you think she's on to something?

In each of the cases above, when we increased or reduced the amount of energy going into the transformation, the amount of transformed energy coming out increased or reduced as well. For example, when the lamp was connected into the circuit it dimmed when we cranked more slowly, when we moved the fan away from the wind turbine (reducing the force of the air flow on the turbine), when we turned down the water flow to the Pelton wheel, and when we shaded the solar panel. In each case the more energy going into the transformation the more came out.

Question 8

Remember what happened when you:

- swapped connections for the lamp, buzzer, fan and LED;
- changed the direction you turned the hand-cranked generator for the lamp and fan.

Derek, another student, says that the results show that electricity always flows in a particular *direction*. Do you think he's right? Explain.

Derek seems to be right, although not all the evidence supports this. In support of the idea that electrical flow has direction is the fact that the fan turned in the opposite direction when the cables were reversed, and also when the hand crank was turned in the opposite direction.. Something made the fan change direction, and all that we had changed was the cable connections or direction of spin, so this seems to say that electricity was first going one way through the fan and then the other way.

The buzzer and LED also support the idea that electricity has direction, though not quite as strongly. In their cases they only work when the cables are connected one way, and not the other. This suggests that the buzzer and LED are designed in such a way that they only operate with electrical flow in one direction.

The lamp doesn't support the idea that electricity flows in a direction – it glows the same whichever way the cables are connected or the crank handle is turned. This doesn't mean that electricity doesn't have a direction of flow, however. It could just mean that lamps work whichever direction the electrical flow is.

2.5 LESSON: BRANCHING TRANSFORMATIONS

In this lesson:

- Students use jumping cups again, to note that there is transformation to sound as well as kinetic energy.
- We introduce energy transformation flow charts, to represent multiple output energy forms from a transformation.
- Most transformations produce heat as one of the output energy forms.
- When energy transformations produce more than one output form we often want just one of these forms and the others are considered 'waste'.

KEY QUESTIONS

- Are energy transformations usually one-to-one?
- How can we represent branching energy transformations?
- What role does heat play in energy transformations?

You should be feeling comfortable with the idea of energy transformations by now, but they're not quite a simple as we've presented them so far. To see this, consider two examples: jumping cups again, and riding a bike.

Example 1: Jumping cups

Make a jumping cup jump on the top of your desk or bench. We know you get this transformation: **elastic** → **kinetic**, but is it the *only* transformation that occurs?

Hint: Listen.

Question 1

What other energy transformation occurs when the jumping cup snaps back into shape?

Elastic → sound

The jumping cup carries out two transformations at once, both starting with elastic energy. These can be represented as two word formulas, as above, but an **energy transformation flow chart** saves time and gives a better overall picture.

You'll see what an energy transformation flow chart is in the next question.

Question 2

Complete the energy transformation flow chart for a jumping cup below.

Example 2: Riding a bike

When you ride a bike, you use chemical energy from your food, and of course the purpose is to make yourself (and the bike) move. But that's not the only energy transformation.

Question 3

Do you stay the same temperature when you ride a bike (at least, if you ride for a while, and the air temperature isn't particularly hot or cold)?

- [ ] Yes, you stay the same temperature.
- [ ] No, you cool down.
- [x] No, you heat up.

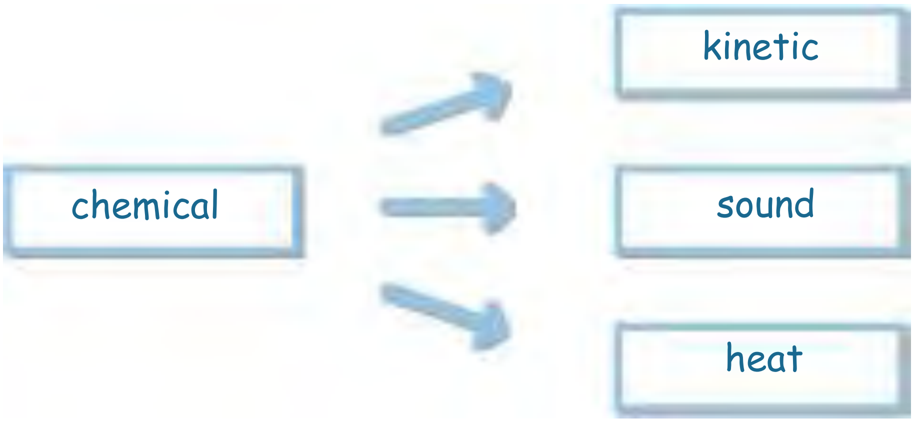
Question 4

Does a bike make any noise (even if it's very little) when you ride it?

- [x] Yes, there's always some sound.
- [ ] No, it doesn't make the slightest sound.

Question 5

With the hints from the questions above, complete a flow chart for the energy transformations that occur when you ride a bike.



Note: It is often said that *all* energy transformations produce some heat, but when a ball or jumping cup going upwards slows down, stops, and then falls, the kinetic → gravitational → kinetic transformations don't produce heat. (At least, very little...there is some due to air resistance. This could be removed if the transformation was carried out in a vacuum).

USEFUL AND WASTE

Whenever we 'use' energy we're actually transforming it from one form into another form that is useful to us.

For example, when we 'use' electricity to run our phones, we're transforming it into light, to see the screen, sound, to listen to music, and radio waves, so that we can make calls. But phones also get warm, due to resistance in the wires that the electricity runs through. So some of the electricity is transformed into heat as well as the forms that we want. From our perspective, the heat is waste energy*.

On the other hand, sometimes we want heat – it just depends on the way we're making use of the energy transformation.

*Maybe this will change in the future – the Australian FLEET Centre (ARC Centre of Excellence in Future Low-Energy Electronics Technologies) is working to create electronics that will have almost no heat loss. 5% of electricity use is for electronics.

5% of electricity use is for IT. The link to FLEET could be good to explore for interested students. It includes some classroom resources.

Question 6

For the machines and devices below, identify which energy types they produce that are useful and which are wasted.

Finish the exercise with two machines or devices of your own.

Device	Wanted energy	Waste energy
	Sound, light	heat
	Mechanical energy (of the engine, shaft and wheels), kinetic energy of the whole car	heat, sound

	Kinetic energy (air blowing) and heat	sound
e.g. Kitchen mixer	Kinetic energy	sound, heat
e.g. gas cooker	Heat	light

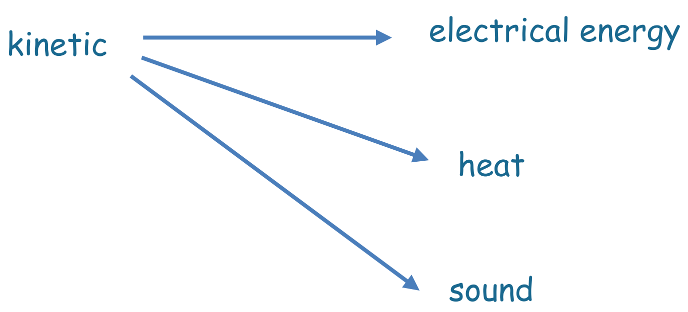
WRAP-UP

What are the main take-away messages you've got from this lesson? The best way to show your teacher is with an energy flow chart.

Question 7

Wind turbines produce electricity, but they make some noise and the mechanisms get hot as well.

Create an energy flow chart to show the energy transformations in a wind turbine.



Question 8

Explain what your chart above means.

The energy form at the start of the transformation is kinetic energy, of the wind. It turns the wind turbine which transforms the wind's kinetic energy into electrical energy but also some sound and heat.

Question 9

Are all the energy types that are produced useful or wanted ? Explain.

No, the sound and heat are waste. Ideally all of the wind's kinetic energy that was transformed would become electrical energy.

2.6 LESSON: ENERGY CONSERVATION

This optional lesson continues from the previous one, covering energy conservation. Officially, energy conservation is introduced in Yr 10 (according to the Australian Curriculum) however nothing in this lesson is beyond Yr 8 students if you choose to include it.

- Students demonstrate that the quantities of sound and kinetic energy that are produced by the jumping cups changes depending on the surface the cups jump from.

Students are asked to consider whether the amount of energy produced in a transformation is the same as the amount of energy in the original form. That is, they're asked to think about whether there is conservation of energy. There's no expectation they'll say there is, but we think there is value in them considering the question for themselves before the answer is given.

Conservation of energy is explained, illustrated with video.

Students design a new way to represent energy transformations that includes the representation of energy conservation. They may well come up with Sankey diagrams on their own. Any other ideas they come up with will be interesting in revealing their understanding.

KEY QUESTIONS

- What happens to the amount of energy during energy transformations?
- How can we represent the amounts of energy in energy transformations?

Most energy transformations produce energy in more than one form. For example, when a jumping cup jumps it transforms elastic energy into kinetic energy, sound and heat.

DEMONSTRATION: JUMPING CUPS, ONE MORE TIME

Use the cups again in a simple demonstration to look at *how much* energy is produced in the different forms: kinetic, sound and heat. We can't measure these accurately – and we won't try to measure heat at all – but it's possible to get enough information to make comparisons:

- the height a cup goes indicates how much kinetic energy it got, and
- how loud it is indicates the amount of sound energy it released.

Try jumping cups on the following surfaces:

- desk or bench-top;
- carpet;
- palm of hand;
- tip of finger;
- any other surfaces you have available.

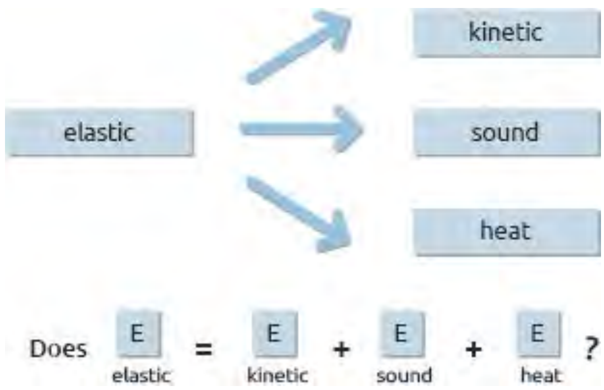
You should have observed quite a range in the heights the cups jumped and some significant differences in the sounds as well!

But, a question:

- Was the total amount of output energy – that is, kinetic, sound and heat – always the same as the amount of elastic energy before the transformation?

If we use $E_{[energy\ form]}$ to represent the amounts of energy (in joules) this is the same as asking if:

$E_{elastic} = E_{kinetic} + E_{sound} + E_{heat}$ is true.



We suggest a show of hands below, although this has the disadvantage that some students may simply vote for the most popular option. You may want to use some other method of getting their opinions.

What's most important is that they give the question some thought and offer reasons for their choices. If they really can't think of any reasons and make a complete guess, they should say so.

Discussion and poll

Discuss the question in groups. You're not going to be able to give an answer for sure, but see if you can think of reasons why you'd answer one way or another. Then answer the poll below in a show of hands.

The options are:

- energy after equals energy before
- energy after is less than energy before
- energy after is more than energy before; and
- it depends...there is not a single rule.

CONSERVATION OF ENERGY

Over many years of observation scientists have concluded that energy cannot be created or destroyed. This is called the **law of conservation of energy**. It means that:

- for the jumping cups that we started this lesson with, $E_{elastic} = E_{kinetic} + E_{sound} + E_{heat}$ is true; and
- In every energy transformation or transfer there is the same amount of energy after as before. The energy is in different forms and/or places but the total number of joules never changes.

Question 1

In almost every energy transformation, a very small amount of energy is destroyed.

☐ true

☑ false

Question 2

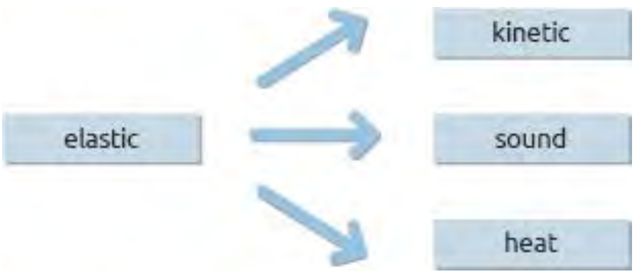
According to the law of conservation of energy, the total amount of energy in the universe never changes.

☑ true

☐ false

Most likely the best way of meeting the challenge below is with Sankey diagrams, but it's good to let students work with their own ideas. If they've already seen Sankey diagrams then they'll probably just reproduce them, but you can still ask them to explain how they work.

CHALLENGE: REPRESENTING THE CONSERVATION OF ENERGY



Flow charts are good at showing when energy transforms into more than one type. But they don't indicate *how much* energy is in each form – for example, in the flow chart to the left, for a jumping cup, it's impossible to tell if most of the energy transformed into kinetic, sound, or heat energy.

Your challenge is to create a way of representing energy transformations that also represents the *amounts* of energy, or at least, the *proportions* of each energy type.

So, for example, your new means of representation should be able to show if (for the transformation above):

- most of the elastic energy became kinetic energy, and
- that overall, energy was conserved.

Question 3

Create a new way to represent energy transformations that indicates relative amounts of energy in each form, and which can be used to represent the conservation of energy.

Note: You'll probably need to try out ideas with pencil and paper, then draw a final copy below.

WRAP-UP

Question 4

In your own words say what the law of the conservation of energy is.

Energy is never created or destroyed, it is only ever transformed from one form into another.

2.7 LESSON: ENERGY EFFICIENCY

This lesson introduces the concept of energy efficiency and the formula used to calculate it.

- In the Australian Curriculum, energy efficiency is introduced with conservation of energy in year 10. We include it as it gives the opportunity to integrate some simple mathematics, which in turn allows students to carry out the experiments that follow. This lesson and the experiments should be well within the capacity of most Year 8 students.

Sankey diagrams are introduced as a way of illustrating efficiency. Energy conservation is implicit in the diagrams but not referred to explicitly.
Note: The idea of some energy forms being wanted and some not was introduced in 3.1 Branching Transformations.

Energy Efficiency extension activities using bouncing balls are found in the Rebound Efficiency resource on the STELR Renewable Energy USB.

KEY QUESTIONS

- What is energy efficiency and how do you calculate it?
- What are Sankey diagrams?

When we transform energy in a machine or with a device, only a portion of the original energy is transformed into the form we want. The rest is wasted – at least, from our perspective.

For example, incandescent light bulbs, like the lamp on your STELR testing station, only transform about 2% of the electrical energy they receive into light. The rest becomes heat. For the purpose that a light bulb is intended to carry out, that's 98% of the energy wasted! In comparison, the LED on the testing station converts a bit under half of the electrical energy it receives into light.

The percentage of energy that a machine or device converts into the form we want is called its **efficiency**.

So in our examples, an incandescent light bulb is just 2% efficient, and an LED is about 50% efficient.

Calculating energy efficiency

Calculate energy efficiency with the following formula:

$$\text{energy efficiency (\%)} = \frac{\text{useful energy out (J)}}{\text{total energy in (J)}} \times 100$$

Example 1

A compact fluorescent light bulb uses 40 J of electrical energy to produce 4 J of light and 36 J of heat. What is the bulb's efficiency?

In this example the useful energy out is the light, so...

$$\text{energy efficiency (\%)} = \frac{\text{useful energy out (J)}}{\text{total energy in (J)}} \times 100$$

$$= \frac{4}{40} \times 100$$

$$= 10\%$$

The bulb is 10% efficient.

Example 2

A toaster uses 80 J of electrical energy to produce 72 J of heat and 8 J of light. How efficient is the toaster?

This time the useful energy out is the heat.

$$\text{energy efficiency (\%)} = \frac{\text{useful energy out (J)}}{\text{total energy in (J)}} \times 100$$

$$= \frac{72}{80} \times 100$$

$$= 90\%$$

The toaster is 90% efficient.

Question 1

A typical coal-fired power station transforms each 1000 J of chemical energy in the coal into 100 J of sound, 550 J of heat, and 350 J of electrical energy. What is such a station's efficiency?

(show your working)

The useful energy in this case is the electricity (350 J), so:

Energy efficiency (%) = (useful energy out/total energy in) x 100 = (350/1000) x 100 = 35%

The power station is 35% efficient.

Question 2

A hair dryer converts each 500 J of electrical energy into 50 J sound, 125 J of kinetic energy (blowing the air), and 325 J of heat. How efficient is the dryer?

Note: Careful...this question is a bit more difficult than the examples.

In the case of a hair dryer there are two forms of energy we want: kinetic energy and heat. So we must add these together to calculate the efficiency.

Wanted energy = kinetic energy output + heat energy output = 125 J + 325 J = 450 J

Now put this into the equation for efficiency:

Energy efficiency (%) = (useful energy out/total energy in) x 100 = (450/500) x 100 = 90%

The hair dryer is 90% efficient.

SANKEY DIAGRAMS

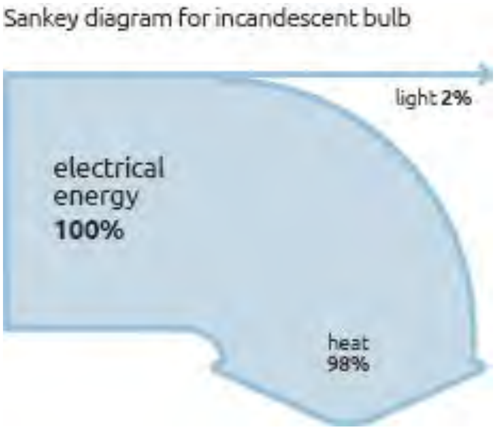
Returning to incandescent bulbs and LEDs, we currently have two ways of representing their energy transformations. We can use a word formula:

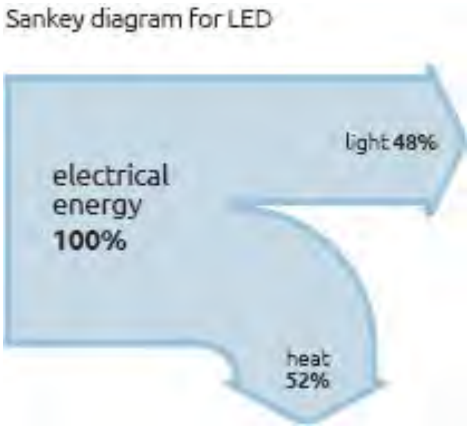
electrical energy → light + heat

or a flow chart, as shown at right.

But with these types of representation incandescent bulbs and LEDs look exactly the same – neither of them show the proportions of the output energy forms.

Sankey diagrams do this:



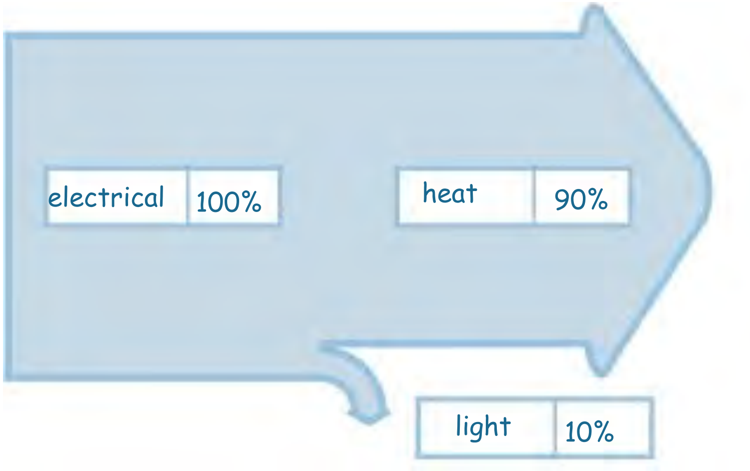


Sankey diagrams use the width of the arrows to represent the proportions of energy. The base of the arrow, on the left, always represents *all* of the starting energy – 100% – then this breaks into arrows to represent each energy type produced in the transformation. Downwards-curving arrows indicate unwanted energy and straight arrows show the energy we want from the transformation.

Question 3

The toaster mentioned above was 90% efficient, wasting the remainder of its input energy as light.

Complete the Sankey diagram for the toaster below by writing the correct energy type – electrical energy, heat or light – in the box for each arrow. Then add the percentage values.



To draw Sankey diagrams accurately you need to calculate the percentage of each of the output energy forms.

This uses essentially the same equation as you used to work out efficiency. For example, to calculate the percentage of energy transformed to heat in a transformation:

$$\text{heat energy (\%)} = \frac{\text{heat produced (J)}}{\text{total energy in (J)}} \times 100$$

or to calculate the percentage of energy transformed to kinetic energy:

$$\text{kinetic energy (\%)} = \frac{\text{kinetic energy produced (J)}}{\text{total energy in (J)}} \times 100$$

Question 4

The hair dryer in the question above transforms each 500 J of electrical energy it receives into:

- 50 J of sound
- 125 J of kinetic energy
- 325 J of heat

So the percentage of sound energy it produces is:

$$\begin{aligned}\text{sound energy (\%)} &= \frac{\text{sound energy produced (J)}}{\text{total energy in (J)}} \times 100 \\ &= \frac{50}{500} \times 100 \\ &= 10\%\end{aligned}$$

Calculate the percentages of kinetic and heat energy that it produces.

kinetic energy (%) = (kinetic energy produced/total energy in) x 100 = (125/500) x 100 = 25%

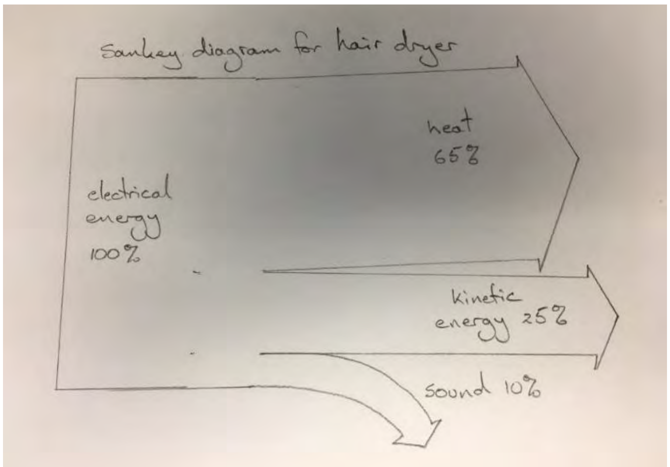
heat energy (%) = (kinetic energy produced/total energy in) x 100 = (325/500) x 100 = 65%

The hair dryer produces 25% kinetic energy and 65% heat.

Question 5

Now draw a Sankey diagram for the hair dryer.

Hint: Don't forget to have the arrows for any waste energy pointing down.



WRAP-UP

Do you know what is meant by efficiency, and how to read and draw Sankey diagrams?

Question 6

In a particular computer tablet, for every 100 J electrical energy that comes from its batteries, 65 J is transformed to light from the screen, 20 J to sound, from audio, and 15 J to heat.

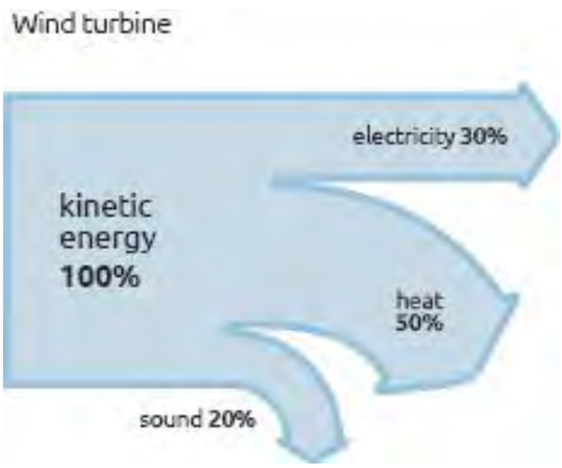
Which of the following are true?

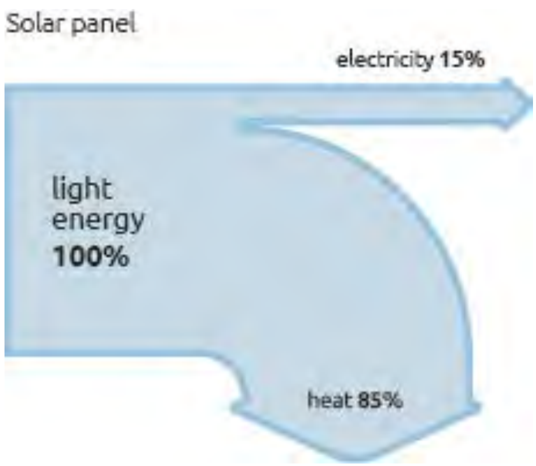
☑ 65% of the tablet's electrical energy is transformed into light energy.

☑ The tablet is 85% efficient.

☑ 15% of the energy transformed from electricity is wasted.

☐ The total output energy (65 J + 20 J + 15 J) equals the input energy (100 J) so the tablet is 100% efficient.





Question 7

The Sankey diagrams above represent the energy transformations that occur in a wind turbine and solar panel.

Which of the following statements are true?

☐ Overall, the wind turbine produces more joules of energy than it receives.

☑ The wind turbine converts more kinetic energy into electricity than sound.

☐ The solar panel is more efficient than the wind turbine.

☑ The solar panel transforms more light into heat than into electricity.

3 ENERGY RESOURCES AND ELECTRICITY

Many trains, including this one on the Gold Coast, are driven by electricity.

This section focuses on the energy form, electricity. The first lesson focuses on electricity in our lives, while the following ones use the STELR equipment to build up understanding of fundamental electrical concepts.

3.1 Fossil Fuels and Greenhouse Gases

This lesson has three main purposes:

- remind students what are fossil fuels and that fossils fuels are a source of greenhouses gases
- Discuss and define the terms renewable and non-renewable. **Renewability:** A quick definition – resources that can be replaced within a human lifetime (around 80 years) are renewable.
- Have students understand that many energy sources are both renewable and also they do not produce greenhouse gases.

KEY QUESTIONS

- What is a fossil fuel?

- What are greenhouse gases?
- What is a renewable energy resource?

FOSSIL FUELS AND GREENHOUSE GASES

Back in lesson 2.1 you watched a video called *Global Warming: Cold Facts, Hot Science*

How well can you remember some of the things you learnt?

Question 1

Burning fossil fuels – coal, oil and natural gas – produces carbon dioxide.

☑ true

☐ false

Question 2

Carbon dioxide is a greenhouse gas.

☑ true

☐ false

Question 3

Increasing the proportion of greenhouse gases in the atmosphere increases the Earth's average air temperature.

☑ true

☐ false

Question 4

Why are coal, oil and natural gas called fossil fuels?

These resources are the fossilised remains of buried plants and animals that died many millions of years ago. (Because the fossilisation process took millions of years, we define these resources as non-renewable)

Question 5

How do you use fossil fuels in your everyday life?

Coal	Very few people use coal directly these days except to fuel a barbeque Some students may know: • that in some states of Australia, coal fired power plants are the major source of electricity • Coal is also an important raw material in steel production
Oil and oil products	Petrol and diesel for transport or to run generators in isolated areas Some students may know: • that oil is a major raw material for the plastics industry
Natural gas	Cooking, heating water Some students may know: • that natural gas is used in some power stations

RENEWABILITY

All of the resources that we use – not only energy resources – can be divided into two categories: renewable and non-renewable.

- **Renewable** resources are those that can be replaced within, roughly, a human lifetime.
- **Non-renewable** resources are those that take longer to be replaced, or they're not replaced at all.

Wheat is a renewable resource – we grow new crops every year. Rock – for concrete, roads and building – is not.

Question 6

Which of the following are renewable resources?

- [ ] diamonds
- [x] wool
- [x] sugar
- [x] timber
- [ ] sand

Question 7

Which of the following energy resources are renewable?

- [x] sunlight
- [ ] coal
- [x] water
- [x] wind
- [ ] natural gas

The point of the questions below is to explore further, the reasons for changing to renewable energy resources.

From the perspective of global warming, we need to change to energy sources that do not produce greenhouse gases.

From the perspective of sustainability, we need to change to energy sources that are not going to run out in the short to medium term.

The major renewable energy sources we use today do not produce greenhouse gases. They are also sustainable. (Note it could be argued that timber is a renewable energy source but it does produce greenhouse gases when burnt).

Are we running out of fossil fuels? Current known reserves give us another hundred years' worth of coal, and about 50 years' each of oil and gas. But new technologies make new deposits viable. For example there are vast amounts of methane hydrate – methane locked in ice crystals – under permafrost and on ocean floors. Currently there are no ways to extract it, but if this becomes possible there is at least twice as much energy value as the known reserves of coal in this potential resource.

You may want to mention carbon sequestration to students – the technology that takes the carbon dioxide from fossil fuel-burning power stations and pumps it underground, where it will remain indefinitely. This provides a means of lowering carbon dioxide emissions into the atmosphere while still using fossil fuels. So it is not essential that we have to stop using fossil fuels in order to cut carbon dioxide emissions. However, carbon sequestration is expensive and has not been taken up to any significant extent.

Question 8

People say that, in order to stop global warming, we have to change to use renewable energy sources. Why?

Most of the renewable sources of energy, including the most prominent ones – hydro power, wind turbines and solar panels – produce electricity without also producing carbon dioxide. Carbon dioxide is the main cause of global warming.

Question 9

How do you think we can make electricity in a more sustainable way?

Answers will vary. Renewable sources of energy, including hydro power, wind turbines and solar panels, are sustainable sources of energy. On the other hand, fossil fuels re not sustainable

Lesson: The Importance of Electricity **Fossil Fuels and Greenhouse Gases**
Students recap their understanding of fossil fuels as a source of greenhouse gases. They explore the concept of renewability.

3.2 Fossil Fuels and Greenhouse Gases

This lesson has three main purposes:

- remind students what are fossil fuels and that fossils fuels are a source of greenhouses gases

- Discuss and define the terms renewable and non-renewable.
  Renewability: A quick definition – resources that can be replaced within a human lifetime (around 80 years) are renewable.
- Have students understand that many energy sources are both renewable and also they do not produce greenhouse gases.

KEY QUESTIONS

- What is a fossil fuel?
- What are greenhouse gases?
- What is a renewable energy resource?

FOSSIL FUELS AND GREENHOUSE GASES

Back in lesson 2.1 you watched a video called *Global Warming: Cold Facts, Hot Science*

How well can you remember some of the things you learnt?

Question 10

Burning fossil fuels – coal, oil and natural gas – produces carbon dioxide.

☑ true

☐ false

Question 11

Carbon dioxide is a greenhouse gas.

☑ true

☐ false

Question 12

Increasing the proportion of greenhouse gases in the atmosphere increases the Earth's average air temperature.

☑ true

☐ false

Question 13

Why are coal, oil and natural gas called fossil fuels?

These resources are the fossilised remains of buried plants and animals that died many millions of years ago. (Because the fossilisation process took millions of years, we define these resources as non-renewable)

Question 14

How do you use fossil fuels in your everyday life?

Coal	Very few people use coal directly these days except to fuel a barbeque Some students may know: • that in some states of Australia, coal fired power plants are the major source of electricity • Coal is also an important raw material in steel production
Oil and oil products	Petrol and diesel for transport or to run generators in isolated areas Some students may know: • that oil is a major raw material for the plastics industry
Natural gas	Cooking, heating water Some students may know: • that natural gas is used in some power stations

RENEWABILITY

All of the resources that we use – not only energy resources – can be divided into two categories: renewable and non-renewable.

- **Renewable** resources are those that can be replaced within, roughly, a human lifetime.
- **Non-renewable** resources are those that take longer to be replaced, or they're not replaced at all.

Wheat is a renewable resource – we grow new crops every year. Rock – for concrete, roads and building – is not.

Question 15

Which of the following are renewable resources?

- [ ] diamonds
- [x] wool
- [x] sugar
- [x] timber
- [ ] sand

Question 16

Which of the following energy resources are renewable?

- [x] sunlight
- [ ] coal
- [x] water
- [x] wind
- [ ] natural gas

The point of the questions below is to explore further, the reasons for changing to renewable energy resources.

From the perspective of global warming, we need to change to energy sources that do not produce greenhouse gases.

From the perspective of sustainability, we need to change to energy sources that are not going to run out in the short to medium term.

The major renewable energy sources we use today do not produce greenhouse gases. They are also sustainable. (Note it could be argued that timber is a renewable energy source but it does produce greenhouse gases when burnt).

Are we running out of fossil fuels? Current known reserves give us another hundred years' worth of coal, and about 50 years' each of oil and gas. But new technologies make new deposits viable. For example there are vast amounts of methane hydrate – methane locked in ice crystals – under permafrost and on ocean floors. Currently there are no ways to extract it, but if this becomes possible there is at least twice as much energy value as the known reserves of coal in this potential resource.

You may want to mention carbon sequestration to students – the technology that takes the carbon dioxide from fossil fuel-burning power stations and pumps it underground, where it will remain indefinitely. This provides a means of lowering carbon dioxide emissions into the atmosphere while still using fossil fuels. So it is not essential that we have to stop using fossil fuels in order to cut carbon dioxide emissions. However, carbon sequestration is expensive and has not been taken up to any significant extent.

Question 17

People say that, in order to stop global warming, we have to change to use renewable energy sources. Why?

Most of the renewable sources of energy, including the most prominent ones – hydro power, wind turbines and solar panels – produce electricity without also producing carbon dioxide. Carbon dioxide is the main cause of global warming.

Question 18

How do you think we can make electricity in a more sustainable way?

Answers will vary. Renewable sources of energy, including hydro power, wind turbines and solar panels, are sustainable sources of energy. On the other hand, fossil fuels re not sustainable

Lesson: The Importance of Electricity Students are led to note the benefits of electricity, in group discussion. Then they are given some real national data on electricity production to analyse. The questions are relatively simple, but give students experience dealing with real data and how it is presented. It also provides background knowledge of actual energy use including current reliance on fossil fuels and potential uses for renewably generated electricity.

Error! Reference source not found. Error! Reference source not found. provides an op portunity for an introductory discussion and research on different energy sources, before they choose one to research in the following project.

3.4 Error! Reference source not found. Students research and present on an e nergy resource of their choosing.

Electricity is central to the way we live in the 21st century, so how does it work? Make some discoveries using the STELR equipment.

3.1 FOSSIL FUELS AND GREENHOUSE GASES

This lesson has three main purposes:

- remind students what are fossil fuels and that fossils fuels are a source of greenhouses gases
- Discuss and define the terms renewable and non-renewable. **Renewability:** A quick definition – resources that can be replaced within a human lifetime (around 80 years) are renewable.
- Have students understand that many energy sources are both renewable and also they do not produce greenhouse gases.

KEY QUESTIONS

- What is a fossil fuel?
- What are greenhouse gases?
- What is a renewable energy resource?

FOSSIL FUELS AND GREENHOUSE GASES

Back in lesson 2.1 you watched a video called *Global Warming: Cold Facts, Hot Science*

How well can you remember some of the things you learnt?

Question 19

Burning fossil fuels – coal, oil and natural gas – produces carbon dioxide.

☑ true

☐ false

Question 20

Carbon dioxide is a greenhouse gas.

☑ true

☐ false

Question 21

Increasing the proportion of greenhouse gases in the atmosphere increases the Earth's average air temperature.

☑ true

☐ false

Question 22

Why are coal, oil and natural gas called fossil fuels?

These resources are the fossilised remains of buried plants and animals that died many millions of years ago. (Because the fossilisation process took millions of years, we define these resources as non-renewable)

Question 23

How do you use fossil fuels in your everyday life?

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RENEWABILITY

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Wheat is a renewable resource – we grow new crops every year. Rock – for concrete, roads and building – is not.

Question 24

Which of the following are renewable resources?

- [ ] diamonds
- [x] wool
- [x] sugar
- [x] timber
- [ ] sand

Question 25

Which of the following energy resources are renewable?

- [x] sunlight
- [ ] coal
- [x] water
- [x] wind
- [ ] natural gas

The point of the questions below is to explore further, the reasons for changing to renewable energy resources.

From the perspective of global warming, we need to change to energy sources that do not produce greenhouse gases.

From the perspective of sustainability, we need to change to energy sources that are not going to run out in the short to medium term.

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Question 26

People say that, in order to stop global warming, we have to change to use renewable energy sources. Why?

Most of the renewable sources of energy, including the most prominent ones – hydro power, wind turbines and solar panels – produce electricity without also producing carbon dioxide. Carbon dioxide is the main cause of global warming.

Question 27

How do you think we can make electricity in a more sustainable way?

Answers will vary. Renewable sources of energy, including hydro power, wind turbines and solar panels, are sustainable sources of energy. On the other hand, fossil fuels re not sustainable

3.2 LESSON: THE IMPORTANCE OF ELECTRICITY

This lesson sets the context for the energy resource project that follows. It starts with a class discussion of the factors that need to be considered in deciding on an energy resource to use at a national level. It has three main purposes:

- remind students of the global warming theme, reinforcing why we're studying energy
- bring the focus from energy in general to electricity in particular – why is electricity so significant in terms of energy resources?
- give students exposure to real, national data related to electricity. This will exercise skills in interpreting data, and give some idea of Australia's energy mix. It ties in with curriculum points relating to resources (Yr 7 in the Australian Curriculum) and provides background preparation for the next section of this unit, 3.3

KEY QUESTIONS

- Why is electricity so useful?
- What energy resources do we use to make electricity?
- How much electricity do we use compared to other types of energy?

WHY ELECTRICITY?

So, what is so good about electricity?

We suggest group followed by class discussion for the following two questions. Hopefully there'll be an element of fun as students forget to say 'transform' instead of 'use'. Also, for the second question, it is amusing to think of a hair dryer or laptop powered by coal or rubber bands (but you could compare old irons that had hot coals put into them).

Question 1

Discuss in groups to make a list of all the ways you can think that we use electricity. Start with your own lives, at home, school, and anywhere else you go, but then think of other places as well.

Some examples might be: we transform electricity into light in lights, into sound and light in TVs, into sound in stereo systems and radios, into light and sound in computers…(and into information), into heat in electric blankets, heaters, ovens, water heaters and toasters, into kinetic energy in mixers, blenders, drills. Into kinetic energy in electric trains, trams and other vehicles. etc.

Question 2

Now discuss what makes electricity so useful. Think of at least two reasons.

Note: If you're not sure, think about some of the ways you use electricity, and whether you could use coal, sunlight, gravitational energy or rubber bands instead.

Reasons we can think of:

- it is relatively cheap and easy to transfer over long distances, once you have the infrastructure set up
- we have a whole range of devices that transform electricity into other forms that we want…all the electrical appliances. Other energy forms aren't as versatile in this way
- electricity is used in electronics, which controls things, often automatically. It can run and use the information from sensors, and then make calculations. This has application from controlling simple electrical appliances through to computers, including digital data (text, images, audio and more) and increasingly, artificial intelligence
- although production of electricity isn't always clean, its use typically is, with heat usually the only waste product.

Some students might note that if we burn bioenergy (in the graph below), it is producing carbon dioxide. This is true, but that carbon dioxide came out of the atmosphere by photosynthesis when the cane or wood grew, so it is just putting back what it took out. For fossil fuels the carbon dioxide has been out of the atmosphere for millions of years.

HOW DO WE MAKE ELECTRICITY?

Electricity isn't a natural resource – there aren't any places on Earth where you just push in some wires and electricity flows out. We have to transform other energy sources into it. What sources do we use? The pie chart below tells you for Australia in 2016.

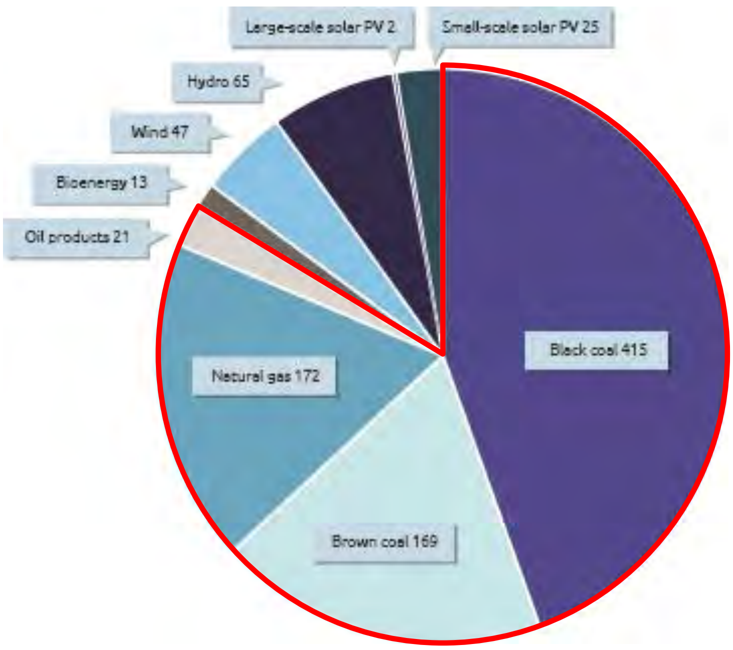
Note:

- Brown coal is a type of coal of lower quality than black coal – you have to burn more of it for the same amount of energy
- Oil products include diesel, petrol, and other types of 'oil'
- Bioenergy is mostly agricultural waste such as sugar cane after the juice has been extracted. It is burned.
- 'PV' means *photovoltaic*, or solar panels. Small-scale refers to the panels on people's roofs – large-scale refers to solar farms

The number after each energy type is the number of petajoules (PJ) of energy it supplied. One petajoule is 1,000,000,000,000,000 joules!

Question 3

On the pie chart below, use a coloured pen to draw around the border of all the segments representing fossil fuels.



Energy sources for electricity production in Australia, 2016 (PJ). Credit: Dept of the Environment and Energy, Australian Energy Statistics, Table O, August 2017.

Question 4

In Australia in 2016, fossil fuels provided _____________ of the energy that was transformed into electricity.

☐ less than 25%

☐ between 25% and 50%

☐ between 50% and 75%

☑ more than 75%

Question 5

Which of the following show the electricity energy sources in the correct order, from smallest contribution to greatest contribution?

(There might be more than one)

☐ small-scale solar PV, large-scale solar PV, hydro, natural gas

☑ small-scale solar PV, large-scale solar PV, hydro, natural gas

☐ bioenergy, hydro, natural gas, large-scale solar PV

Question 6

All the energy sources that aren't fossil fuels are *renewables*.

In 2016 all the renewables together contributed more energy for electricity than natural gas.

☐ true

☑ false

3.3 LESSON: ENERGY RESOURCES

This lesson sets the context for the energy resource project that follows. It starts with a class discussion of the factors that need to be considered in deciding on an energy resource to use at a national level.

KEY QUESTIONS

- What factors does society need to consider in choosing energy resources?
- What energy resources do we use today?
- What is a renewable resource?
- How can we compare the outputs of electricity power stations?

There are many sources of energy available on Earth. In ancient times, food was the major source. We used it to feed the animals and people who did all the work.

Today, in the early 21st century, we mostly use machines, and they mostly get their energy directly or indirectly from fossil fuels. But the carbon dioxide produced when we burn these fuels leads to global warming. To overcome this we need to change to energy sources that don't produce carbon dioxide.

But every energy resource poses its own problems and we have to balance many factors when we decide which ones to use.

We suggest students pool ideas for the question below. In class discussion, lead them towards any major items they miss.
Our list of factors to consider in selecting an energy resource for a country is (in no particular order, with overlap):

- cost: so the country can afford to build the infrastructure, and final users can afford to pay for energy
- safety: nuclear energy is most commonly cited here, with great potential for death, illness and destruction, although overall its safety record is good...far better than coal's for example (see here). Safety is an issue in coal mines but pollution causes most coal-related deaths.
- pollution: e.g. all the fossil fuels produce air pollution from impurities they contain. This has health impacts for humans and other species (plants and animals) as well. For example, sulphates and nitrates in fossil fuel exhaust gases cause acid rain. Oil spills cause significant damage to local environments.
- health: air and water pollution probably pose the highest risk to health, but, for example, some claim that noise from wind turbines poses a health risk
- production of greenhouse gases
- environmental impact: this can take many forms including: direct destruction of landscape and ecosystems e.g. from open cast mining, including earthquakes, flooding behind dams and increased erosion of downstream rivers due to hydro-electric dams; damage to ecosystems, e.g. from wide-spread air pollution (e.g. acid rain) or changes to temperature and oxygen

content of river water from hydroelectric dams; deaths of birds in wind farms and concentrated solar thermal plants.

- reliability: can the energy resource be relied on to produce energy when you need it? Of course, energy storage systems mitigate against this problem, but add to the cost
- infrastructure: how much do you have to build to handle the energy resource? E.g. consider all the electrical infrastructure in Australia, or all the petrol stations and the tankers that distribute to them, or the resources needed to build a coal or hydro power station, or wind or solar farm.
- using a waste product: e.g. bio-waste...this is getting energy from something that would otherwise have to be disposed of
- diverting from other uses: a lot of corn has been used to make biofuels...this could instead have been used as food for animals or humans
- aesthetic impact: large power plants, open cast mines and wind farms might all be considered to be eyesores

Question 1

Discuss

Imagine you are in government with responsibility to decide what energy resources your country will use.

What factors do you have to take into account in making your decisions? After discussing in groups and/or class, list them below.

Hint: Try thinking of ways that we get or use energy now, and what is good or bad about these energy sources.

Students will offer different ideas…see teacher's notes above.

3.4 PROJECT: ENERGY RESOURCES

This project is intended as a substantial one, with students carrying out their own research, writing (drawing, assembling) their content, and making a presentation to the class. We suggest giving students some weeks for it – they can be working on it while you progress through other, earlier sections of this unit.

- We suggest students work in groups of three or four.
- We suggest each group does a class presentation of their work. Beyond this, we leave it to individual teachers what they will require as to written work, files, or posters, etc.

Note that we give some information about wind and solar energy in following sections – students should do more than simply reproduce the content covered here. On the other hand, weaker students might benefit from having the information presented here to get them started.
There is an optional final question below re 'what other questions do you have?', for when students have seen others' presentations.

Research one energy resource and make a presentation of your findings to the class.

Work in groups of three or four. Each group should investigate a different resource.

Suitable energy resources include:

- PV (photovoltaic) panels ('solar panels')
- printed flexible solar panels
- solar water heating
- solar thermal power stations
- wind turbines
- geothermal power stations
- hydro-electric power stations
- pumped hydro
- biogas for generating electricity and producing heat energy
- petrol for transport
- a bio-fuel used for transport (such as bio-ethanol or bio-diesel)
- electric cars
- hydrogen fuel for transport
- tidal power
- wave power
- nuclear power stations
- coal-fired power stations
- gas-fired power stations
- coal seam gas
- gas or oil from fracking

WHAT TO FIND OUT

What is the science and technology behind the resource?

- How does this energy resource work? What devices are used?
- What are the main energy transformations and energy transfers that take place? Include a flow chart showing the energy transformations.
- Is this energy resource renewable or non-renewable? Explain.

How much is the energy resource used?

- Is this energy resource used in Australia, and if so, to what extent? Is it a large- or small-scale energy resource? Is it used in particular locations? Why or why not?
- Is this energy resource used across the world and if so, to what extent? Which countries are the main ones using it? Is there a reason why some countries are using it and others are not?

What are the benefits and problems associated with this energy resource?

- What are the main advantages of using this energy resource? Will increased use of the resource help reduce global warming?
- What health and safety concerns are associated with this energy resource?
- What environmental concerns are associated with this energy resource?

What does the community think about this resource?

- What are the views of members of the community to use of this resource? If possible, get opinions from within your school and/or local community about reactions if a resource of this kind were to be established nearby.

What is the likely future of the resource?

- Is the energy resource likely to be a useful and widely used energy source for Australia and across the world in the future? Why?

HOW TO PRESENT YOUR PROJECT

The main product of your project is the class presentation, but upload any files that you use in the project space below:

- copy text into the text widget, so your teacher can read it in Stile
- upload presentation files (e.g. PowerPoint) with the files and media widget;
- upload photographs of posters, models, or other static material;
- if possible, upload a video of your presentation.

Think about the best way to present your information so that it engages your audience. For example, use:

- photographs, diagrams, models, flow charts and maps
- tables and graphs of data
- video clips
- posters
- your own recordings of interviews and site visits
- a PowerPoint presentation

REEOURCES YOU CAN USE

- Experts in the field – it will help your project a lot if you can ask someone working in the industry questions about it
- see the subject resources menu on the STELR website; and
- books and/or web sites, but be sure to use trust-worthy sites. Ask your teacher if you're not sure.

Important You must include a bibliography, showing where you got all your information.

Answer the following question after you have seen all the other project presentations for your class.

Question 1

You should have learned a lot about your energy resource, and quite a bit about other resources as well, from other students' presentations.

What more would you like to find out about energy resources?

Various answers

4 BATTERIES

Batteries come in many shapes and sizes and they can be a convenient way of 'storing' electrical energy.

This section focuses on batteries as a source of electrical energy. In the following sections on wind energy and solar panels, students will use STELR equipment to measure the amount of energy they can produce under different conditions. The activities help students to become familiar with the STELR equipment and to revise their knowledge of electric circuits.

For additional help and practice using electric circuits, you can also refer to the *Circuit Training* resource found on the STELR Renewable Energy USB.

3.1 Fossil Fuels and Greenhouse Gases

This lesson has three main purposes:

- remind students what are fossil fuels and that fossils fuels are a source of greenhouses gases
- Discuss and define the terms renewable and non-renewable. **Renewability:** A quick definition – resources that can be replaced within a human lifetime (around 80 years) are renewable.
- Have students understand that many energy sources are both renewable and also they do not produce greenhouse gases.

KEY QUESTIONS

- What is a fossil fuel?
- What are greenhouse gases?
- What is a renewable energy resource?

FOSSIL FUELS AND GREENHOUSE GASES

Back in lesson 2.1 you watched a video called *Global Warming: Cold Facts, Hot Science*

How well can you remember some of the things you learnt?

Question 2

Burning fossil fuels – coal, oil and natural gas – produces carbon dioxide.

☑ true

☐ false

Question 3

Carbon dioxide is a greenhouse gas.

☑ true

☐ false

Question 4

Increasing the proportion of greenhouse gases in the atmosphere increases the Earth's average air temperature.

☑ true

☐ false

Question 5

Why are coal, oil and natural gas called fossil fuels?

These resources are the fossilised remains of buried plants and animals that died many millions of years ago. (Because the fossilisation process took millions of years, we define these resources as non-renewable)

Question 6

How do you use fossil fuels in your everyday life?

Coal	Very few people use coal directly these days except to fuel a barbeque Some students may know: • that in some states of Australia, coal fired power plants are the major source of electricity • Coal is also an important raw material in steel production
Oil and oil products	Petrol and diesel for transport or to run generators in isolated areas Some students may know: • that oil is a major raw material for the plastics industry
Natural gas	Cooking, heating water Some students may know: • that natural gas is used in some power stations

RENEWABILITY

All of the resources that we use – not only energy resources – can be divided into two categories: renewable and non-renewable.

- **Renewable** resources are those that can be replaced within, roughly, a human lifetime.
- **Non-renewable** resources are those that take longer to be replaced, or they're not replaced at all.

Wheat is a renewable resource – we grow new crops every year. Rock – for concrete, roads and building – is not.

Question 7

Which of the following are renewable resources?

- [ ] diamonds
- [x] wool
- [x] sugar
- [x] timber
- [ ] sand

Question 8

Which of the following energy resources are renewable?

- [x] sunlight
- [ ] coal
- [x] water
- [x] wind
- [ ] natural gas

The point of the questions below is to explore further, the reasons for changing to renewable energy resources.

From the perspective of global warming, we need to change to energy sources that do not produce greenhouse gases.

From the perspective of sustainability, we need to change to energy sources that are not going to run out in the short to medium term.

The major renewable energy sources we use today do not produce greenhouse gases. They are also sustainable. (Note it could be argued that timber is a renewable energy source but it does produce greenhouse gases when burnt).

Are we running out of fossil fuels? Current known reserves give us another hundred years' worth of coal, and about 50 years' each of oil and gas. But new technologies make new deposits viable. For example there are vast amounts of methane hydrate – methane locked in ice crystals – under permafrost and on ocean floors. Currently there are no ways to extract it, but if this becomes possible there is at least twice as much energy value as the known reserves of coal in this potential resource.

You may want to mention carbon sequestration to students – the technology that takes the carbon dioxide from fossil fuel-burning power stations and pumps it underground, where it will remain indefinitely. This provides a means of lowering carbon dioxide emissions into the atmosphere while still using fossil fuels. So it is not essential that we have to stop using fossil fuels in order to cut carbon dioxide emissions. However, carbon sequestration is expensive and has not been taken up to any significant extent.

Question 9

People say that, in order to stop global warming, we have to change to use renewable energy sources. Why?

Most of the renewable sources of energy, including the most prominent ones – hydro power, wind turbines and solar panels – produce electricity without also producing carbon dioxide. Carbon dioxide is the main cause of global warming.

Question 10

How do you think we can make electricity in a more sustainable way?

Answers will vary. Renewable sources of energy, including hydro power, wind turbines and solar panels, are sustainable sources of energy. On the other hand, fossil fuels re not sustainable

Lesson: The Importance of Electricity **Why Use Batteries** students think about the usefulness of batteries in their everyday lives and consider that some batteries are rechargeable and others are not.

4.2 Fossil Fuels and Greenhouse Gases

This lesson has three main purposes:

- remind students what are fossil fuels and that fossils fuels are a source of greenhouses gases
- Discuss and define the terms renewable and non-renewable. **Renewability:** A quick definition – resources that can be replaced within a human lifetime (around 80 years) are renewable.

- Have students understand that many energy sources are both renewable and also they do not produce greenhouse gases.

KEY QUESTIONS

- What is a fossil fuel?
- What are greenhouse gases?
- What is a renewable energy resource?

FOSSIL FUELS AND GREENHOUSE GASES

Back in lesson 2.1 you watched a video called *Global Warming: Cold Facts, Hot Science* How well can you remember some of the things you learnt?

Question 11

Burning fossil fuels – coal, oil and natural gas – produces carbon dioxide.

☑ true

☐ false

Question 12

Carbon dioxide is a greenhouse gas.

☑ true

☐ false

Question 13

Increasing the proportion of greenhouse gases in the atmosphere increases the Earth's average air temperature.

☑ true

☐ false

Question 14

Why are coal, oil and natural gas called fossil fuels?

These resources are the fossilised remains of buried plants and animals that died many millions of years ago. (Because the fossilisation process took millions of years, we define these resources as non-renewable)

Question 15

How do you use fossil fuels in your everyday life?

Coal	Very few people use coal directly these days except to fuel a barbeque Some students may know: • that in some states of Australia, coal fired power plants are the major source of electricity • Coal is also an important raw material in steel production
Oil and oil products	Petrol and diesel for transport or to run generators in isolated areas Some students may know: • that oil is a major raw material for the plastics industry
Natural gas	Cooking, heating water Some students may know: • that natural gas is used in some power stations

RENEWABILITY

All of the resources that we use – not only energy resources – can be divided into two categories: renewable and non-renewable.

- **Renewable** resources are those that can be replaced within, roughly, a human lifetime.
- **Non-renewable** resources are those that take longer to be replaced, or they're not replaced at all.

Wheat is a renewable resource – we grow new crops every year. Rock – for concrete, roads and building – is not.

Question 16

Which of the following are renewable resources?

- [ ] diamonds
- [x] wool
- [x] sugar
- [x] timber
- [ ] sand

Question 17

Which of the following energy resources are renewable?

- [x] sunlight
- [ ] coal
- [x] water
- [x] wind
- [ ] natural gas

The point of the questions below is to explore further, the reasons for changing to renewable energy resources.

From the perspective of global warming, we need to change to energy sources that do not produce greenhouse gases.

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The major renewable energy sources we use today do not produce greenhouse gases. They are also sustainable. (Note it could be argued that timber is a renewable energy source but it does produce greenhouse gases when burnt).

Are we running out of fossil fuels? Current known reserves give us another hundred years' worth of coal, and about 50 years' each of oil and gas. But new technologies make new deposits viable. For example there are vast amounts of methane hydrate – methane locked in ice crystals – under permafrost and on ocean floors. Currently there are no ways to extract it, but if this becomes possible there is at least twice as much energy value as the known reserves of coal in this potential resource.

You may want to mention carbon sequestration to students – the technology that takes the carbon dioxide from fossil fuel-burning power stations and pumps it underground, where it will remain indefinitely. This provides a means of lowering carbon dioxide emissions into the atmosphere while still using fossil fuels. So it is not essential that we have to stop using fossil fuels in order to cut carbon dioxide emissions. However, carbon sequestration is expensive and has not been taken up to any significant extent.

Question 18

People say that, in order to stop global warming, we have to change to use renewable energy sources. Why?

Most of the renewable sources of energy, including the most prominent ones – hydro power, wind turbines and solar panels – produce electricity without also producing carbon dioxide. Carbon dioxide is the main cause of global warming.

Question 19

How do you think we can make electricity in a more sustainable way?

Answers will vary. Renewable sources of energy, including hydro power, wind turbines and solar panels, are sustainable sources of energy. On the other hand, fossil fuels re not sustainable

Lesson: The Importance of Electricity **Batteries** Students test the STELR battery packs using the STELR multimeter. They then use the STELR battery pack to complete a circuit. The look at the effect of adding in a second battery pack, both in parallel and in series. The measure the voltage in the circuits.

Error! Reference source not found. **Lesson: Battery Technology** Students explore b attery technology and what features are useful in different situations where batteries are used.

Batteries contain chemicals that can produce a flow of electrons when connected to a circuit. They are a 'store' of electrical energy. Batteries vary in size from those small enough to fit in a hearing aid, to ones that are the size of a shipping container. Some batteries can be recharged using electrical energy to reverse the original chemical reaction.

One of the largest batteries in the world was built at Hornsdale in South Australia to store excess energy generated by nearby wind turbines.

4.1 LESSON: WHY USE BATTERIES?

In this lesson students think about batteries in their daily life and what it would be like if batteries had not been invented. It is important to know that batteries transform chemical energy into electrical energy, but the chemicals and the chemical reactions are not covered.

Students also consider whether the batteries the use daily are rechargeable or not.

Teachers may wish to explain that in recharging a battery, electrical energy is converted into chemical energy.

Use the title images to discuss the use of batteries to store renewable energy in large power stations or household situations.

NOTE: Small disc batteries are pictured in the title images. Reinforce that these can be very dangerous (even fatal) if swallowed. Small children should never be given toys or devices containing these batteries.

KEY QUESTIONS

- Why do we use batteries?
- What have batteries got to do with renewable energy?

Question 1

Make a list of all the batteries that you use in your everyday life. Discuss the list with others in the class and include as many as you can.

When the list is complete, make two groups: rechargeable and non-rechargeable batteries.

Rechargeable	Non-rechargeable
Phone battery	Torch, bicycle light
Car battery	Smoke alarm battery
Computer/tablet battery	Remote control battery (TV, stereo, garage door air conditioner etc.)
Electric toothbrush	Any battery powered toys

Solar powered garden or festive lights (the battery is charges during the day and the lights use the battery power at night)	Any battery powered gadgets such as label makers, hand held fans, calculators, electronic weighing scales, flashing dog collars
Smart watch, fitness tracker	Watch
Electric bicycles, scooters and or buses	Portable speakers, radios, disc players etc
Home battery (for storing electricity from solar panels)	Gaming consoles
	Hearing aids

Question 2

Imagine what your life would be like if batteries had not been invented. What would be the most important changes?

Answers will be many and varied.

- Only being able to use your computer/tablet/phone/smart watch/speaker when it is plugged into the mains power.
- Hand-cranking cars to get them started.
- No electric vehicles.
- No portable lights such as torches. (Dynamo bike lights instead)
- No remote control devices (or only ones attached by a power cord).
- No battery powered toys.

4.2 PRAC: CONNECTING BATTERIES

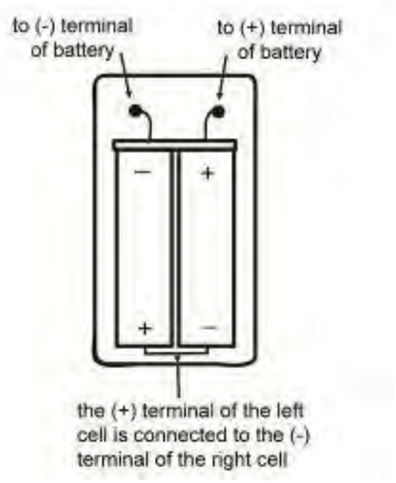
In this prac students become familiar with the STELR battery pack which contains two AA cells. Encourage students to open the back of the battery pack and see the cell inside, noting that the positive terminal of one cell is connected to the negative terminal of the other cell. There are two parts to this prac.

4.2.1 Testing The Batteries. Students learn how to use the multimeter to test if the two battery packs in their kits are fully charged.

4.2.2 Adding in Batteries. Students set up a circuit containing the battery pack, the lamp on the STELR Test rig and a switch. They then add in a second battery pack in series and see the effect on the globe. The second battery is changed to the parallel position and the effect on the globe is noted. This procedure is then repeated with the addition of the multimeter, being used to measure voltage.

KEY QUESTIONS

- What happens when you add more batteries to a circuit?
- What are volts and how do we measure them?
- What is the difference when batteries are connected in series or in parallel?



BATTERIES AND CELLS

Scientifically speaking, a single battery is called a cell. If there are two or more cells together in a circuit, it is called a battery. The STELR battery contains two 1.5V (double A) cells.

Single household cells usually deliver 1.5 volts when fully charged. Unfortunately, they do not deliver enough power to run most devices, which is why you usually have to use more than one to get them to work.

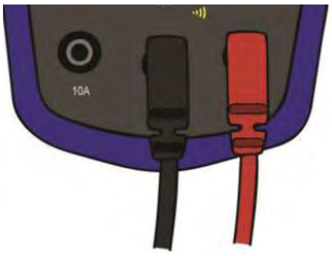
Materials

- 2 x STELR batteries
- STELR testing station
- STELR multimeter
- connecting cables
- STELR switch

4.2.1 TESTING THE BATTERIES

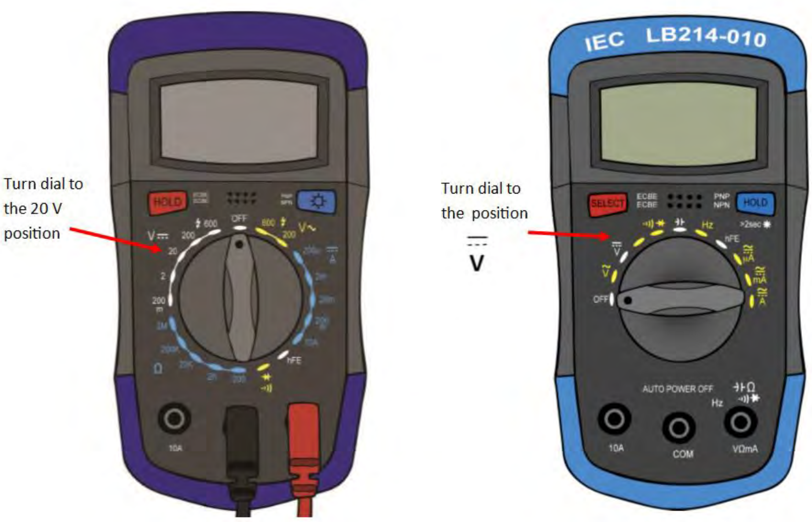
It is recommended that the batteries are removed from the battery packs if not being used for long periods. This avoids battery leakage and corrosion of the terminals. If the battery packs have been stored for some time with the batteries inside, they may have gone flat. Students test the two battery packs to determine if they are fully charges and showing around 3V. It is suggested that if the reading is lower than 2.5V students are given replacement AA cells to put into their battery pack.

WHAT TO DO



To measure the voltage, use the middle socket of the multimeter for the negative terminal and the right-hand socket for the positive terminal.

There are two different STELR multimeters. Look at the pictures below to determine which one you have. When you are ready to measure the voltage, turn the rotary switch to the position shown on the picture.



Label one of your STELR batteries 'A' and the other 'B'.

Connect battery 'A' to the multimeter as shown in this diagram.

Measure and record the voltage. Repeat with battery 'B'.

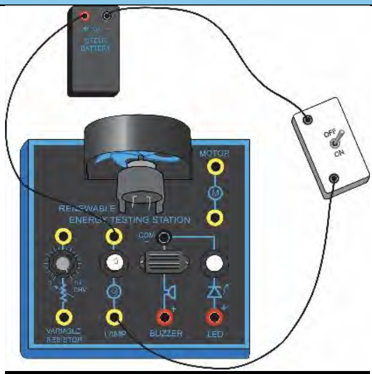
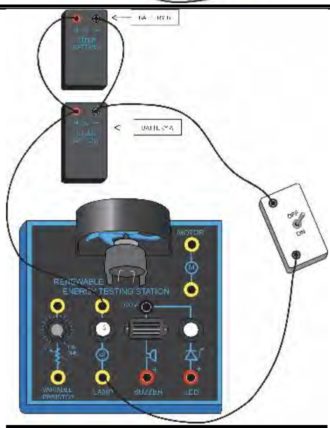
Voltage for Battery A	Voltage for Battery B
3V (approx)	3V (approx.)

NOTE: The rest of this experiment will work best if both batteries measure close to 3 volts. If this is not the case, ask you teacher for a replacement battery and re-test it.

4.2.2 ADDING IN BATTERIES

WHAT TO DO

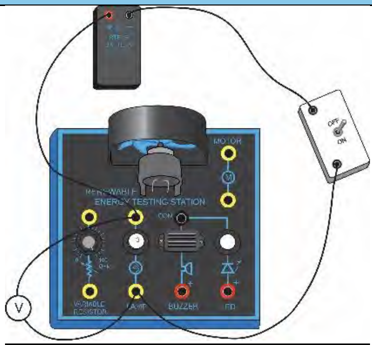
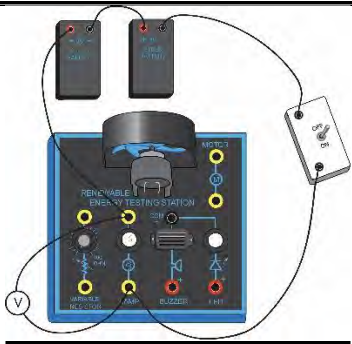
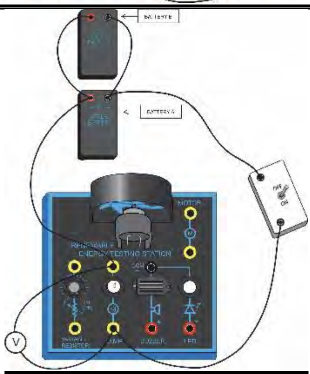
Connect up the circuits that are illustrated below and notice what happens to the brightness of the lamp when the second battery is added.

	Set-up	Brightness of the lamp
One battery		Bright
Two batteries in series		Very bright (twice as bright as above)
Two batteries in parallel		About the same brightness as one battery

VOLTS: ENERGY IN A CIRCUIT

The circuit above gets its energy – electrical energy – from chemical reactions in the battery. The energy is transferred around the circuit through the cables, and transformed into light and heat at the lamp. Energy in electrical circuits is often measured in terms of **volts**, symbol **V**.

A volt is not a basic measure of energy but for our purposes we will use volts to measure electrical energy in circuits.

	Set-up	Voltage
One battery		**3.2 V** This voltage will be less if the batteries are "going flat".
Two batteries in series		**6.4 V** This voltage will be less if the batteries are "going flat".
Two batteries in parallel		**3.2 V** This voltage will be less if the batteries are "going flat".

You may have noticed that when the two batteries are connected in parallel, they deliver a similar voltage to the single battery.

Connecting a second battery in **series** will make the globe brighter but the batteries will run out of energy quickly.

Connecting a second battery in **parallel** does not affect the brightness of the globe but it will glow for twice as long.

4.3 LESSON: BATTERY TECHNOLOGY

KEY QUESTION

- What are the useful features of different types of batteries?

Making smaller and lighter batteries that last longer is a developing technology.

This picture is of one of the first types of mobile phones. It is pictured next to an apple so you can see how big it was. It was so big because most of the size was the battery. These batteries could be recharged but they became less and less effective each time they were recharged.

Over the years, scientists and technologists have developed smaller and more powerful batteries for phones.

Foe the question below, note that often smaller batteries are more expensive than larger batteries. To make batteries smaller, different materials and technology must be used, which can be more expensive.

Rechargeable batteries are generally more expensive that non-rechargeable ones.

Some batteries are required to deliver small, but constant amounts of energy for a long time, such as in a watch or a hearing aid. Other batteries, like a car battery (used to start a petrol car), are required to provide large bursts of energy over a short period of time.

Question 3

Imagine you were designing a better battery for each of the following situations.

Describe the features of the battery that are important in each case. Consider the importance of the following:

- size;
- weight;
- the amount of energy needed and how often it is used;

- how long it needs to last;
- if it need to be rechargeable;
- if changing the battery is difficult; and
- if cost is an issue.

Situation	Battery features
Battery for a hearing aid	Needs to be very small and light (especially as hearing aids are getting smaller and smaller). Hearing aids only require a small amount of energy to run. It needs to last a long time if possible and being able to recharge the batteries would be convenient.
Battery to store electricity generated by a wind farm	This would need to be able to store as much energy as possible, and be rechargeable. Size is not an issue if there is plenty of space near the wind farm. Keeping hat cost down would be more important than keeping the size down.
Battery for an electric car	Size and weight are important. A large heavy battery would make the car less efficient. The battery would need to last as long as possible before being recharged. Most electric cars have batteries designed to last the lifetime of the car, so in theory, never need to be replaced.
Battery for the TV remote control	Needs to be small, enough to fit into the remote but not too small. The remote is used intermittently and batteries are easy to replace, It does not need to be rechargeable.
Battery to store excess electricity generated by solar panels in a house	These need to be large enough to store as much energy as possible, but small enough to fit in houses or apartments with small spaces. The need to be rechargeable. Currently , in Australia, the cost for home storage batteries is too high for many people to afford.
Battery for a lap-top computer	This needs to be small enough to fit into the lap-top. It needs to be rechargeable. Many people use their lap-tops on mains

	power as well as electricity, so in this case, the battery does not need to last more than a couple of days between charging.
Battery to power a space station	Space stations are usually powered by a battery that is charged from solar panels. So it must store as much energy as possible and be rechargeable. At the same time it must be small as is practically possible, because weight is an issue when deigning space craft. It is virtually impossible to change the battery on a space station.

5 WIND ENERGY

The 140 MW Woolnorth Wind Farm on the far north-west coast of Tasmania. Credit: Hydro Tasmania

This section looks at the generation of electricity using wind turbines. Students think about the advantages and disadvantages of wind turbine, then use the STELR equipment to test the effect of blade angle and number of blades on the amount of electricity generated.
They are also introduced to the concept of dependent, independent and controlled variables.

Pracs investigating blade angle and number of blades are given in detail. Teachers may also choose to adapt the pracs to investigate other variables such as blade length, wind (fan) speed and so on. Different groups in the class could investigate different variables.

Students will need to understand how to connect up electric circuits. Teachers may wish to refer students needing a 'refresher', to the *Circuit Training* resource found on the STELR Renewable Energy USB.

5.1 Lesson: Wind Turbines provides general information about wind energy – of a kind similar to that expected in students' projects. It uses an online real-time map of wind speeds for them to consider good sites for wind farms, comparing this with another online map of average wind speeds.
5.2 Lesson: Wind Turbine Design aims to introduce students to the STELR equipment and become familiar with its use. They make a guess at what they think would be the best design for a wind turbine.
5.3 Prac: Wind Turbine Blade Angle takes students through an experiment to determine the best blade angle for wind turbines.
5.4 Prac: Number of Blades takes students through an experiment to determine the best number of blades for a wind turbine.

There are many sources of energy that we can use. Each one has benefits but brings problems with it too. Which ones should we use, and how do we get the best out of them?

5.1 LESSON: WIND TURBINES

This lesson presents an overview of wind turbine technology and how we use it. It looks briefly at the technology, the energy transformations and transfers, where wind farms should be located (using real data), advantages and disadvantages of wind power, and some interesting design ideas for turbines.

Discussion

Where to put wind farms and advantages and disadvantages are suggested as discussion questions.
Students use a real-time map of wind speeds around Australia:
https://earth.nullschool.net/#current/wind/surface/level/orthographic=-222.63,-26.76,1401/loc=133.460,-33.058
and a map showing average wind speeds:
http://nationalmap.gov.au/renewables/#share=vYUobz

Teachers outside Australia

This exercise should be easily convertible to your country. Use the same 'nullschool' map (first link above) for the real-time wind speeds (drag and size to show your country then copy the URL to give to the students) then locate an average wind speed map for your country on the web, e.g. NZ here, or Indonesia here.
You can find additional information on the STELR website here, and links to additional resources here, including a PowerPoint presentation you can use to stimulate discussion about wind energy.

KEY QUESTIONS

- What energy transfers and transformations occur in a wind turbine?
- Where does the wind blow most in Australia?
- What are the advantages and disadvantages of wind turbines?

In Australia, wind turbines are the fastest growing renewable energy resource.

At the end of 2018, there were 94 wind farms with just over 2,056 turbines. Another 24 wind farms were under construction at this time. These wind farms produced over 16,000 gigawatt hours (GWh) of electricity.

HOW WIND TURBINES WORK

Watch the video *How a wind turbine works*.

VIDEO How a wind turbine works
https://youtu.be/57NFcXLd9BA

Question 1

Increasingly, wind farms are being built coupled with massive batteries that store electricity when the turbines produce more than is needed, and supply it when the turbines aren't producing enough.

Write in the boxes to complete the description of the transfers and transformations that occur when a wind turbine charges a battery. Use the following words:

electrical | transferred | kinetic | transformed | mechanical | transferred
transformed | chemical

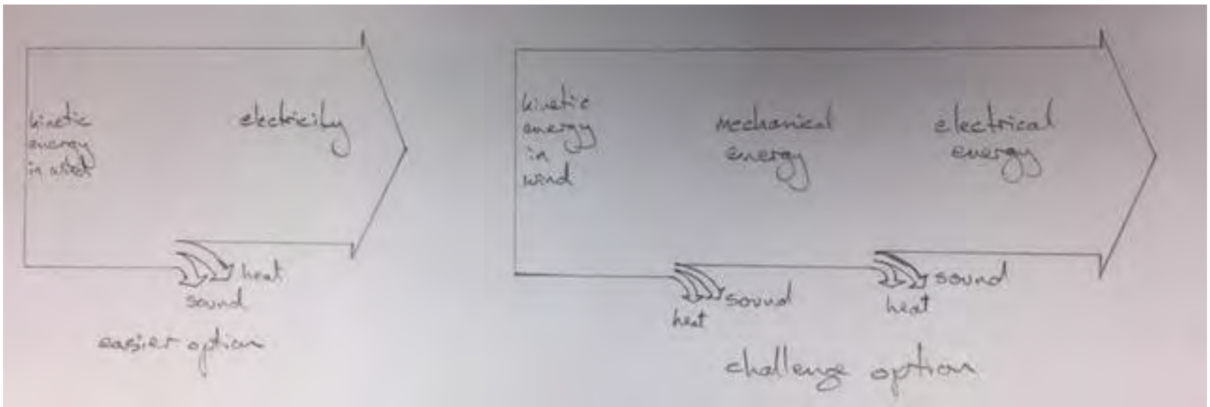
Wind has **kinetic** energy. This energy is transformed, becoming **mechanical** energy of the turbine. This is **transferred** along the main shaft to the generator where it is **transformed** into **electrical** energy. This energy is then **transferred** through cables to the battery where it is **transformed** into **chemical** energy.

Question 2

Wind turbines take about half of the wind's kinetic energy. Of that, most is converted into mechanical energy, with a little lost as heat and sound. Then, most of the mechanical energy is transformed into electrical energy, again with small losses to heat and sound.

Draw a Sankey diagram showing the transformations that occur. (Do not include the kinetic energy that remains in the wind).

- **Easier option:** start with the wind energy and only show the final outputs.
- **Challenge option:** make the diagram longer by showing the mechanical energy stage.



If students don't have their own devices, open the web sites below to show the whole class:

https://earth.nullschool.net/#current/wind/surface/level/orthographic

http://nationalmap.gov.au/renewables/#share=vYUobz

(The latter site defaults to 60% opacity…we recommend changing to 100% with the slider on the left).

WHERE TO PUT WIND TURBINES?

Obviously, the best place to put a wind turbine is where it's windy. Turbines work best in smooth air flows, so they should be placed away from obstructions such as tall buildings or rugged landscapes, which break up the air flow. And the higher you go up the stronger the wind, so engineers make turbines as high as they can.

Some wind farms are built off-shore, in the ocean. These cost more, but winds are generally stronger and people don't object to them spoiling the landscape.

Where in Australia, on land or off the coast, are the best locations for wind farms?

Open the web site below and navigate to Australia. Where are the strongest winds now? If you click on a location the wind speed is shown in the box at the bottom left of the screen.

earth
https://earth.nullschool.net/#current/wind/surface/level/orthographic

Question 3

On the map below, in one colour:

- draw circles around the three areas where the winds are strongest;
- beside the circles, write in the top wind speeds in those areas;
- write in a map key in the bottom left corner of the map:
  - a. name the pen colour you are using,
  - b. then beside it write 'Most wind' and the date

Write in small letters because you will soon add more information to the map.

Now, go to this web site:

Australian Renewable Energy Mapping Infrastructure
http://nationalmap.gov.au/renewables/#share=vYUobz

(Click 'I agree' to see the map. You'll see better if you move the opacity slider to 100% once you're in, too.)

This map shows the average wind speeds 100 m above the ground all around Australia – dark blue areas have the lowest average speeds and red areas the highest. To get accurate readings, zoom in and click on a location – the average wind speed there is displayed in a text box.

Question 3 continued…

Now, using another colour, add the following to the map on the previous page:

- Circle the three areas with the highest average wind speeds.
- Beside the circles write in the average wind speeds at those locations.
- To the map key:
  a. add the name the pen colour; and
  b. write 'Highest average wind speeds'.

Question 4

Compare the wind speed data today with the average wind speed information in your map:

- Did the areas that you circled overlap at all? Explain.
- How do the wind speeds today compare to the averages for the areas?

Answers will depend on the data at the time the students investigate.

Question 5

Wind turbines need average wind speeds of 6 m/s or more to operate effectively.

Looking at the average wind map, what proportion of Australia has enough wind to support wind turbines?

☐ less than 25%

☐ between 25% and 50%

☐ between 50% and 75%

☑ more than 75%

> The following question might be difficult for some students, especially if they have little knowledge of Australia's topography, so some guidance may be required.
> The main point we think is that the most windy places – in Tasmania, north-east Queensland, and the Alps – are remote, in difficult terrain, and often quite far from population centres and connections to the national grid.

Question 6

Discuss

If wind speed was the only factor involved in deciding where to build wind farms, we would put them in the areas where the average wind speeds are highest.

Looking at the wind map, can you think of reasons why these might not always be good places for wind farms?

Wind farms have to be built, maintained, and connected to the grid so the electricity can flow to where it is needed. The areas of Australia with the highest average winds tend to be remote and in rugged land, not particularly close to population centres, so they are not ideal sites for wind farms. For example, the south coast of Tasmania is very rugged country in national park, and it would be a long way to connect to existing power systems.

ADVANTAGES AND DISADVANTAGES OF WIND POWER

For the discussion below, some points you may want to feed in:

- **Carbon dioxide:** wind turbines don't produce carbon dioxide when they're operating, but there is probably some produced in their manufacture and installation. But note, in future, if all power and transport comes from renewables, this will be greatly reduced.
- **Cost:** Obviously, wind is free. With respect to overall cost, wind power is now comparable to or cheaper than fossil fuel-generated power.
- **Environment:** Wind turbines are responsible for some bird and bat deaths. However, the numbers are small (and, according to the evidence, far less than caused by fossil fuel power generation...see here).
- **Reliability:** Obviously the amount of wind varies in any specific location. On the other hand, if there are many wind farms spread out over a large area then it's likely there is wind in some proportion of them, and this can be quite reliable. In contrast to solar energy, wind blows at night.
- **Locations:** Some of the windiest places are not close to population centres or grid connections, and may be in rugged land. Wind farms can be placed in agricultural land with minimal impact.
- **Community acceptance:** Some people are strongly opposed to wind farms. They cite aesthetic and/or health reasons.

Question 7

Discuss

There are many factors to consider when deciding how we should produce electricity. Some are listed in the table that follows.

- In small groups, discuss how wind power stands with respect to each factor, and then summarise the main points you decide on. Sometimes there might be several points relating to a factor.

On the basis of the points you've made, rank wind power as good (Y), bad (N) or somewhere in the middle (–).

Factor	Discussion – how is wind power with respect to this factor?	Y, N or –
Carbon dioxide	(possible answers) No carbon dioxide is produced in the generation of electricity	Y
Renewability	Wind is a renewable resource	Y
Cost	Wind is free. Cost of production of electricity from wind is now one of the cheapest sources available	Y
Pollution	There is no pollution from wind power	Y
Environment	Wind farms have minimal impact on the environment, though they do cause deaths of some birds and bats. They have an aesthetic impact on the environment (i.e. they change how it looks.	Y
Reliability	Wind does not reliably blow all the time (though with current forecasting we can be fairly sure days ahead if it will blow or not, and can plan for this)	N
Suitable locations	Some of the windiest locations are not suitable for constructing wind farms. Can put turbines on agricultural land	-

Community acceptance	Most of the population are accepting of wind farms…they are very common in some European countries for example, with no community backlash. Some groups oppose them strongly, on aesthetic grounds and because they believe they cause illness.	Y/-

5.2 LESSON: WIND TURBINE DESIGN

For the discussion below, some considerations you could use:

- Where have students seen wind farms? Why are they located where they are?

They are usually located in an open area on land or offshore. This takes advantage of prevailing winds which need to be fairly constant. While stronger winds are generally better, wind turbines typically operate within certain limits and have a built-in cut out speed where the turbine shuts down in the wind is too strong to prevent unnecessary strain on the rotor. Having wind turbine in an open area minimises the effect of turbulence caused by obstacles in the wind's path.

- How many blades are there on a typical wind turbine? Why are they shaped the way that they are?

Generally there are three. This is most probably a compromise between cost and efficiency. Discussion could be prompted by showing students photos of other wind machines such as wind mills and wind pumps as well as the photo of the early wind turbine on page 88 of the student book.

If you want to transform the energy in the wind into electricity, you want machines that do this as efficiently as possible – at least within your cost limits.

There are many factors that contribute to the efficiency and cost-efficiency of wind turbines, such as the materials used and the height of the towers. Some factors you can test with the STELR wind turbine.

Question 1

Brainstorm all the factors that you can think of that could affect the energy output and cost-effectiveness of wind turbines.

There are a large number of factors including:

- Wind speed
- Angle to the wind
- Height above ground
- Number of blades
- Length of blades
- Surface area of the blades to the wind
- Mass of the blades
- Shape of the blades
- Type and efficiency of the generator
- Obstacles that effect wind speed and regularity

Question 2

Now look at the STELR wind turbine equipment. Which of the above factors do you think you could test using the STELR equipment?

The following could be tested easily:

- Wind speed (by changing the settings on the three speed fan. An anemometer could be used to measure the actual wind speed.)
- Angle to the wind
- Number of blades
- Length of blades
- Surface area of the blades to the wind (surface area is printed on each blade)

- Obstacles that effect wind speed and regularity (use boxes to represent buildings)

As part of their extended investigation at the end of this course, students might choose to tackle more challenging variables like the mass and design of the blades by 3D printing their own blades.

Height above ground could be tested by using a high-speed pedestal fan instead of the STELR tabletop fan.

Question 3

Make a guess at what you think would be the best design for a STELR wind turbine.
There is no right answer here. The important thing is for the students to make a guess.

Following are two experiments to run with the STELR wind turbine equipment. They investigate:

- what is the best angle for the turbine blades,

what is the best number of blades.

The two experiments are presented with a high degree of guidance:

- students identify dependent, independent and controlled variables from options given to them

the instructions include explicit directions not to vary critical controlled variables, such as distance from and angle to the fan

a results table is provided for students to complete

students are given a graph with title and axes already labelled for them to enter data

Discussion following experiments

Each experiment finishes with discussion questions. These could be good for class discussion. Even if you don't use all the questions provided we encourage some form of group debrief so students reflect on their procedures and results.

Different results

To a significant extent there are no right or wrong answers for these experiments – two groups using reasonable experimental technique might get different results. Wind turbines are complex, so in this sense these experiments are genuine investigations into the particular equipment that each group has. On the other hand, if a group gets results very different from others', it is worth investigation as to their procedure and equipment why this was so.

Practical notes

- Make sure students remove the hubs from the turbine bodies to adjust blades.

Stress to students that they must tighten the hubs firmly once the blades are in place – to avoid blades flying off.

The turbine bodies must be firmly secured to the retort stands, to stop vibration.

Make sure the retort stands hold firmly when the fans are blowing on them with the turbines attached – tape them to the bench tops if necessary

If a wind turbine vibrates, check that the blades are properly inserted and that the retort stand is screwed firmly into the base.

The voltmeter will give a fluctuating reading because the rotating fan produces a fluctuating stream of air. Encourage students to use the 'hold' button on the multimeter to take 3 readings at regular (say 10-second) intervals and then average their reading.

The experiment procedure could be easily modified to test other variables if you wish. Tests could include:

- Length of the blades
- Distance from the fan
- Fan speed
- Using different combinations of blades that give the same blade area (e.g. 60 cm^2)

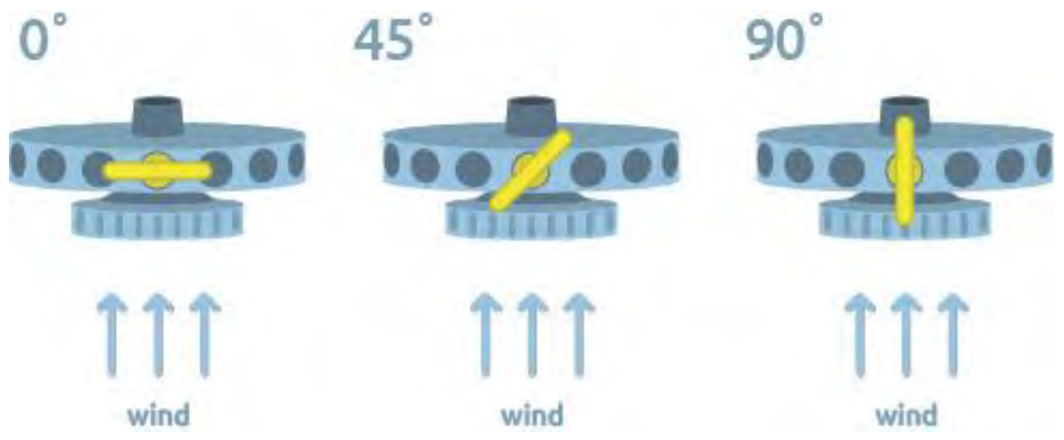
5.3 PRAC: WIND TRUBINE BLADE ANGLE

In this experiment students find out the best blade angle for the STELR wind turbine blades.

KEY QUESTION

- Which blade angle on the STELR wind turbine produces the greatest voltage?

First, check the diagram below to see which angle we're measuring.



The videos listed below demonstrate two ways of setting blade angles. Your teacher will provide you with a STELR protractor if they want you to use it.

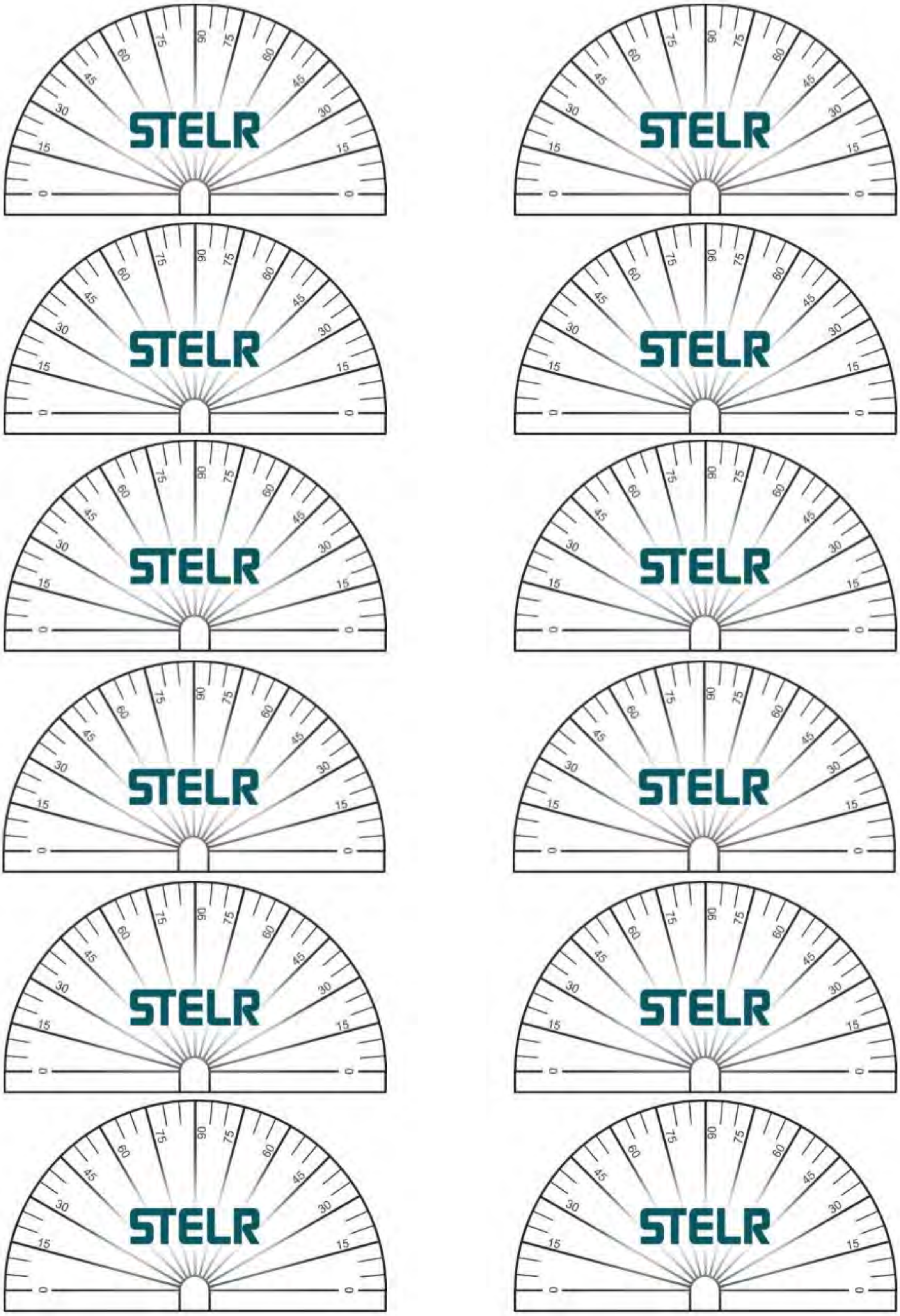
VIDEO Setting blade angle using hub marks
https://youtu.be/j4Vg3mubQlM

VIDEO Setting blade angle using STELR protractor

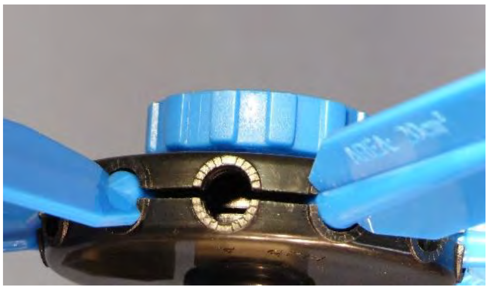
https://youtu.be/8ov2zqosyxg

https://australiascience.tv/episode/stelr-wind-turbine-blade-angle/

Optionally print the next page and cut out and laminate the protractors. Alternatively there is a file of these images (called 'Protractor') on the STELR USB.


STELR
0 15 30 45 60 75 90 75 60 45 30 15 0

The photo of the wind turbine hub to the right clearly shows the 15° marks around the blade sockets.



EXPERIMENT SETUP

Aim

Based on the key question at the start of the prac, write an aim for your investigation.

Find the blade angle that produces the highest voltage from the STELR wind turbine.

Hypothesis

Before you start, predict which blade angle you think will produce the highest voltage.

Explain why you think this.

Various answers acceptable, but students should attempt to give a reason.

Materials

- STELR model wind turbine and hub
- 2 × STELR 150 mm turbine blades (red)
- retort stand
- STELR testing station
- STELR multimeter
- connecting cables
- three-speed electric fan
- tape measure or ruler
- STELR hub protractor

Risk assessment

Complete the following risk assessment.

Fact	Risks	Precautions
The STELR wind turbines are fragile.	They could break	Always handle with care
Objects can fly out from things that are spinning fast.	If the blades aren't secure they could fly out from the turbine and hit someone	Make sure that the blades are secure within the turbine hub. Wear safety glasses to protect eyes.
Electric fans spin fast.	Possible injury if a spinning blade strikes a finger	Take care with the fan. Make sure it is secure and everyone clear before turning it on.

Variables

In any experiment it is essential to know what the variables are, and to control them appropriately. This ensures that the experiment addresses the experiment aims and gives a meaningful result. You will need to consider the:

- **independent variable:** the variable you change to see the difference it makes
- **dependent variable:** the variable you measure to see if/how it changes when you change the independent variable
- **controlled variables:** other factors that you keep constant so they don't have any impact on the dependent variable

Identify which of the following variables are independent, dependent, and controlled:

voltage | length of blades | distance between fan and wind turbine
angle of blades | fan setting | number of blades | angle of wind turbine to fan

Independent variable:

angle of th blades

Dependent variable:

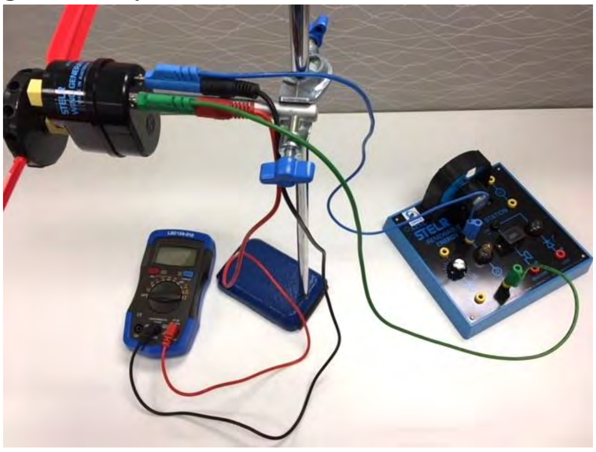
voltage

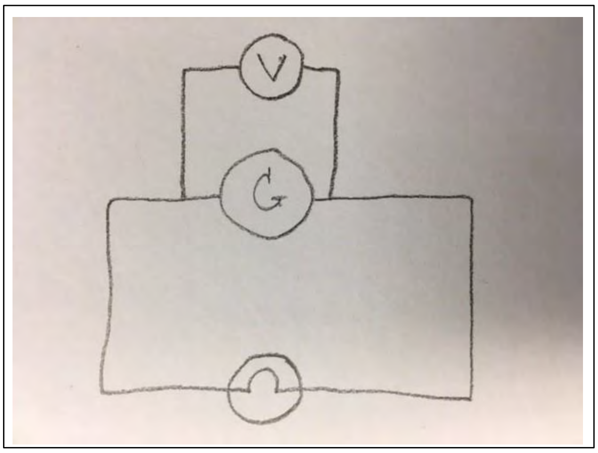
Controlled variables:

all the others listed above

1. Attach the wind turbine body to the retort stand.
2. Make a circuit with the wind turbine and lamp in series.
3. Connect the multimeter so it can read the voltage across the turbine. Don't turn it on yet.

The photo below shows how to connect the circuit. Draw a circuit diagram for it in the blank space on the right. Use a G in a circle to represent the wind turbine (G is for generator).



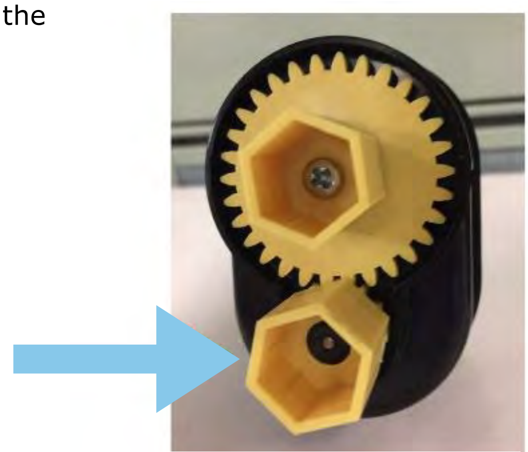


Procedure cont...

4. Attach two blades to the hub of the wind turbine:
   a. position the blades opposite each other
   b. insert each blade at 30° (each mark around the slot rim is 15°, or use the STELR hub protractor)

Note: Ensure you tighten the hub firmly once your blades are in place.

5. Attach the hub to the *ungeared* connection on the turbine body – the connection with the *small* cogged wheel.



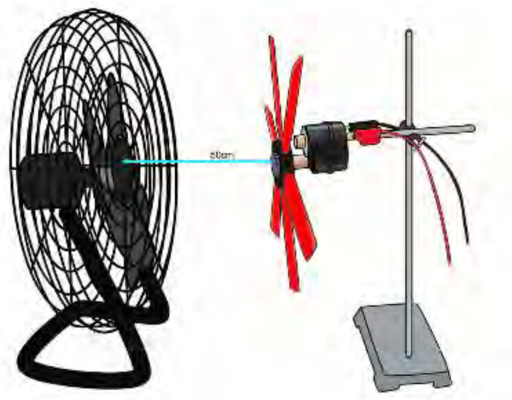
Attach the hub to the small, ungeared connection on the turbine.

6. Position the turbine 50 cm in front of the fan, measured from hub to hub:

   a. Ensure that the turbine and fan are angled so the turbine faces the fan front on.

   b. Adjust the height of the turbine so its hub is the same height as the fan's hub.

7. Ask your teacher to check your setup. **Proceed when you have permission**.



8. Set the multimeter to 20 in the white 'V' range, or the white V (depending on your model multimeter) to measure voltage.

9. Turn the fan to its highest setting and measure the voltage across the wind turbine.

   Enter the voltage in the Results table below.

   Note: The reading on the multimeter is likely to vary. Estimate what you think the average reading would be.

10. Turn off the fan and multimeter.

Repeat for other blade angles

- Remove the wind turbine hub and change the blade angles.
- Tighten the blades and replace on the turbine body.

  Ensure that the positions of the wind turbine and fan haven't changed.
- Turn the fan on to full and read the voltage.
- Repeat for 15°, 45°, 60° and 75°.
- Based on your results, try other angles to find which one gives the highest voltage.

Try it out!

While you have the equipment set up, try out some other angles...how about 0° and 90°? Or, what happens if the blades have the same angle but are in opposite directions?

RESULTS

Record your results in the table below.

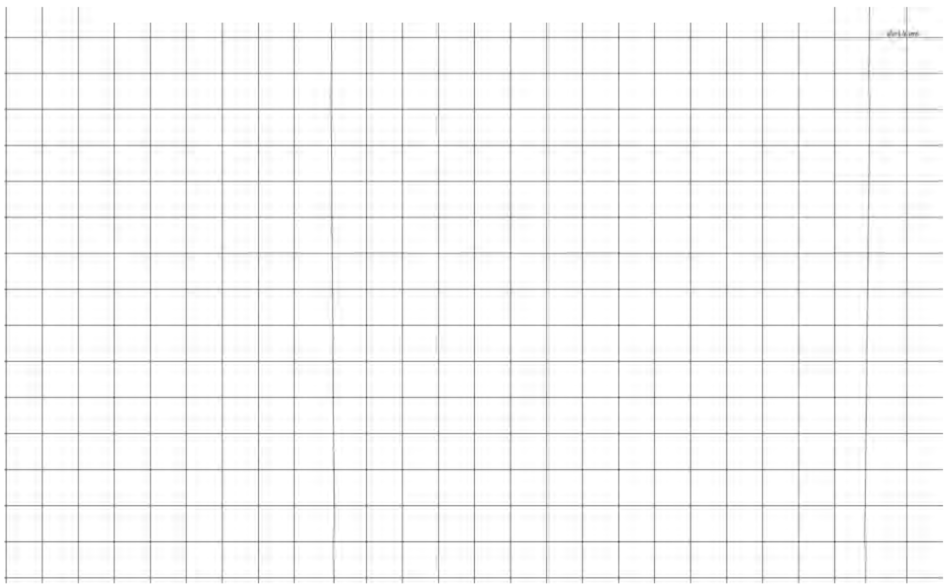
Angle (°)	Voltage (V)
15	*Answers will vary*
30	
45	
60	
75	

Plot your results on the graph below.

Note: You will need to add numbers to the axes.

STELR wind turbine: voltage vs. blade angle

Voltage (V)



Blade angle (°)

What blade angle produced the highest voltage?

Students will get different results. [We have found generally around 12 °]

DISCUSSION

Typically, we find that the best angle is around 12°, but students may legitimately get other results. It is important not to create a sense that there is a correct answer that they're expected to get...each setup will be a bit different.
If any groups get quite different results from others, this is a good opportunity to discuss as a class. It means that one or more of the controlled variables are different for this group...what could it be?

Did the results from your experiment match your prediction?

- If so, do you think this is for the reason you gave? Explain.
- If not, what do you think explains the results that you got?

Various responses depending their hypothesis and how the experiment went.

Did you have any practical difficulties carrying out the experiment? If so, how did you resolve them?

Various responses

For the question below students need to know other groups' results. This might be discussed with the class as a whole.
For this prac we suggest just an informal sharing of results. In the next one students integrate others' results with their own and there are more questions about the differences.

Did all the groups in your class agree on the best angle for the blades?

- Was there much variation?
- Why do you think the results differed as much as they did?

Differences in the equipment and setups probably account for the differences.

Conclusion

Write a conclusion to your experiment.

Hint: Go back to check your experiment aim. Your conclusion should be a short statement that addresses this.

Various, according to the experiment outcome.

5.4 PRAC: NUMBER OF BLADES

In this experiment students find out how many blades produce the highest voltage in the STELR wind turbine.
This experiment is presented with a high degree of guidance. You may want to modify it to provide less guidance.
Although the setup here is essentially identical to the previous experiment we have repeated the instructions in full.

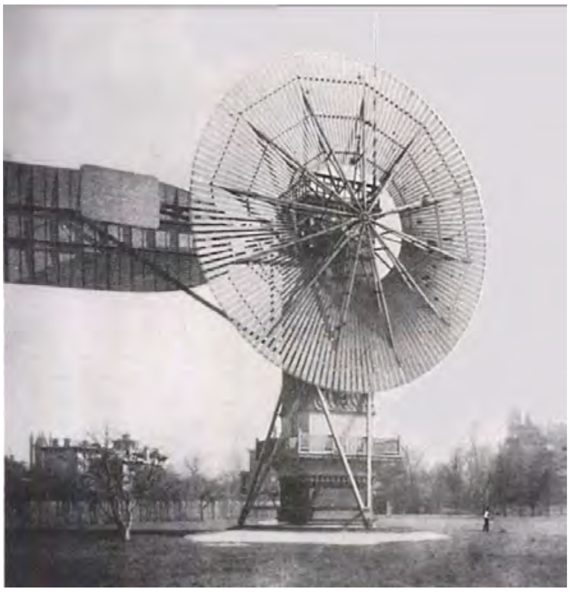
KEY QUESTION

- How many blades give the greatest voltage on the STELR wind turbine?

How many blades should a wind turbine have?

Charles Brush, from Ohio, USA, made one of the world's first electricity-generating wind turbines in 1888, shown at right. Clearly, he thought the answer to the question was, 'a lot'.

In this prac, you'll find out what the answer is for the STELR wind turbine.



Charles Brush's wind turbine, Cleveland, Ohio, 1888.

EXPERIMENT SETUP

Aim

Based on the key question above, write an aim for your investigation.

Find the number of turbine blades that produces the greatest voltage from the STELR wind turbine.

Hypothesis

Before you start, predict which number of blades (2, 3, 4, 6 or 12) will produce the highest voltage.

Explain why you think this.

Various answers acceptable, but students should attempt to give a reason.

Materials

- STELR model wind turbine and hub
- STELR 150 mm turbine blades
- retort stand
- STELR testing station
- STELR multimeter
- connecting cables
- three-speed electric fan
- tape measure or ruler

Risk assessment

Complete the following risk assessment.

Fact	Risks	Precautions
The STELR wind turbines are fragile.	They could break	Always handle with care
Objects can fly out from things that are spinning fast.	If the blades aren't secure they could fly out from the turbine and hit someone	Make sure that the blades are secure within the turbine hub. Wear safety glasses to protect eyes.
Electric fans spin fast.	Possible injury if a spinning blade strikes a finger	Take care with the fan. Make sure it is secure and everyone clear before turning it on.

Variables

What are the independent, dependent, and some important controlled variables in this experiment?

- **independent variable:** the variable you change to see the difference it makes
- **dependent variable:** the variable you measure to see if/how it changes when you change the independent variable
- **controlled variables:** other factors that you keep constant so they don't have any impact on the dependent variable

Identify which of the following variables are independent, dependent, and controlled:

voltage | length of blades | distance between fan and wind turbine
angle of blades | fan setting | number of blades | angle of wind turbine to fan

Independent variable:

Number of blades

Dependent variable:

Voltage

Controlled variables:

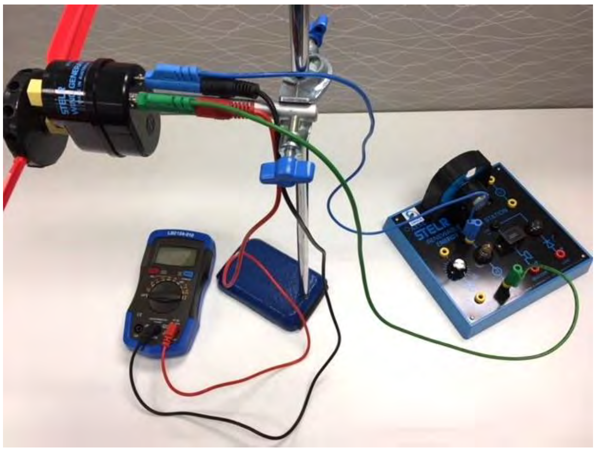
All the others listed above

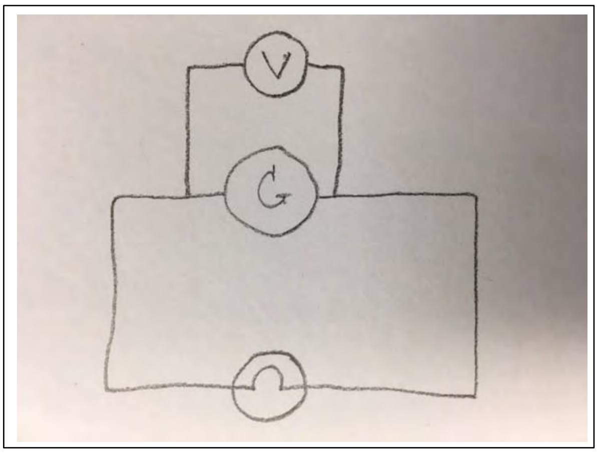
Procedure

1. Attach the wind turbine body to the retort stand.
2. Make a circuit with the wind turbine and lamp in series.
3. Connect the multimeter so it can read the voltage across the turbine. Don't turn it on yet.

> The question below is the same as in the previous experiment, and the circuit is unchanged so the answer is the same.

The photo below shows how to connect the circuit. Draw a circuit diagram for it in the blank space on the right. Use a G in a circle to represent the wind turbine (G is for generator).





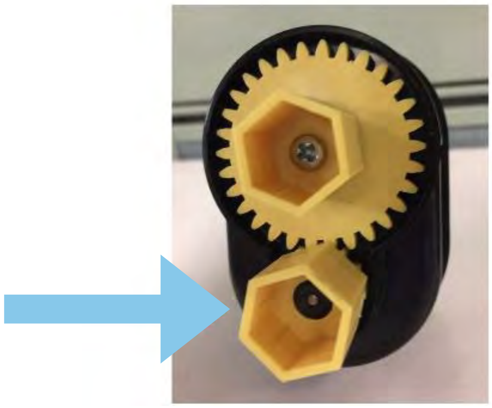
You may want to show students how to set constant blade angle with this STELR video:
https://www.youtube.com/watch?time_continue=130&v=xMKsQN-D59s

Procedure cont...

4. Attach six blades to the hub of the wind turbine:
   a. space the blades evenly around the hub
   b. insert each blade at 45° (each mark around the slot rim is 15°)

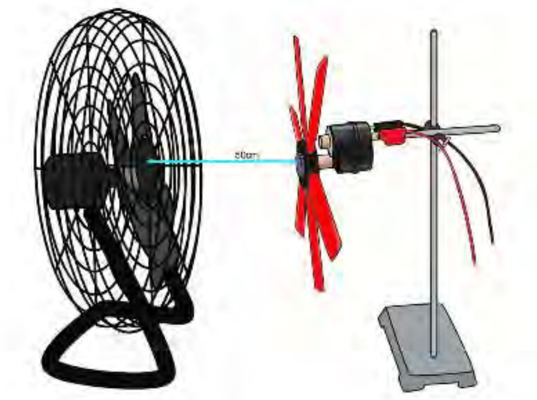
   Note: Ensure you tighten the hub firmly once your blades are in place.

5. Attach the hub to the *ungeared* connection on the turbine body –the connection with the *small* cogged wheel.



Attach the hub to the small, ungeared connection on the turbine.

6. Position the turbine 50 cm in front of the fan, measured from hub to hub. Ensure that the turbine and fan are angled so the turbine faces the fan front on
7. Adjust the height of the turbine so its hub is the same height as the fan's hub.
8. Ask your teacher to check your setup. **Proceed when you have permission**.



9. Set the multimeter to 20 in the white 'V' range, or the white V (depending on your model multimeter) to measure voltage.
10. Turn the fan to its highest setting and measure the voltage across the wind turbine.

    Enter the voltage in the Results table below.

    Note: The reading on the multimeter is likely to vary. Estimate what you think the average reading would be.
11. Turn off the fan and multimeter.

Repeat for other blade numbers

- Remove the wind turbine hub and change the number of blades.
- Tighten the hub to secure the blades and replace on the turbine body.
- Ensure that the blade angles are 45°.
- Ensure that the positions of the wind turbine and fan don't change.
- Turn on the fan to full and take the voltage reading.
- Repeat until you have readings for 2, 3, 4, 6 and 12 blades.

RESULTS

Record your results in the table below.

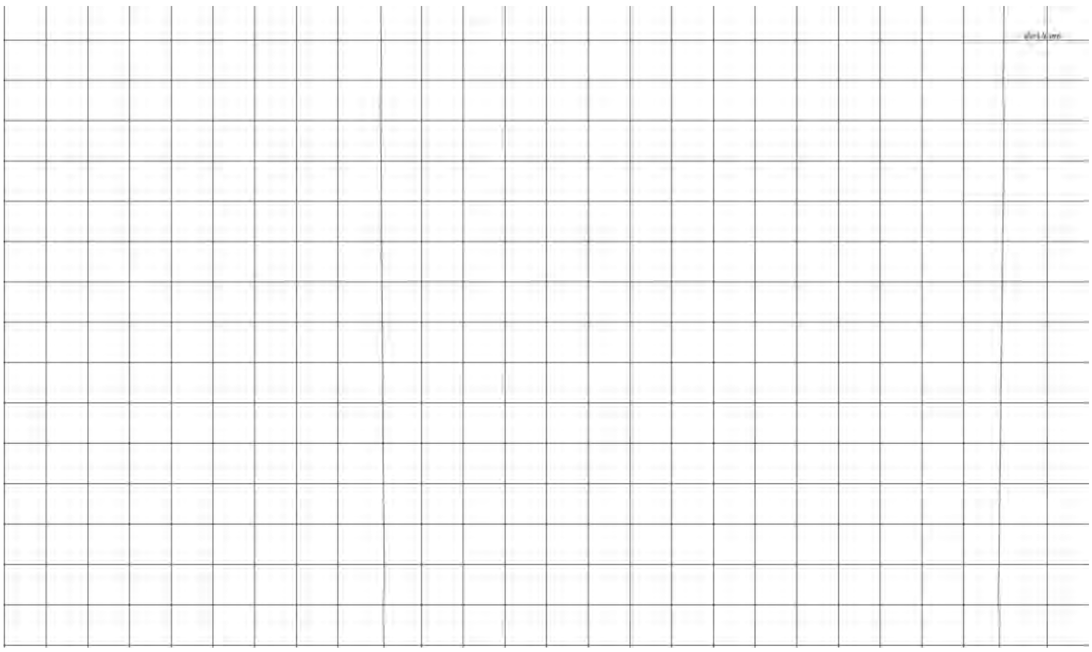
No. o f blades	Voltage (V)
2	Results will vary
3	
4	
6	
12	

Plot your results on the graph below.

Note: You will need to add numbers to the axes.

STELR wind turbine: voltage vs. no. of blades

Voltage (V)



No. of blades

Swap results

Swap your results data with two other groups. Add their results to your graph.

You should graph your results with points – do not join the points to make a line graph. Explain why you think this is.

The number of blades is always a whole number – there aren't half or third blades, for example, so it doesn't make sense to draw lines on the graph suggesting that there are values between the whole numbers.

DISCUSSION

Typically, we find 6 blades gives the highest voltage, but it need not imply that students have made a mistake if they get a different result.
We expect most students will have hypothesised either 12 or 3 blades:

- 12 blades because intuitively more blades mean more push from the wind
- 3 blades because they may have seen this on large modern commercial turbines

The intuition that says more blades is better is correct, but is balanced by the fact that adding blades also adds mass, so more energy is required to rotate them. The controlled variable may also have an impact. If a different blade angle, wind speed or length of blade had been chosen, the optimum number of blades may be different.

Did the results from your experiment match your prediction?

- If so, do you think this is for the reason you gave? Explain.
- If not, what do you think explains the results that you got?

Various answers depending on predictions and the results they got.

How did your results differ from those of the groups that you swapped results with? For example, did you agree on the best number of blades?

Describe the main differences in the three results sets.

Various, depending on results.

Factors responsible for different results include:

Recording of results

- Different estimates of the voltage, given that the value on the voltmeter wasn't steady.

Variables that we tried to control but which still had variances

- Blade angles
- Distance between the fan and turbine
- Angle of the fan to the turbine

- Fan speed

Other variables not previously identified

- Small differences in the equipment, e.g. wind turbine, turbine blade weight and shape, fan, voltmeter, cabling

Ambient wind conditions – air movement from different group's fans plus any other wind in classroom

Other…?

Why do you think that the results from the three groups differ as they do?

Hint: We identified some of the variables involved in this experiment in a previous question. Were the controlled variables successfully controlled? Could there be other variables that had an effect on the results?

Differences in reading unsteady measurements on the multimeters; differences in setup and equipment (see note above).

Why do you think that this experiment didn't test 1, 5, 7, 8, 9, 10 or 11 blades?

Because these can't be put in the hub so that they are evenly spaced. Putting them in unevenly will cause the turbine to spin poorly.

Did you have any practical difficulties carrying out the experiment? If so, how did you resolve them?

Various answer

Conclusion

Write a conclusion to your experiment.

Hint: Go back to check your experiment aim. Your conclusion should be a short statement that addresses this.

Various answers

6 SOLAR PANELS

Solar ‘farms’ are large paddocks of solar panels. Some solar farms even have sheep or cattle grazing under the panels.

This section looks at the generation of electricity using silicon-based photovoltaic (solar) panels. Students think about the advantages and disadvantages of using solar power, then use the STELR equipment to test the effect of connecting solar cells in series and changing the angle of the solar panel to the light source.
Two halogen lamps are supplied in the STELR equipment kit to be used as an alternative light source for the STELR solar panels. The light from the halogen lamps gives the closest wavelengths of light to that of the Sun. Be aware that the lamps can get quite hot after prolonged use. Encourage students to turn off the lamps when not in use.

Teachers are encouraged to have students undertake the pracs outside on a sunny day if practicable.

Students will need to understand how to connect up electric circuits. Teachers may wish to refer students needing a ‘refresher’, to the *Circuit Training* resource found on the STELR Renewable Energy USB.

The prac about angle to the light is given in less detail, so that students can design their own investigation.
6.1 Lesson: How solar panels work provides a simple explanation of how solar panels work, how they are manufactured, where in Australia gets the most sun and new solar technologies.
6.2 Prac: Exploring Solar Panels This prac helps students to become familiar with the STELR solar panel and then explore the output from the STELR solar panel with the cells connected in series.
6.3 Prac: Angle to the Light This prac is given in less detail, encouraging students to design and carry out the experiment themselves.

At the end of 2018, one in five houses in Australia had rooftop solar panels and 59 large-scale solar projects were being built.

Typical household rooftop installations have a capacity of 1–3 kW. Any electricity not used in the house can be sold into the electricity grid or stored in household batteries.

Many commercial buildings such as schools, universities, factories, shopping centres and markets are also installing solar panels.

In 2019, Australia’s largest solar farm in Coleambally, New South Wales, had capacity to produce 150 MW, which is enough to power 52,000 homes.

6.1 LESSON: HOW SOLAR PANELS WORK

This lesson provides an overview of solar photovoltaic technology and its use in Australia.
Students are asked to say what they know about solar panels to begin, then it quickly covers the energy transformation and how solar panels are made. There is a simple, high-level explanation of how a solar cell works and then students interpret solar radiation maps for summer and winter.
The lesson finishes with a creative sketching exercise, where students think of a new application for solar technology.

New Zealand

Solar irradiation maps for January and July in New Zealand are available on the STELR web site under Subject Resources / Renewable Energy. Source: National Institute of Water and Atmospheric Research (NIWA).

Indonesia

An annual average solar density map can be found here: solargis.com/maps-and-gis-data/download/Indonesia. Use the *Global Horizontal Irradiation* map.

KEY QUESTIONS

- How are solar panels made?
- How do solar panels work?
- Where does the sun shine most in Australia?

WHAT DO YOU KNOW ABOUT SOLAR PANELS?

Solar panels are common on roof tops in Australia, but how much do you know about them?

Work in small groups to put together everything you know, or think you know, about solar panels.

Include these questions:

- What do they do?
- What is another name for them?
- What is the difference between a solar *cell* and a solar *panel*?
- What are they made out of?

Question 1

List all the things you know, or think are true, about solar panels.

Various answers acceptable.

What do solar panels do?

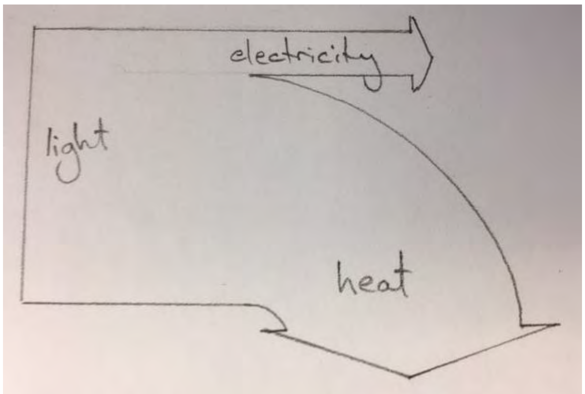
Solar panels transform the energy of sunlight directly into electricity.

- They produce no carbon dioxide when they operate, so provide us with usable energy without contributing to global warming.
- They are a renewable energy technology because the sun replaces the energy that they use every day – at least, if it is not cloudy.

Question 2

Most solar panels are less than 20% efficient, producing heat as waste energy.

Draw a Sankey diagram to represent the energy transformations that occur in a solar panel.



What's another name for solar panels?

Solar panels are also known as *photovoltaic* (PV) panels:

- 'photo' means light;
- 'voltaic' refers to electricity.

Question 3

Using a different text colour, add the words 'photo' and 'voltaic' to your Sankey diagram above, placing them close to the words that they mean.

What are solar panels made of?

Watch this video to see...

VIDEO Bosch Solar How it's Made (1)
https://youtu.be/B6rjm9bk5qs

Question 4

Solar cells are made from the element silicon. This is extracted from quartz sand. The extracted material is made into a rectangular shape then sliced into wafers, which are 1 mm thick.

What's the difference between a solar cell and a solar panel?

Watch the rest of the video, although – be careful – the narrator talks about solar *modules* instead of solar *panels*.

VIDEO Bosch Solar How it's Made (2)
https://youtu.be/NdMwOuCD7nI

Question 5

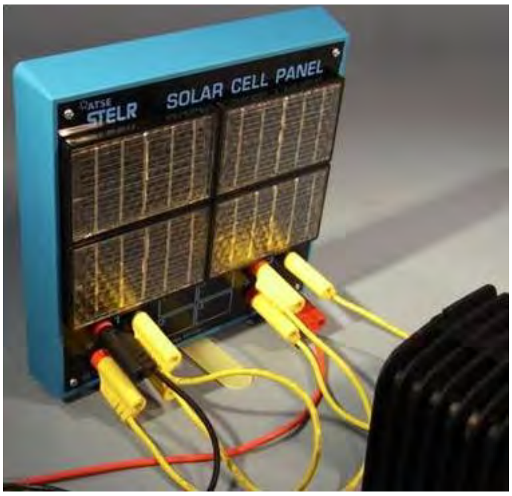
Each solar cell is stamped with a metal coating to transport the electricity. After testing, they are assembled. They are connected so that the voltage accumulates. There are 60 solar cells in a solar panel/module .

Actually, not all solar panels have 60 cells – some commercial ones have 72 cells.

Question 6

How many solar cells are there on the STELR solar panel?

4

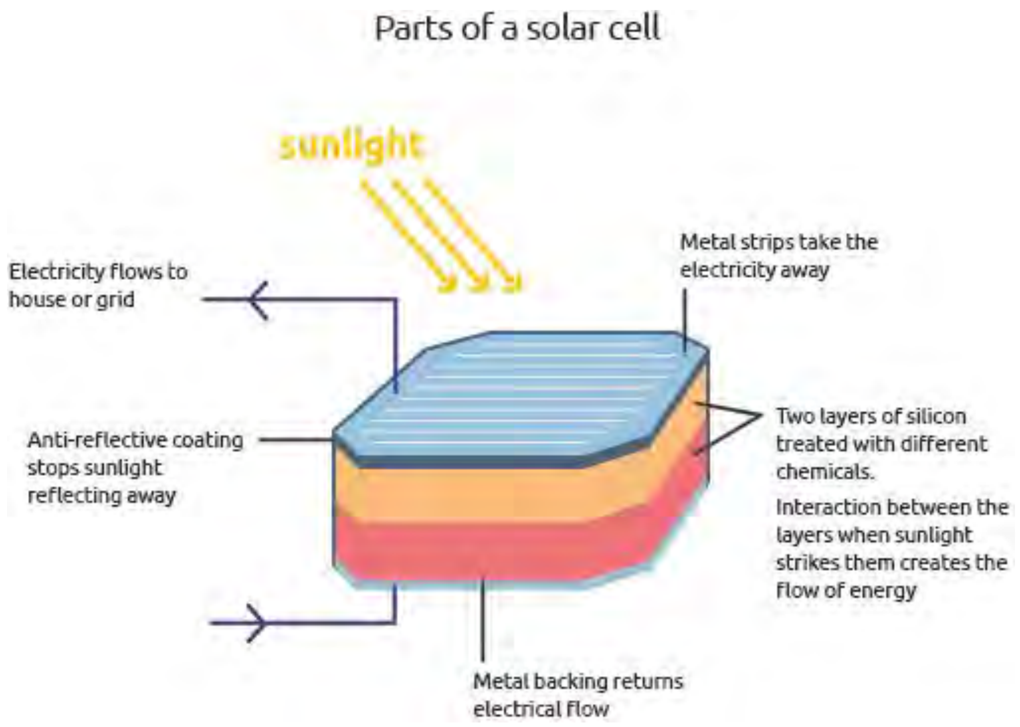


The description below of how solar cells work has no detail of the interaction between the silicon wafers. If you want to enlarge on this consider the video found here:
https://www.youtube.com/watch?v=XlOEPt2mMEI
or here:
https://australiascience.tv/episode/how-solar-pv-cells-produce-electricity/

The silicon wafers are 'doped' – mixed with small quantities – with boron or phosphorus. It could be good to point out that these are both elements, as is silicon (elements are introduced in Year 8 in the Australian Curriculum).

HOW DO SOLAR CELLS WORK?

The heart of a solar cell is two thin layers of silicon pressed together. The layers are almost pure, but have had small amounts of different chemicals mixed into them. When sunlight penetrates into them, the interaction between the two layers creates an electrical flow. Metal layers on the top and bottom of the cell take and return the flow of electricity that is created.



Question 7

In a solar cell, electricity is created by the interaction between:

- ☐ the metal strips and anti-reflective coating
- ☐ the two metal layers at the top and bottom
- ☑ the two silicon layers
- ☐ mechanical energy
- ☐ the bottom silicon layer and the metal backing

Question 8

Solar panels have to be connected into a circuit in order to provide useful energy.

- ☑ true
- ☐ false

SOLAR POWER IN AUSTRALIA

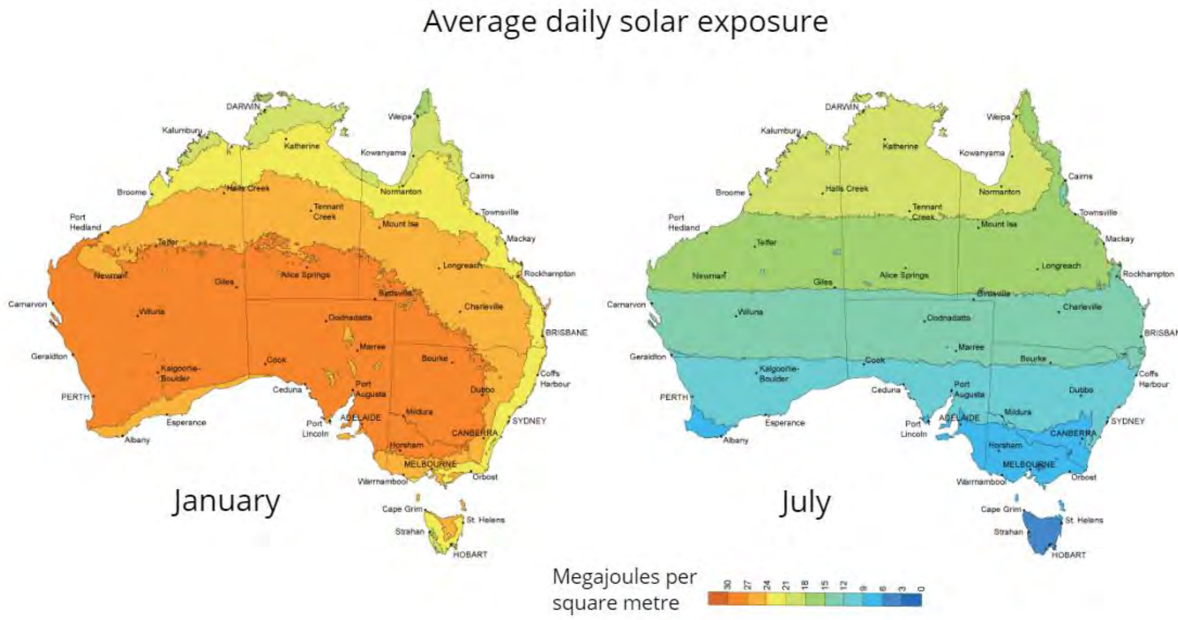
Solar panels on the Sydney Town Hall, and the 53 MW Broken Hill Solar Farm, which covers 140 hectares.
Credit: Broken Hill, Jeremy Buckingham,Wikimedia Commons

In 2016 solar panels produced 7000 GWh of electricity – about half the output of wind turbines. Almost all of this came from rooftop installations rather than solar farms, but there are plans to build more solar farms much larger than the existing ones.

Typical household rooftop installations have a capacity of 1–3 kW. Any electricity not used in the house can be sold into the electricity grid.

The largest solar farm currently has capacity to produce 100 MW. A new one planned for Queensland will be ten times bigger.

We include just a few questions for the solar radiation maps below, but you could easily develop more questions to give students further experience interpreting this type of map and understanding the patterns they show. You could write questions or discuss as a class. For example, note the differences between summer and winter, and greater sun exposure in the south during summer, presumable due to cloud cover in the north.
The maps come from this Australian Bureau of Meteorology site, where you can also get annual and other time period averages.



The maps above show how much sunlight different parts of the country get in January – mid summer – and July – mid winter. Use them to answer the questions that follow. (Source: Bureau of Meteorology www.bom.gov.au/climate/data/index.shtml).

Question 9

Which of the following statements are true?

- [x] In January, Adelaide gets more sunlight than Darwin.
- [x] Darwin gets about the same amount of sunlight per day in January as in July.
- [x] On average, Perth gets more than twice as much sunlight per day in January compared to July.
- [ ] On average, Brisbane gets over 20 megajoules per square metre of sunlight per day in July.

> The following question could be a good basis for class discussion. Students might only give a simple reading, e.g. 'Albany has between 6 and 9 MJ/m^2 sunlight a day in July', or more interesting comparisons between locations or times of year.

Question 10

Make a true statement of your own shown by one or both of the maps.

There are many possible statements.

> The question below might look difficult to some students, but they should be able to get it. They should know that joules are a measure of energy, and m^2 a measure of area, so the unit measures the sunlight energy delivered to a unit of area over a day.

Question 11

The units used in the maps are megajoules per square metre (MJ/m^2).

How would you explain what these units mean to a grade 6 student?

Hint: Your answer will need to include the words energy*,* area*, and* day*.*

Joules is the unit of energy, and one megajoule is a million joules. In this case it is measuring how much sunlight energy falls on each square metre of the Earth's surface in a day.

NEW SOLAR TECHNOLOGIES

Photovoltaic technology is advancing at a rapid rate. Some emerging technologies include:

- flexible solar cells that can be put into fabrics
- solar cells integrated into building materials, for example roofing and windows

Solar cells in tents and windows.

Question 12

Using the photos above as a prompt, think of a new product that could use solar cells in an interesting and useful new way.

Draw a sketch of your idea and label to help explain your idea.

Various responses acceptable

Question 13

Look at another student's answer to the previous question. Outline their idea here and then imagine you are on a panel of reviewers to fund this product. Provide some constructive comments on it, including:

- Who might be interested in the product?
- How much might it cost to make?
- How useful is it going to be?

Various responses acceptable

6.2 PRAC: EXPLORING SOLAR PANELS

This prac measures the voltage delivered by a single cell on the STELR solar panel and compares this to the voltages of the four cells in parallel and in series.
The experiment has a moderate amount of guidance, for example, results tables are provided. Students should work in small groups.
At the end, students share their results and calculate averages. A set of final questions, good for group and/or class discussion, consider differences between individual results and what these mean for scientific method.
Note: In this experiment students measure voltages across solar cells that are not in a circuit. Given the importance placed on circuits so far this might surprise some students. You may need to explain that this is acceptable for sources of electrical energy.
A video showing how to set up the STELR solar panel to generate electricity can be found here: https://australiascience.tv/episode/how-to-use-the-stelr-solar-cells/
Or here: https://www.youtube.com/watch?v=UttPMAlFnWA
A video specifically showing how to connect the solar cells in series can be found here: https://www.youtube.com/watch?v=ZGabr_Hp8M4

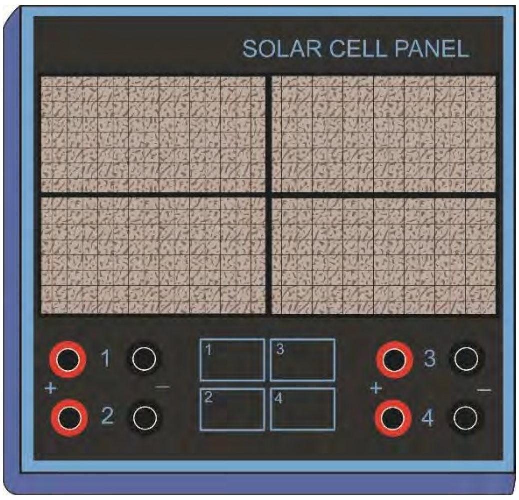
KEY QUESTION

- What voltages does the STELR solar panel produce when the cells are connected in series?

The STELR solar panel has four solar cells, as shown at right.

The cells are numbered – shown in the key at the bottom of the panel – and the connectors for each cell identified.

In this activity you will compare the voltages delivered by the panel's cells in series and parallel, but first, measure the voltage from a single cell, to provide a basis for the comparison.



Aims

- To measure the voltage delivered by a single STELR solar cell.
- To measure the voltage delivered by a STELR solar panel with the four cells in series.

Hypothesis

What do you predict the voltages of the four cells will be when they're in series?

Mark how many times the voltage of a single solar cell on the scales below.

Correct answer shown above, but as a hypothesis students aren't expected to get these right.

Materials

- STELR testing station
- STELR multimeter
- 2 x halogen lamps
- STELR solar panel
- connecting leads
- STELR A.C. power supply

Risk assessment

Complete the following risk assessment.

Fact	Risks	Precautions
Multimeters are sensitive instruments	They could be damaged if dropped, knocked, or used roughly	Handle them with care
The halogen lamps get very hot	You could get burnt	Turn off the lamps when you don't need them. Handle them carefully so as not to be burnt
The halogen lamps use a power pack connected to mains electricity	Possibility of electric shock when connecting and disconnecting from mains power	Take care when connecting and disconnecting the power source

Variables

Identify:

- the independent variable – the variable you change to see the difference it makes;
- the dependent variable – the variable you measure to see if/how it changes when you change the independent variable;
- three controlled variables – other factors that you keep constant so they don't have any impact on the dependent variable.

Note: There are many variables that you should control – pick ones that you think will make the most difference if you don't control them (for example, where the halogen lamps are pointing).

independent variable:	whether the cells on the solar panel are connected in series or in parallel
dependent variable:	the voltage produced by the solar panel
controlled variable 1:	the position on the solar panel that the halogen lamps are shining on
controlled variable 2:	the distance of the halogen lamps from the solar panel
controlled variable 3:	the angle of the solar panel to the light coming from the lamps

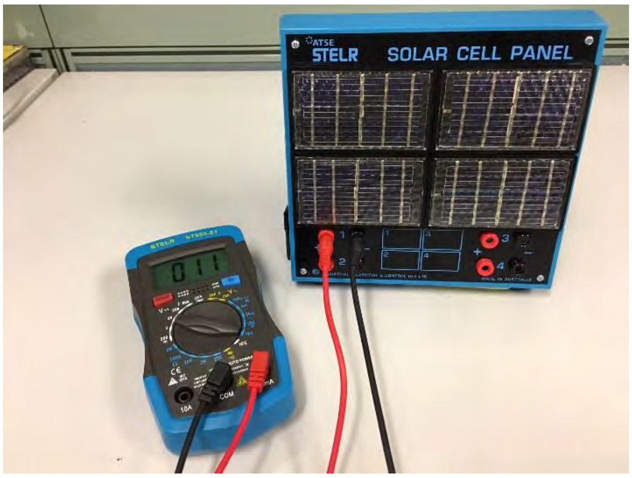
READ THE VOLTAGE OF A SINGLE SOLAR CELL

For electricity to do anything it must be in a circuit, but the voltage of electricity sources, like batteries and solar cells, can be measured when they're not in a circuit. We'll do this in this experiment.

First, connect the multimeter to solar cell 1 on the STELR solar panel, as shown:

- connect the cell **1 +** connector on the panel to **VΩmA** on the multimeter;
- connect the cell **1 –** connector on the panel to **COM** on the multimeter;
- turn the multimeter to **20** in the **white V** range or the **white V** (depending on your multimeter).

You should get a small voltage reading from the light in the room.



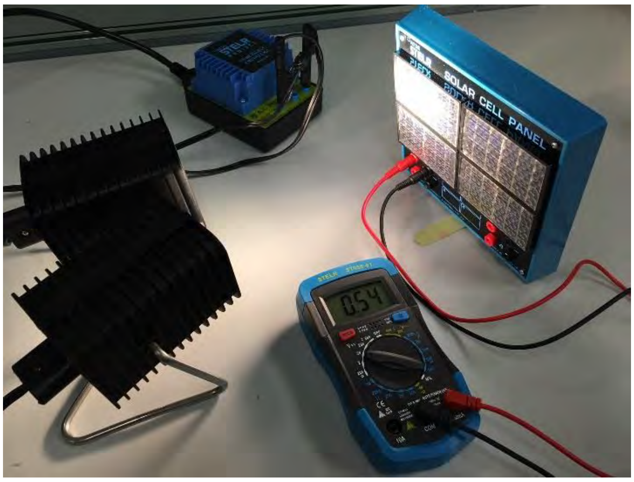
Try moving the panel or pass your hand over the cell – see the difference it makes.

Now set up the halogen lamps and shine them directly on solar cell 1.

The halogen lamps produce a light similar to sunlight.

- Connect each halogen lamp to the **0 V** and **12 V** connectors on the power supply pack.
- Plug the power supply into a wall socket and turn on.

Read the voltage across the cell and record below.



Check all the solar cells

Attach the voltmeter cables to each of the cells in the panel, direct the halogens onto the cell, and read the voltage it produces.

Fill in your voltage readings in the table below, and then work out the average.

Solar cell no.	1	2	3	4	Average
Voltage (V)					

With both halogen lamps directed at a cell it should produce over 0.5 V (if any of your cells are less than this, let your teacher know).

FOUR CELLS IN SERIES

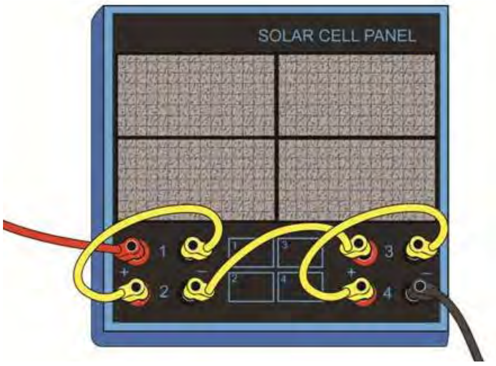
Now to measure the voltage of four solar cells in series. You will compare this with the same cells connected in parallel.

To make sure that the comparison is fair, ensure that all the variables – except the one you are testing – stay the same.

> Probably the most important variable to control is the distance between the halogens and solar panel, and perhaps too where the halogens are aimed on the panel. If students don't think of this you may want to hint.

Now connect the solar cells in series, as shown at right:

- connect the **–** connector of cell **1** to the **+** connector of cell **2**
- connect the **–** connector of cell **2** to the **+** connector of cell **3**
- connect the **–** connector of cell **3** to the **+** connector of cell **4**
- connect the multimeter to cell **1** **+** and cell **4** **–**



The 4 solar cells connected in series

Place the panel in position in front of the halogen lamps and turn them on. Read the voltage and record it in the Results section to follow.

Note: It may be more convenient to connect the cells from the back of the panel instead of the front.

RESULTS

Fill in your results below.

Average voltage of a single solar cell (V):	Answers will vary but should be around 0.5V
Voltage produced by 4 solar cells in series (V):	Answers will vary but should be around 2V

Compare results with other groups. Share your data to fill in the table below.

Copy your results and results from four other groups into the table below, and work out the averages.

		Voltages (V)	
Group no.	**Students in group**	**Single cell (avg)**	**4 cells in series**
1			
2			
3			
4			
5			
Average	**N/A**		

Summarise the class's results. How do the average voltages for four cells compare to the average single-cell voltage?

Hopefully, results show that the voltage from four cells in series is four times the voltage of a single cell, and four cells in parallel give the same voltage as a single cell.

DISCUSSION

Discuss the questions below in your groups before answering.

It could be good to have class discussion of the following questions before or after students answer.
On the question of how to deal with radically different results, the usual practice is to reject outlying data on the assumption that there was some error in the experiment. This means, in effect, that one or more 'controlled' variables was not controlled. But for genuine research, this should not be done lightly – really you should be sure what went wrong before you reject the results. It could be that you controlled all the known variables and there was an unknown variable that affected the result. That could be a new discovery!

Did the results agree with your hypothesis? If so, repeat your hypothesis here, and if not, describe how the results differed.

Can you explain the results?

Various answers depending on students' hypotheses.

It is highly unlikely that the results of the different groups were the same. Give two reasons why there might have been differences.

Different setups, e.g. distance of lamps from the solar panel. Small differences in the equipment, e.g. the brightness of the lamps, solar cell efficiency, multimeter accuracy.

Why do you think the class data was averaged?

In a single experiment some particular aspect may have a strong effect on the results. Other groups in the class are unlikely to have exactly the same issue, so by averaging all the results the effect that it has on the overall results is lessened. Hopefully, just the effects of the variables that all the experiments had in common (the difference between series and parallel connections) is seen in the averaged results.

If one group had very different results from all the other groups, do you think you should exclude their results? Explain.

If one group's results are very different then it suggests that there was something wrong with that group's equipment or in the way they ran the experiment. So it is probably fair that their results are excluded. However, this shouldn't be done unless you can identify what the problem was. In real research, unexpected results can be what lead to new discoveries.

Assess the experiment as carried out by your group. For example, did it go well, and do you think it was a fair test? (Reasons it might not have been include that the basic design was flawed, or you had practical difficulties carrying it out.)

Various answers depending on how the experiment went.

Conclusion

Write a short summary of the experiment addressing its aims.

Various answers acceptable.

6.3 ANGLE TO LIGHT

In this experiment students test the difference it makes when the angle that the light strikes a solar panel is varied.
Minimal guidance is given for this prac. There is probably not a great deal of variation in the way the experiment can be set up, however this is left to students to decide. They also have full control over the design and presentation of most other aspects of the experiment, including how the results are presented.

- **Measuring angles:** we give directions and provide a printable 'alignment circle' to measure angles, so all students use the same method and can compare results.
- **Comparing results:** the instructions don't ask students to compare results between groups, but this will be a fruitful exercise, with discussion, if you have time.

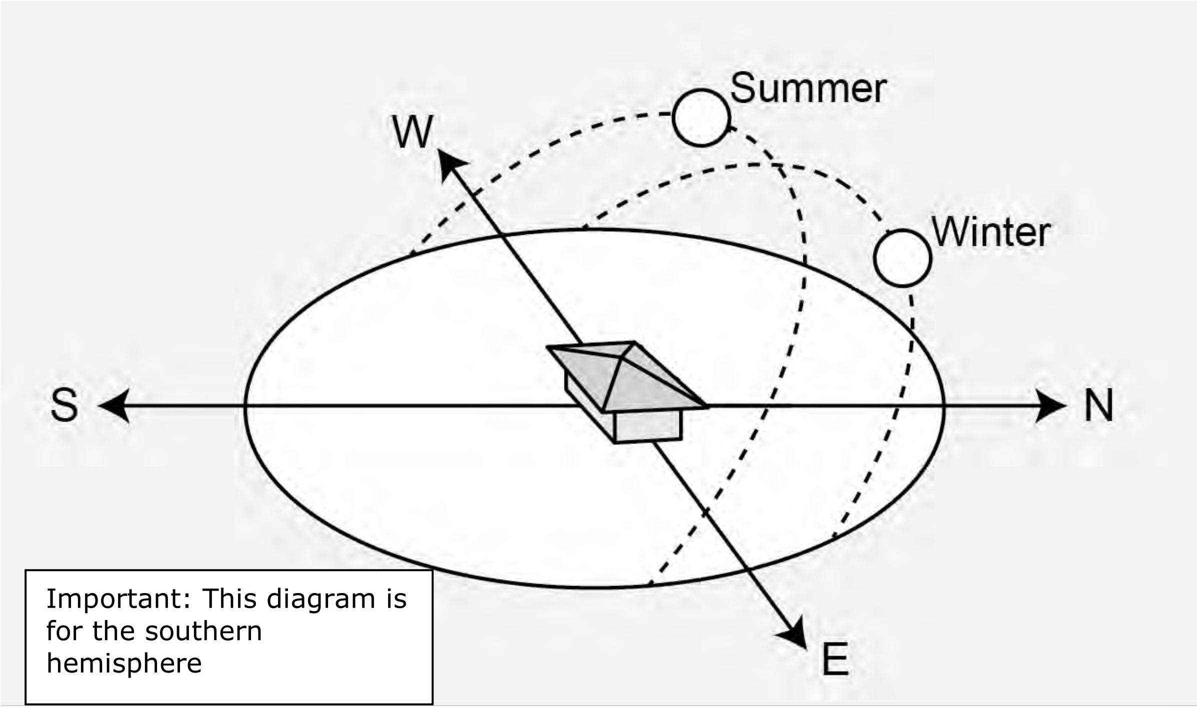
KEY QUESTION

- How does the angle that light strikes a solar panel affect the voltage?

Some solar panels, like the ones pictured above, are mounted so that they twist about to follow the sun, but most are fixed in one position. Engineers need to know the angles to point the panels to produce the most electricity. This isn't simple because the sun moves in two different ways:

- daily – across the sky from east to west
- yearly – the daily path shifts from south to north and then back again.

So where the sun is in the sky depends on the time of day and the time of year. It also depends on where you are on the planet.



Every day the sun goes from east to west (the dotted paths), but in summer the path is closer to the south, making the sun higher at noon (in the southern hemisphere), and in winter the path is more to the north, making the sun lower in the sky at noon.

The purpose of this prac is to find out how much difference the angle of the light to a solar panel makes.

Use the STELR equipment to investigate this, but beyond that, you will have to decide in your groups how you design, conduct and report the experiment.

MEASURING ANGLES

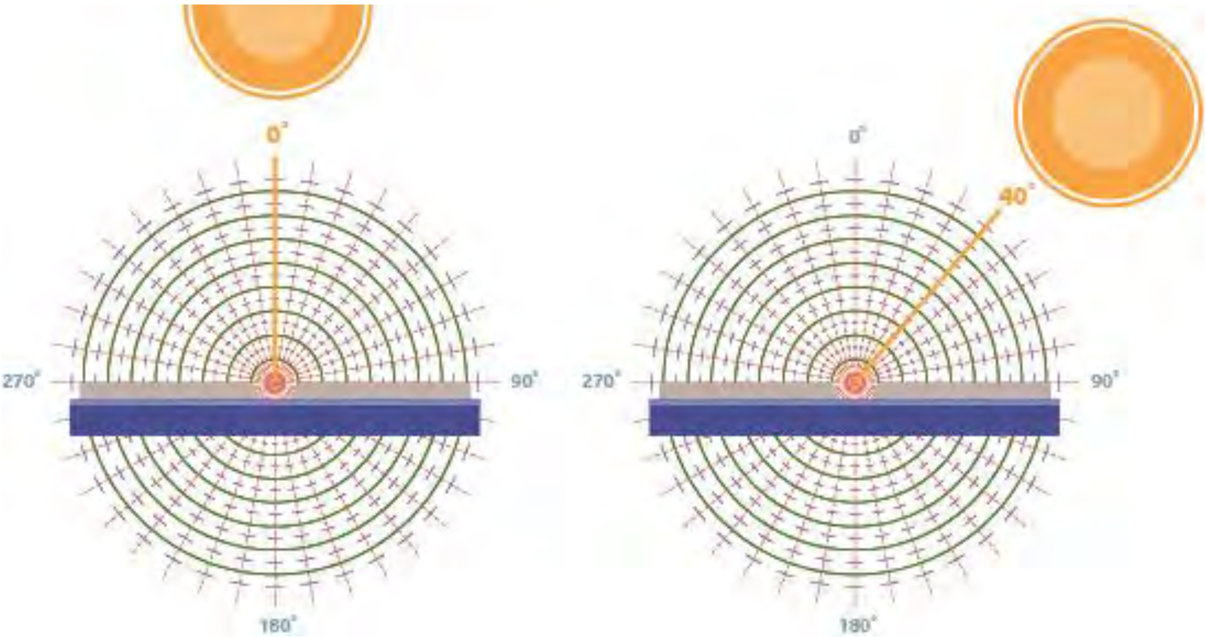
So that you can compare results around the class, everyone should use the same method to measure the angles of the light to the solar panels.

Use the alignment circle provided, as illustrated below.

- 0° is when the light source is directly in front of the panel.

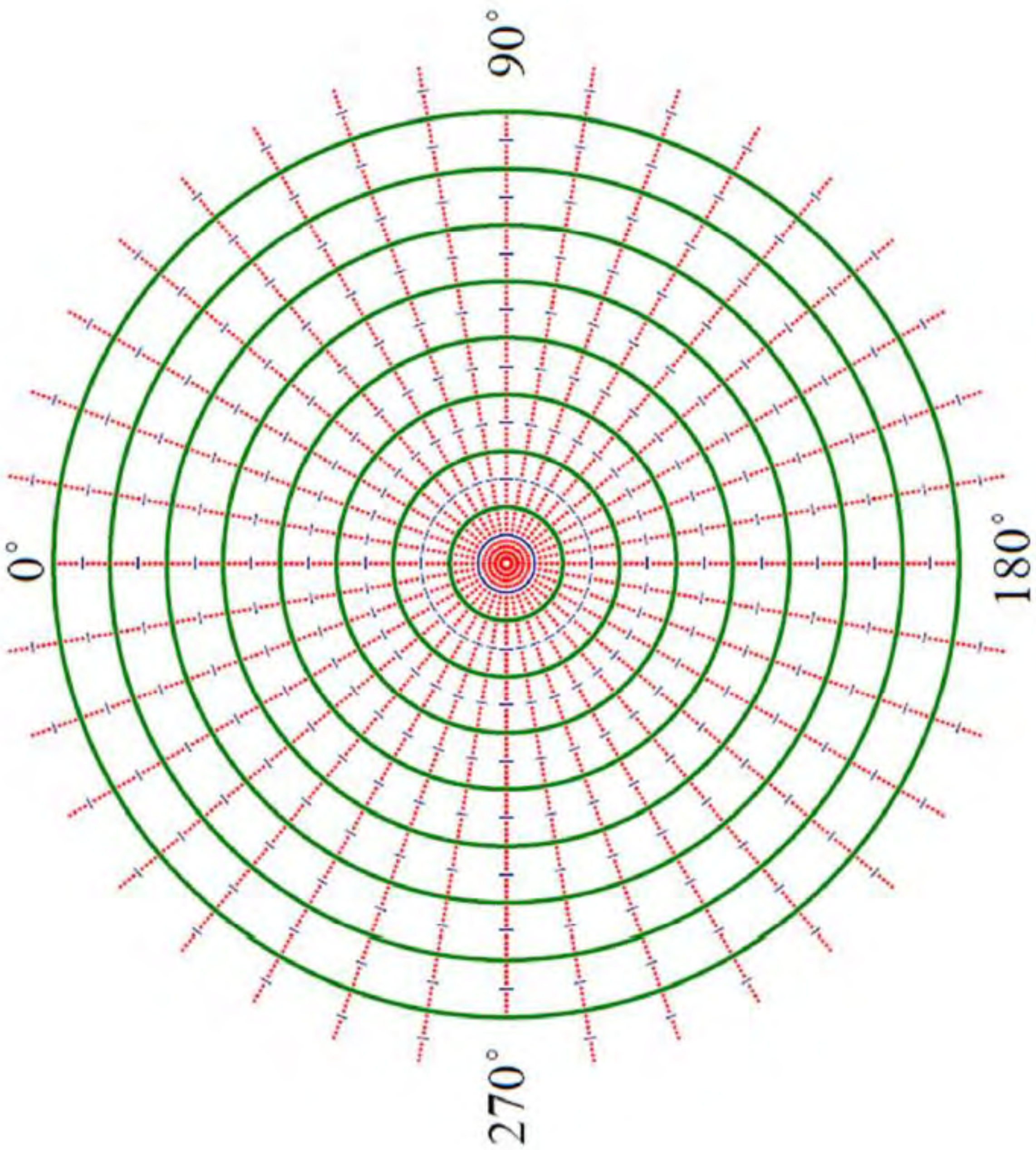
Some questions:

- Should you test between 90° and 270°? That puts the light source behind the panels.
- If you test between 0° and 90°, should you test between 270° and 0°?



How to use the STELR alignment circle to measure the angle of light to the solar panel. The solar panel is shown from above.

STELR solar panel alignment circle



From here, students design and carry out the experiment for themselves. Some factors you may want to look out for:

- students can use previous experiments for pointers on how to proceed
- the independent variable is the angle of the light to the panel, the dependent, the voltage produced
- to be accurate, students should measure the voltage produced by ambient light and subtract this from all their measurements (but failure to do this is unlikely to make a lot of difference)
- for a fair test students should make sure that the lamp is the same distance from the solar panel for each reading, also that the light is centred on the same point or points on the panel
- the test can be carried out with a single cell or cells connected in series or parallel. Arguably a single cell is closer to real-world examples in that the whole of the cell surface is illuminated, as it would be outside, whereas with four cells the outer edges are likely to get less light than the centre.

DESIGN AND RUN THE EXPERIMENT

Write up your experiment.

You must include:

- aim;
- hypothesis;
- materials;
- method (consider including diagrams or photographs of your setup);
- risk assessment;
- variables (note: it is important to keep all variables except the independent variable at the same levels, to make your test fair);
- results, presented clearly (is it possible to graph them?);
- conclusion (addressing the aim).

Important! Have your teacher check your preparation before you carry out the experiment.

There are two pages in the book to write up the experiment – use your own paper and attach if this is not enough.

There are some discussion questions to finish.

Students provide full experiment write-up.

DISCUSSION

Did your results agree with your hypothesis? If so, repeat the hypothesis here, and if not, describe how the results differed.

Can you explain the results?

Various answers depending on students' hypotheses and results.

Assess the experiment you carried out. For example, did it go well, and do you think it was a fair test? (Reasons it might not have been include that the basic design was flawed, or you had practical difficulties carrying it out.)

Various answers acceptable depending on how the experiment went.

Re implications for real solar panels, in our experiments there was no significant change in the voltage until 40°, and even at 60° there was only about a 15% drop. So there's a fair degree of leniency in the angle that panels can be placed. Nevertheless, an optimum pitch is likely to be the mid-points of the daily and yearly trajectory changes.

Some differences that might be noted between the experiment and real-world conditions:

- clouds (but these won't vary reliably with the angle of light)
- atmosphere...sunlight has to pass through more air close to the horizon, filtering it, so in the real world we would expect voltages to drop off more at these angles

Also:

- in real application there might be more interest in producing electricity at certain times of the day. So, for example, if more electricity is required in early evening then panels should have a westward orientation.
- to maximise electricity production over a year it would pay to pitch them slightly higher than the summer/winter mid-point, to take advantage of the longer summer days

Do you think that your results have implications for the placement of solar panels on buildings and in other locations?

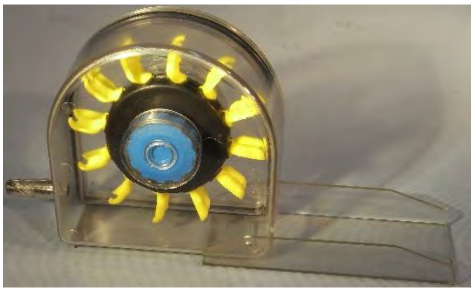
- If not, why not?
- If so, what are the implications? Explain.

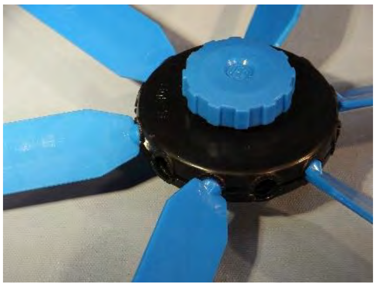
Various answers…see teacher note above.

If you were given the opportunity, what further investigation would you carry out to build on what you learned from this investigation?

Various answers acceptable.

7 OPEN INQUIRY





As much as possible encourage students to come up with their own ideas to investigate.
Some other possibilities might be:

- different light sources for solar panels
- the effect of increasing or decreasing the temperature of the solar panels (put them in the refrigerator overnight)
- blade length for the wind turbine
- wind speed for the wind turbine
- different combinations of wind turbine blades to give the same surface area
- how does the height of a wind turbine above the ground effect output?
- how does the angle to the wind effect the energy output
- how do obstacles in the wind's path (modelling buildings, for example) effect energy output?
- use the Pelton wheel to investigate hydro-electricity. The flow-rate through the Pelton wheel can be calculated by measuring the volume of water passing through the wheel over a set period of time.

More challenging ideas:

- Design your own wind turbine blades. Use the dowel sticks in the STELR kit and materials such as heavy card or plastic (e.g. ice cream container lids). Hot glue blades to the dowel and insert into the turbine hub. Schools with 3D printers can design and print their own wind blades. Drawings and files are provided on the USB that comes with the STELR resources.
- Use the variable resistor on the STELR test rig to determine the optimal resistance required to get the most power from the wind turbine.

In groups, conduct your own investigation with the STELR solar panel or wind turbine.

There are some suggestions below, but try to think of your own ideas. Of course, you'll have to agree on your investigation as a group.

You must design, conduct and report on your investigation, using the same format as in previous experiments.

Important: Get permission from your teacher before you carry out your experiment.

Possible inquiry questions:

Solar panel

- What is the effect of clouds on the energy delivered, or dust or leaves?
- Does temperature have any effect on energy output? If so, how?

Wind turbine

- Will combinations of different blade lengths and/or angles generate more electricity?
- How does blade surface area relate to energy output?
- How do gears and gear ratios affect the output of a wind turbine?

Pelton Wheel

- How does the flow rate of water affect the output of a hydro power station?

PLAN, CARRY OUT AND REPORT

First, plan your experiment. You will need to include enough information in your plan to convince your teacher that you are ready to go ahead. Use the investigation planner on the following page.

When you have permission, carry out the experiment. It may not work properly straight away – you may need to change materials and/or procedure before you take your data readings.

Finally, record your data and present it in a meaningful way. Then discuss what it shows.

In your final report, make sure you include:

- inquiry question (also, because this is your own question, include any background discussion to explain why you are interested in this question);
- aim;
- hypothesis;
- variables;
- materials;
- procedure;
- risk assessment;
- data table and, if appropriate, a graph;
- discussion, including:
    - how the experiment went, including any problems encountered and whether they were overcome;
    - if the results agreed with your hypothesis;
- conclusion.

INVESTIGATION PLANNER

What are you investigating?	
What are you going to investigate?	What do you think will happen? Explain why.
What is your hypothesis?	What is the aim of your investigation?
Designing your experiment	
What variables might affect the outcome of your investigation?	What variable(s) will you test?
How will you make your tests fair?	What observations and measurements will you need to take?
How will you ensure that your measurements are reliable?	What calculations (if any) will you need to make?
What risks might there be? What safety precautions do you plan to take?	What materials and equipment will you need?

Your results	
How will you record your observations and measurements?	What graphs can you draw? What spreadsheets can you design to display your results?
Conducting your investigation	
Once your teacher has approved your plans and you have the materials, conduct your investigation. Record how the investigation was performed. Include any modifications that you made and why you made them.	
Analysing your results: your conclusions	
Examine your results. Use them to answer your aim.	From your conclusions, were your predictions and hypothesis correct? Does your hypothesis need to be modified? Discuss.
Evaluating the investigation	
How reliable do you think your results were? Discuss.	How could you modify your procedure to make your results more reliable?
If you were given the opportunity, what further investigation would you carry out to build on what you learned from the investigation?	

8 STEM AT WORK

This lesson gives students an insight into some careers in STEM-related fields – specifically renewable energy. We ask them to consider two career profiles – Jessica Ong (video) and one other from a selection on the STELR web site (text). Students answer basic questions about the roles then consider questions intended to make them think about how engineering contributes to society and about their own ambitions and skills.
Some of the questions would be good for discussion.

There are many careers in STEM-related fields (science, technology, engineering and mathematics) – and not always as scientists, engineers or mathematicians. Renewable energy is a particular growth area.

Watch the video below and choose one person from the STELR *Career Profiles, Renewable Energy* web page. Then answer the questions that follow.

VIDEO

Sheena Ong, graduate engineer

https://www.youtube.com/watch?v=R2o2VtaFArI
https://australiascience.tv/episode/sheena-ong-renewables-engineer/

STELR Career Profiles, Renewable Energy
www.stelr.org.au/career-profiles-renewable-energy/

Question 1

Fill in some basic information about Sheena and the person you chose from the STELR website.

	Person 1	**Person 2**
Name	**Sheena Ong**	
Organisation & what it does		
Role		
High school subjects		
Other qualifications		
Job duties		
What they like about the job		

The question below could be good for discussion.
Presumably, humanitarian engineering means engineering for the benefit of people (as opposed, perhaps, to governments or corporations). Arguably, *humanitarian* includes sympathetic consideration of the environment and other species as well.

Question 2

In the video, Sheena talks about her interest in *humanitarian engineering*.

- What do you think this term means?

Describe two possible engineering projects, one humanitarian and the other not. Explain what makes the difference, in your opinion.

Various responses are acceptable (but see teacher note above).

Question 3

All of the people profiled carry out a variety of tasks within their jobs, often mixing field work, office work on the computer, and liaising with a diverse range of people.

- From the two profiles that you've looked at, which type of task would you like best?

How could you train yourself to be better at this type of task?

Various responses depending on students' interests and self-assessment.

Question 4

Do you think there will still be jobs like the two you've looked at in 20 years? If not, do you think your two career profilees will be well equipped to adapt? Explain.

Various answers are acceptable. To the extent that the profilees do repetitive tasks, these could likely be replaced by robots and computers. To the extent that they

9 WRAP-UP

This section has the answers to the post-test for the unit. The test is in a separate file and is found on the STELR USB provided with the STELR equipment.

There is also a comprehensive glossary. The Renewable Energy Student Book contains a blank glossary table on the last page. Students should be encouraged to use it to enter new words, phases and their meanings.

9.1 POST-TEST

This test has multiple choice and written-answer questions. Unless indicated otherwise, the multiple choice questions may have more than one correct answer.

GLOBAL WARMING

Question 1

The greenhouse effect:

- [x] is essential for life on Earth
- [ ] is what gives the sky its blue colour and the sea its blue-green colour
- [x] keeps Earth warmer than it would otherwise be
- [ ] is the result of smoke pollution
- [x] is the 'trapping' of some of the Earth's heat radiation in the atmosphere

Question 2

The *enhanced* greenhouse effect:

- [x] has been occurring for the last 200 years
- [ ] is caused by the hole in the ozone layer
- [ ] shields the planet from harmful radiation
- [x] has the burning of fossil fuels as its main cause
- [ ] is essential for life on Earth

Question 3

What role do fossil fuels play in global warming?

- [x] When they are burned they produce carbon dioxide, which is a greenhouse gas
- [ ] All the fossil fuels are greenhouse gases
- [ ] They cause global warming because they are not renewable
- [ ] When they are burned they release heat, which is the main cause of global warming

Question 4

Which of the following are likely effects of global warming?

- [x] More, and more severe instances of torrential rainfall
- [x] Rising sea levels
- [ ] Increased radiation from the sun
- [ ] Increased volcanic activity
- [x] Melting of polar ice

Question 5

Sarah says that greenhouse gases are bad for the planet. What would you say in response?

Greenhouse gases are good and bad.

We need a certain amount of them, because they raise the average temperature to one that supports life. Life on Earth has evolved for the temperatures that result from low levels of greenhouse gases, that give the Earth an average temperature of 16°C.

But greenhouse gases are bad if we get too much of them. Then they raise average temperatures beyond what life has evolved for. If the proportion of greenhouse gases goes up too fast, many species are likely to go extinct. The rapid warming will also have direct negative impacts on humans, with more droughts, fires and floods, and rising sea levels.

WHAT IS ENERGY?

Question 6

Which of the following statements about energy are true?

- [ ] Electric batteries don't have energy themselves, but can give other things energy
- [x] Energy has many different forms, such as can be found in natural gas, sunlight, and water in mountain lakes
- [ ] If you train hard you will build up your energy
- [ ] If something has energy it has to be moving, for example a train speeding along
- [ ] Pushes, pulls and twists are all forms of energy

Question 7

Which of the following are examples of objects increasing in energy?

- ☑ A leaf: when it's photosynthesising
- ☐ A car engine: while it's cooling down after a long run
- ☑ A ball: picking up speed as it rolls down a hill
- ☑ A lizard: being carried to the top of a tree by a bird that has caught it
- ☑ A rubber ball: when it's being squashed

Question 8

The scientific unit of energy is the:

(*select only one*)

- ☑ joule (J)
- ☐ ampere (A)
- ☐ volt (V)
- ☐ watt (W)
- ☐ kilowatt hour (kWh)

For question 9, in fact a compressed car spring does have kinetic energy, because there is motion in the atoms and molecules. Students are unlikely to think of this, however the iron bar heated to red hot is intended to elicit exactly this observation. This is the reason for the 'according to the descriptions given' in the question...

- a compressed spring has potential and not kinetic energy, due to its compression
- an hot iron bar differs from a cool iron bar in the kinetic energy of its atoms
- a piece of firewood has potential chemical energy with respect to its function to be burned

Question 9

Which of the following are examples of things with a form of kinetic energy, using the descriptions given?

- [x] Atoms in a red hot iron bar
- [ ] A car spring, compressed when the car is fully loaded
- [ ] A piece of firewood
- [x] A turbine in operation at a hydro-electric power plant
- [x] X-rays radiating from an X-ray machine

Question 10

'A book on top of a wardrobe has more energy than a marble rolling slowly across the floor.'

Discuss this statement. Could it be true? Does it even make sense? Explain.

The statement does make sense, and could be true. Both of the objects referred to have energy, so the amount of energy each one has can be compared.

The book has energy because it is up above the ground, and so has gravitational potential energy. The marble has energy because it is moving. The movement means that it has kinetic energy. Even though the forms of energy are different, and one is only potential, they are still fundamentally the same thing...energy, measured in joules.

[Some students may note that both objects have chemical and nuclear energy as well.]

ENERGY TRANSFERS AND TRANSFORMATIONS

Question 11

Which of the devices pictured above carries out this energy transformation?

light → electricity

- [ ] Bunsen burner
- [ ] Wind turbine
- [ ] Torch
- [x] Solar panel

Question 12

What is the *main* energy transformation carried out by a Bunsen burner (for which it is used)?

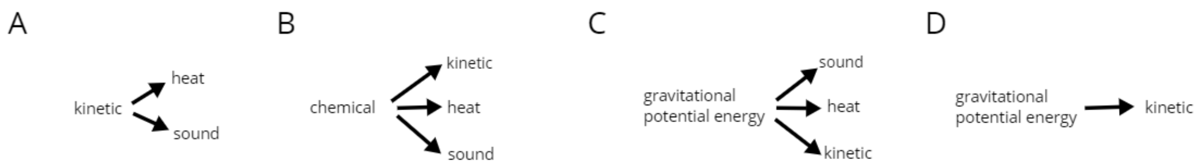
- [x] chemical → heat
- [ ] kinetic → heat
- [ ] chemical → light
- [ ] elastic → kinetic

Question 13

When you place soup in a saucepan over a gas flame, the lid heats up even though the flame isn't touching it.

Which is the best explanation?

- [ ] chemical potential energy in the metal lid is being transformed into heat
- [x] the heat energy of the flame is being transferred through the saucepan to the lid
- [ ] the heated saucepan is transforming heat into the lid
- [ ] heat energy from the flame is transformed into chemical energy in the soup, which is then transformed back into heat in the lid



Question 14

A girl is standing on her skateboard, rolling down a hill.

Which flow chart, above, most accurately represents the energy transformations?

☐ A

☐ B

☑ C

☐ D

Moiwa hydro-electric power station in Japan. Credit: 禁樹なずな Wikimedia Commons.

Question 15

What energy transformations occur in a hydro-electric power station?

- Where and/or what equipment is involved in each transformation?
- Do you think all of the original energy is transformed into the final form? Explain.

The original energy resource for a hydro-electric power station is gravitational potential energy. Water is collected in a dam above the powerhouse. The water is piped down to the powerhouse. It picks up speed as it flows down...this is a transformation from gravitational potential to kinetic energy. In the powerhouse the water forces a turbine to spin. This is a transformation of kinetic energy in the water to mechanical energy in the turbine. [Equally correct would be to say it is a transfer of kinetic energy from the water to the turbine.]

The spinning turbine is connected to a generator, which also spins, generating electricity. The generator transforms mechanical energy into electricity.

No, not all of the original gravitational energy of the water is transformed into electricity. Some of that energy is lost as heat and sound. This will occur in the fast-moving water and in the turbine and generator.

ENERGY EFFICIENCY

Question 16

Electric cars run with efficiencies of around 60%. This means that:

(*remember, there may be more than one correct answer*)

- ☐ on average, electric cars operate at 60% of what they are capable of doing
- ☐ about 60% of the electrical energy delivered to the cars is wasted
- ☑ about 40% of the electrical energy delivered to the cars is transformed into forms of energy we don't want
- ☑ about 60% of the electrical energy delivered to the cars is transformed into kinetic energy

Question 17

If 100 joules of electrical energy is supplied to an LED downlight but only 47 joules of light is emitted, the energy efficiency of the light is:

- ☐ 2.13
- ☑ 47%
- ☐ 53%
- ☐ 147 J
- ☐ 4700

Question 18

A netball is dropped onto a flat surface from a height of 2 m and rebounds to 1.3 m.

- What is the ball's rebound efficiency? (Show your working)

Why doesn't the ball rebound to the height it was dropped from?

Note: Your answer must include the words transform or transformation.

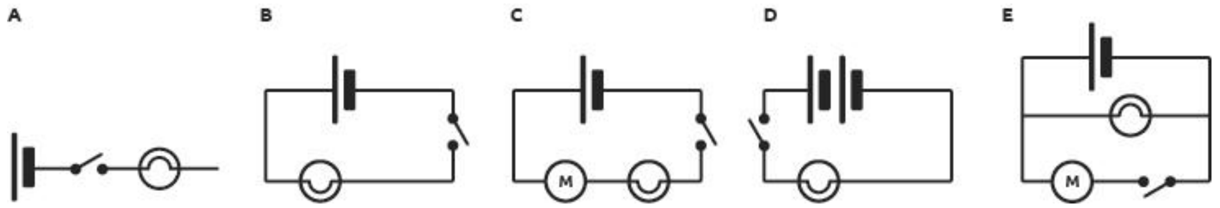
The formula to calculate a ball's rebound efficiency is the rebound height divided by the drop height, multiplied by 100 to turn it into a percentage.

In this case this is: 1.3/2 x 100 = 65%

The ball's rebound efficiency (on this surface) is 65%.

The ball doesn't rebound to its drop height because energy is lost in the transformations that occur when it bounces. The ball starts with an amount of gravitational potential energy related to its height. As it falls the gravitational energy transforms into kinetic energy. When the ball hits the ground most of the kinetic energy transforms into elastic energy, but some is 'lost', transforming into heat and sound. Heat and sound are lost again in the transformation from elastic back to kinetic, when the ball starts to rise again. After it leaves the ground the ball's kinetic energy transforms back into gravitational as the ball gets higher. Because energy was lost there can't be as much gravitational energy as originally – the ball doesn't go as high.

ELECTRICITY



Question 19

In which of the circuits above would the lamp glow when the switches were closed?

- ☐ A
- ☑ B
- ☑ C
- ☑ D
- ☑ E

Question 20

In which circuit would the lamp glow the brightest?

Note: Select more than one circuit if you think the lamp would glow equally bright in them.

- ☐ A
- ☐ B
- ☐ C
- ☑ D
- ☐ E

Question 21

In which circuit would the lamp glow the dimmest?

Note: Select more than one circuit if you think the lamp would glow equally dim in them.

- ☐ A
- ☐ B
- ☑ C
- ☐ D
- ☐ E

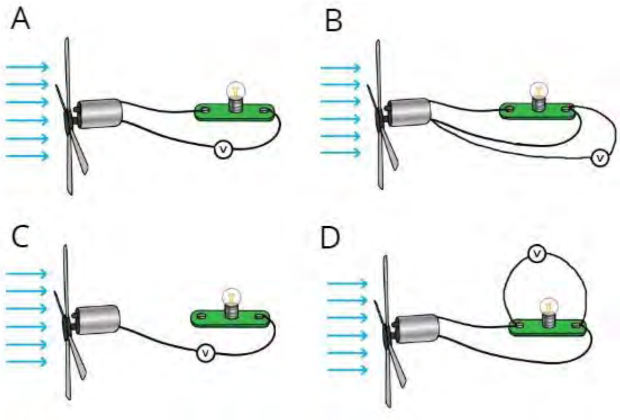
Question 22

Which of the following energy transformations occur in circuit C (when the switch is closed)?

- ☐ electricity → light → kinetic
- ☑ chemical → electricity → light
- ☐ kinetic → electricity → light
- ☑ chemical → electricity → heat
- ☐ gravitational → chemical → electricity

Question 23

A wind turbine is connected to a lamp. Which diagram, right, shows the correct way to connect a voltmeter to read the voltage across the lamp?



☐ A

☐ B

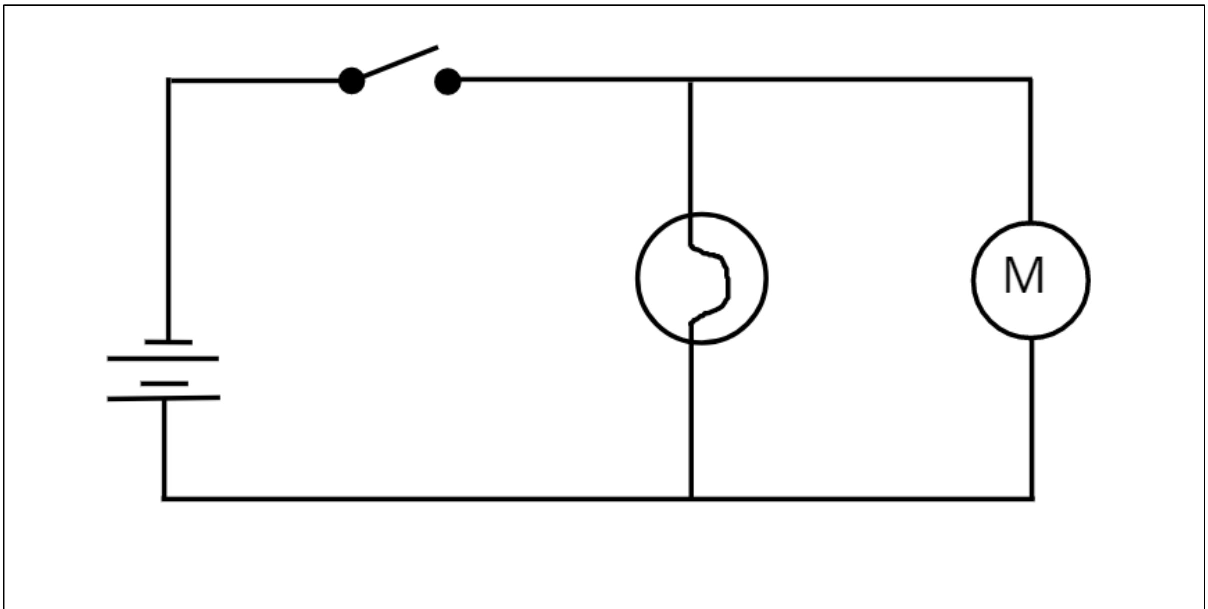
☐ C

☑ D

Question 24

Draw a circuit diagram with the following features:

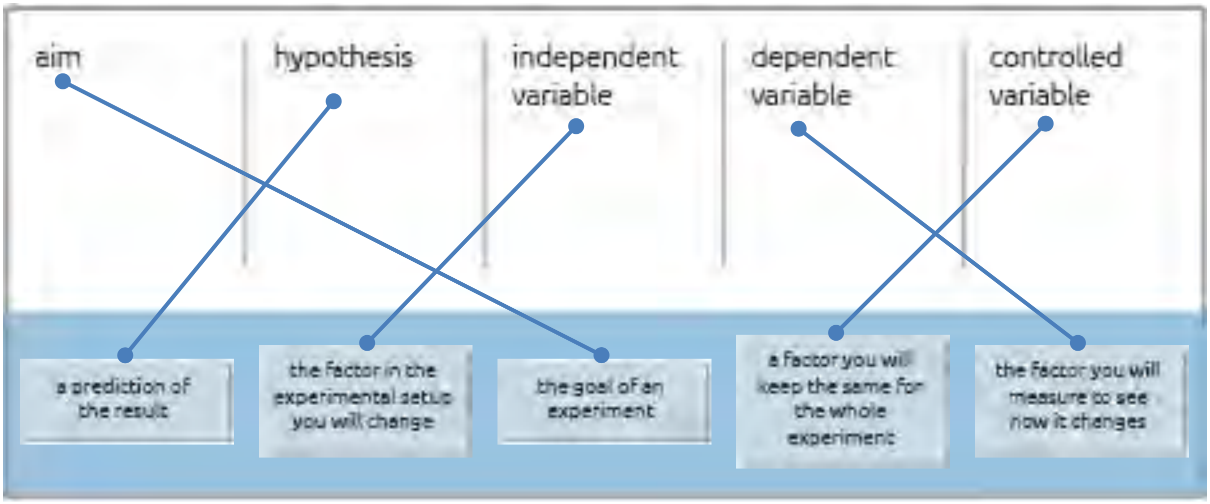
- two cells in series
- a lamp and a fan in parallel (use an M – for motor – in a circle to represent the fan)
- a switch, positioned so that the lamp and fan turn on and off at the same time



INQUIRY

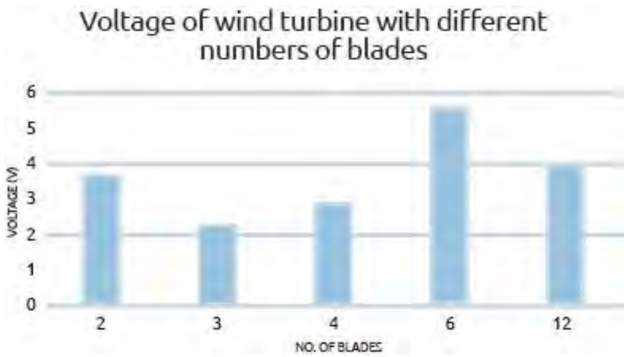
Question 25

Draw lines between each term and its definition.



Question 26

Jeff's group carried out an experiment to measure the maximum voltage produced with different numbers of blades on a small wind turbine. He graphed the results as shown.



From this graph, what would be the best number of blades for that wind turbine in those conditions?

- ☐ 2
- ☐ 3
- ☐ 4
- ☑ 6
- ☐ 12

Question 27

Other members of Jeff's class carried out the same experiment. They used the same procedure and the same types of equipment. None had any problems carrying out the experiment.

When the class's results were averaged, they were a bit different from Jeff's, including that the voltage for three blades was slightly higher than for four blades.

Which of the following statements are correct?

- ☐ Jeff should use his results rather than the class averages because he knows that he carried out the experiment carefully
- ☑ The different results are probably due to small differences in the controlled variables in each experiment
- ☑ The different results could be due in part to small differences in the equipment, for example some turbines might spin more freely than others

Question 28

Susan conducted an experiment to see if temperature affects the output of solar panels. She ran the experiment outside, using sunlight, over a few weeks so that she could take measurements in a range of air temperatures. For example, she got her reading for the coldest temperature early one morning, and three days later on a hot afternoon got her highest temperature reading.

Was this good experimental technique? Explain.

This isn't good experimental technique because there are a number of variables that should be controlled and from the description they weren't:

time of day: the amount of light outside changes during the day so this variable should be controlled. That is, the readings should all have been taken at the same time of day.

weather conditions: obviously some days are sunnier than others, for example with varying amounts of cloud and dust. So this is another variable that should have been controlled. That is difficult to do, so it suggests that the experiment should have been carried out quickly, at the same time.

angle of light: the description above doesn't mention the angle of the solar panel to the light. This is another variable that should be controlled. The sun moves during the day so the solar panel should change angle too to keep the angle to the light constant.

location: the description also doesn't mention if the panel was placed in the same location. Some locations might have more reflected light than others, so location can affect the results.

The overall impact of these factors is that Susan cannot be sure that the voltage readings she took were due to differences in temperature or to other factors such as time of day, cloud, etc.

ENERGY RESOURCES

Question 29

Which of the following statements about the world's use of energy resources are correct?

- [ ] By 2015 wind turbines were supplying over 10% of the world's energy requirements
- [x] In 2015 hydro-electric power stations provided more energy than solar photovoltaics
- [x] Since 2000 over half of the world's energy has come from fossil fuels
- [ ] Since 2000 over half of the world's energy has come from natural gas

Question 30

Which of the following types of electricity power plant contribute significantly to global warming?

- [ ] Solar farm
- [ ] Wind turbine
- [x] Coal-fired power station
- [ ] Hydro-electric power station
- [ ] Nuclear power station

Question 31

Which of the following electricity power plants use renewable energy resources?

- [x] Solar farm
- [x] Wind turbine
- [ ] Coal-fired power station
- [x] Hydro-electric power station
- [ ] Nuclear power station

Question 32

Why, if we use renewable energy resources, will this slow and possibly stop global warming?

- ☐ Renewable energy resources are replaced within a human life-time
- ☐ Renewable energy technologies don't produce any heat when they transform the energy resource into electricity
- ☑ Renewable energy technologies don't produce any carbon dioxide when they transform the energy resource into electricity
- ☐ Renewable energy technologies produce waste gases that shield the Earth from solar radiation

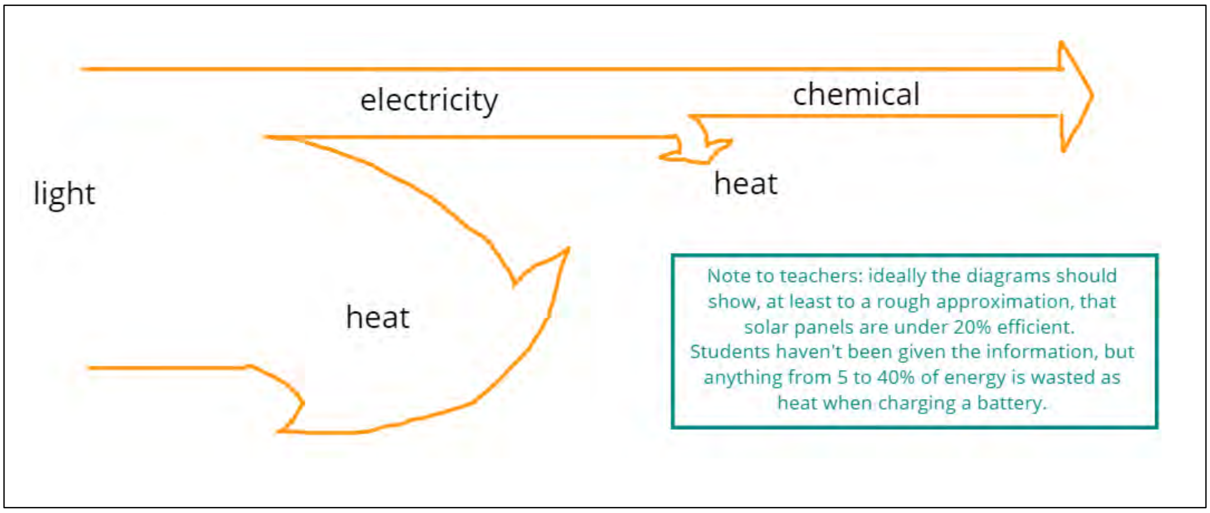
> For the Sankey diagram below, students won't know how much energy is lost as heat when charging a battery. In fact it is highly variable, depending on the battery type. For lithium ion batteries it might be 5 to 10%. It could be over 30% for other battery types.
> The question doesn't provide the information that solar panels usually have efficiency a bit under 20% – this is provided in the *Solar Panels* lesson.

Question 33

Draw a Sankey diagram to represent the energy transformations that occur when a solar panel charges a battery.

Hint: Have you noticed that the charger and phone warm up when a phone is charged?

Note: You don't need to label the diagram with percentage values, but as much as possible try to get your arrows about the right size.



Question 34

Choose one energy resource and answer the following questions about it:

- Is the energy resource renewable, and does its use contribute to global warming?

Is the resource used much in Australia or elsewhere in the world?

What are the advantages and disadvantages of this resource? Is its use likely to increase or decrease? Why?

Answers will vary according to the resource chosen.

Advantages and disadvantages should refer to such questions as cost, production of carbon dioxide or not, pollution, environmental effects, locations of good sites (near population centres or not), safety and community acceptance.

9.2 GLOSSARY

A

ampere (or amp, A)
unit of electrical current. One amp is one *coulomb* per second.

B

battery
two or more electrical *cells* connected in series. Produces electrical energy by transforming chemical energy.

C

capacity factor
the percentage of the maximum possible energy output of a power plant that is actually produced, usually measured over a year.

carbon dioxide (CO_2)
a gas, required for photosynthesis and produced when fossil fuels are burned. It is the *greenhouse gas* most responsible for the *enhanced greenhouse effect.*

cell (electrical)
a device that transforms chemical energy into electrical energy. Two or more cells connected in series make a *battery.*

cell (solar)
a device that transforms light energy into electrical energy. Solar cells are connected to form *solar panels*.

charge
the property of electrons and protons that make them attract each other. There are two types of charge: positive and negative. Like charges repel and unlike charges attract. The unit of charge is the coulomb (C).

chemical energy
a type of *potential energy* stored in chemical bonds between atoms.

circuit (electrical)
a continuous loop of material (usually metal) around which electricity flows.

climate
the average weather conditions in an area over long periods of time (typically decades). It includes temperature, rainfall (or snow) and wind conditions.

climate change
changes in the climate of a region or the planet over medium to long terms. Typically applied to the current global changes due to the *enhanced greenhouse effect*.

conservation of energy (law of)
the principle that energy is never created or destroyed but only ever transforms into other forms

coulomb (C)
the unit of *charge*.

current (electrical)
the flow of electrical *charge* through a *circuit*. Its unit is the *ampere*.

E

elastic energy
a form of *potential energy* in objects that are compressed or stretched.

electricity
a form of potential energy held by charged particles (see *charge*). In an electrical circuit electricity flows around the circuit, transferring the energy.

electromagnetic energy
also known as electromagnetic radiation, a form of kinetic energy that exists as waves of different wavelengths. It includes visible light, x-rays and radio waves.

electron
a subatomic particle with very little mass and a negative *charge*. *Electricity* flowing through metal cabling consists of a flow of electrons.

energy
what something has when it is moving or when it has the potential to move

energy efficiency
in devices that transform energy, the percentage of the original energy that is converted into useful forms.

energy transfer
when energy changes location or moves from one object to another without changing form.

energy transformation
when energy changes from one form to another, for example chemical energy in the gas of a gas oven is transformed into heat and some light and sound.

enhanced greenhouse effect
the increased warming of the Earth due to emissions of greenhouse gases from human activity (mostly the burning of fossil fuels) over the last 200 years.

F

force
a push, pull, or twist. If something changes its motion when a force is applied to it, energy is transformed.

fossil fuel
coal, oil and natural gas. These were all formed in the Earth over millions of years from living matter such as plants and plankton. Fossil fuels all have carbon in them, which forms *carbon dioxide* when the fuels are burned.

G

generator
a device that transforms mechanical energy into electricity (by spinning a magnet within coiled wiring). Generators are often driven by a *turbine*.

global warming
the average increase in temperature of the Earth's atmosphere due to the *enhanced greenhouse effect*.

gravitational potential energy
the potential *energy* objects have due to their height above the Earth. If not held in place the objects fall, transforming the gravitational potential energy into *kinetic energy*.

greenhouse effect
the trapping of heat radiation emitted from the Earth's surface by certain gases – *greenhouse gases* – in the atmosphere.

greenhouse gas
gases in the atmosphere that capture *heat* radiation emitted from the Earth's surface. The gases re-emit the radiation in random directions, so some is directed back to Earth or sideways into the atmosphere. Carbon dioxide, methane and water vapour are the principal greenhouse gases.

H

heat
a form of *energy*, felt by humans as warmth. There are two kinds: i) the motion of atoms and molecules in a substance, related to its temperature, and ii) radiant heat, a form of *electromagnetic radiation* (in the infra-red wavelength range).

hydro-electricity

form of *electricity* generation using the *gravitational potential energy* of water at higher altitudes. The water is dammed and/or piped and used to drive a *turbine*.

J

joule (J)
the standard scientific unit of *energy*. One joule is the energy required to raise a mass of 100 grams one metre.

K

kilowatt hour (kWh)
a unit of energy commonly used to measure electricity. One kilowatt hour equals 3.6 million *joules*.

kinetic energy
the *energy* that something has because it is moving. Usually the term is applied to medium and large-sized objects when they move, but, for example, the motion of atoms that we call '*heat*' is also a form of kinetic energy. Other forms of kinetic energy include *sound* and *electromagnetic radiation*.

L

LED
an electrical component that transforms *electricity* into *light* (and *heat*) when electricity flows through it in one direction but not the other. Acronym for light emitting diode.

light
electromagnetic radiation within a particular range of wavelengths, visible to humans (other wavelengths are not visible, though infra-red wavelengths are felt as heat).

M

mechanical energy
the *kinetic energy* of machinery parts when they are in motion.

methane (CH_4)
a powerful *greenhouse gas*, although present in the atmosphere in smaller quantities than *carbon dioxide*. Natural gas consists mostly of methane.

N

non-renewable
resources that cannot be replaced within a human lifetime are non-renewable. Examples include fossil fuels, which take millions of years to form.

nuclear energy
the *potential energy* contained within atoms. It is transformed into *heat* in nuclear reactions in stars, nuclear bombs, and nuclear power stations.

O

ozone (O_3)
a form of oxygen that forms a layer in the Earth's upper atmosphere, blocking harmful wavelengths of *electromagnetic radiation* from the sun. In recent decades a hole has formed in the layer, exposing the Earth's surface to increased radiation, however this is not a significant cause of *global warming*.

P

parallel circuit
an electrical *circuit* where the flow of electricity has more than one path to follow.

photovoltaic cell (PV cell)
a device, mostly made of silicon, that transforms *light* into *electricity*. Also known as a *solar cell*. PV cells are connected to make PV panels (also known as *solar panels*).

potential energy
all the forms of energy that do not involve motion, but which have the potential to create motion. Examples include gravitational potential energy, elastic energy, chemical energy and nuclear energy.

power
the rate at which energy is transferred or transformed. The unit of power is the watt (W), equal to one joule per second.

R

renewable
a resource that can be renewed in less than a human lifetime. Examples include crops, water and sunlight.

S

Sankey diagram
a diagram used to represent *energy transformations*. The width of the arrows represents the proportions of each *energy* type.

series circuit
an *electrical circuit* in which the *electricity* has only one pathway to follow.

solar cell
a device, made mostly of silicon, that transforms *light* into *electricity*. Also known as a *photovoltaic cell*, or PV cell. Solar cells are connected to make *solar panels*.

solar farm
a large commercial installation of *solar panels*. Solar farms are often over 100 hectares in size, with capacity to produce tens or hundreds of megawatts.

solar panel
a panel with, typically, 60 or 72 connected *solar cells* on it, used to produce *electricity* from sunlight. Solar panels are mounted on roofs or in large purpose-built *solar farms*.

sound
a form of *kinetic energy*, it is vibrations in the particles that make up fluids such as air.

T

turbine
a piece of machinery that is made to spin by flowing air, water or steam. Often a turbine is connected to a *generator*, which transforms the *mechanical energy* into *electricity*.

V

volt (V)
the unit of how much *energy* a unit of *charge* has. One volt is equal to one *joule* per *coulomb*.

W

water vapour
the gaseous form of water. In the atmosphere, water vapour is a powerful greenhouse gas.

watt (W)
the unit of *power*, or the rate of *energy transfer* or *transformation*. One watt equals one *joule* per second.

wind farm
a large commercial installation of *wind turbines*.

wind turbine
a machine that rotates in the wind, transforming the wind's *kinetic energy* into *electricity*.

10 SUPPORT FOR TEACHERS

This section has three assessment rubrics to use and information about replacement parts for the STELR kits

10.1 ASSESSMENT RUBRICS

The STELR Project is not assessment-driven. However, assessment provides valuable feedback to students and helps teachers track their progress.

Following are three assessment rubrics you can copy and modify. They cover:

- science inquiry skills
- group projects
- peer assessment of presentations

ASSESSMENT RUBRIC – SCIENCE INQUIRY SKILLS

STUDENT NAME: ____ CLASS: __________

Science inquiry skill	Undeveloped	Developing	Proficient	Exemplary
Designing an experiment	The student can: • Develop a testable hypothesis with assistance. • Show some understanding of the variables operating. • With assistance can design simple fair tests and select equipment suited to the purpose.	The student can: • Develop a testable hypothesis with assistance. • Identify some variables with assistance. • Design simple fair tests and select equipment suited to the purpose.	The student can: • Develop a testable hypothesis. • Identify a number of variables and, with assistance, design an experimental investigation a procedure in which these are tested one at a time and repeat trials are conducted. • Select equipment suited to the purpose. • Suggest some ways to reduce risk in the investigation.	The student can: • Develop a testable hypothesis based on prior observations and/or secondary sources. • Design an experimental investigation, including using repeat trials and replicates, independently identifying and controlling variables and selecting equipment suited to the purpose. • Suggest a number of ways to reduce risk in the investigation that show insight into the specific risks involved.
Collection of data	The student can: • With assistance, collect data in a consistent and ethical manner, including using ICT where possible. • Use equipment and materials safely, with assistance and advice.	The student can: • With assistance, collect data in a consistent and ethical manner, including using ICT where possible. • Use a wide range of equipment and materials safely.	The student can: • Collect data in a consistent and ethical manner, including using ICT where possible. • Use a wide range of equipment and materials safely and show consideration of the safety of others.	The student can: • Collect data in a consistent, efficient and ethical manner, including using ICT where possible. • Use a wide range of equipment and materials safely and manage the working environment for the safety of self and others.
Recording and processing data	The student can: • Record some data in provided tables with accuracy. • With assistance, construct graphs with reasonable accuracy.	The student can: • Record data in provided tables accurately. • With assistance, construct graphs with accuracy. • Use simple statistical tools to process and analyse data, with assistance.	The student can: • Select and design tables and graphs for the recording and analysis of **some** data. • Record data in provided tables accurately. • Construct graphs with accuracy. • Use simple statistical tools to process and analyse data with accuracy.	The student can: • Select and design tables and graphs for the recording and analysis of data. • Record data efficiently and accurately. • Construct graphs with accuracy • Use simple statistical tools to process and analyse data with accuracy.

Science inquiry skill	Undeveloped	Developing	Proficient	Exemplary
Analysis and evaluation of data	The student can: • Draw conclusions from observations, evidence and data, and relate this to hypotheses, with assistance. • With assistance, identify sources of error in the investigation method.	The student can: • Draw conclusions from observations, evidence and data, and relate this to hypotheses and scientific concepts, with assistance. • With assistance, Identify sources of error in the investigation method.	The student can: • Draw conclusions from observations, evidence and data, and relate this to hypotheses and scientific concepts. • Identify sources of error in the investigation method and suggest specific improvements that would reduce error.	The student can: • Draw conclusions or explain interactions from observations, evidence and data, and relate this to hypotheses and scientific concepts. • Identify sources of error in the investigation method and suggest specific improvements that would reduce error. •Critique reports of investigations noting any flaws in design or inconsistencies of data.
Communication of findings	The student can: • With assistance, communicate findings using scientific language and meaningful representations and make evidence-based arguments.	The student can: • Communicate findings using scientific language with a fair degree of accuracy and using some meaningful representations. • With assistance, make evidence-based arguments.	The student can: • Communicate findings using scientific language with a good degree of accuracy and fluency, and using meaningful representations. • Make evidence-based arguments.	The student can: • Communicate findings using scientific language with a high degree of fluency and accuracy, and using meaningful representations and make evidence-based arguments.

Overall evaluation with comment/evidence:

Teacher's signature: ____

Date: __________________________

ASSESSMENT RUBRIC – GROUP PROJECTS

STUDENT NAME: ____ CLASS: __________

NAMES OF GROUP MEMBERS: ____

RENEWABLE ENERGY RESOURCE INVESTIGATED: ___________________________________

Aspect	Undeveloped	Developing	Proficient	Exemplary
The science and technology behind the energy resource	The group: • Showed little evidence of suitable research. • Displayed a limited understanding of the science and technology behind their chosen renewable energy resource.	The group: • Researched this aspect to some degree. • Displayed some understanding of the science and technology behind their chosen renewable energy resource.	The group : • Researched this aspect to a reasonable depth. •Displayed a good understanding of the science and technology behind their chosen renewable energy resource and communicated this with clarity.	The group: • Researched this aspect in depth. • Displayed a thorough understanding of the science and technology behind their chosen renewable energy resource and communicated this in a logical way with clarity and fluency, including an explanation of unfamiliar terms.
The benefits and problems associated with the energy resource, and community views	The group: • Showed little evidence of suitable research. • Presented conclusions that were based on insufficient evidence and analysis.	The group : • Researched this aspect to some degree. • Applied some critical thinking skills to draw their conclusions.	The group: • Researched this aspect to a reasonable depth. • Presented some evidence-based arguments and applied some critical thinking skills to draw their conclusions.	The group : • Researched this aspect in depth. • Presented evidence-based arguments and applied well-developed critical thinking skills to draw their conclusions.
The uses of the energy resource and its likely future	The group: • Showed little evidence of suitable research. • Presented conclusions that were based on insufficient evidence and analysis.	The group : • Researched this aspect to some degree. • Applied some critical thinking skills to draw their conclusions.	The group: • Researched this aspect to a reasonable depth. • Presented some evidence-based arguments and applied some critical thinking skills to draw their conclusions.	The group : • Researched this aspect in depth. • Presented evidence-based arguments and applied well-developed critical thinking skills to draw their conclusions.

Aspect	Undeveloped	Developing	Proficient	Exemplary
Presentation of findings	The group: • Presented some findings using a small number of visual aids. • Showed some understanding of their subject. • Was sometimes audible and sometimes established eye contact with their audience.	The group : • Showed some evidence of preparing for their presentation. • Presented their findings using some visual aids. • Showed some understanding of their subject and were able to answer some questions. • Was generally audible and generally established eye contact with their audience.	The group: • Prepared well for their presentation. • Presented their findings in an engaging way, making use of a range of visual and other communication aids. • Showed good understanding of their subject and were able to answer questions clearly. • Was audible, established eye contact with their audience and involved their audience.	The group: • Prepared thoroughly for their presentation. • Presented their findings in a creative and engaging way, making full use of a range of visual and other communication aids. • Showed a thorough understanding of their subject, answering questions confidently. • Was clearly audible, established good eye contact with their audience and involved their audience to a great degree.
Student contribution to group	The student: • Co-operated with the group most of the time. • Contributed to most aspects of the project.	The student : • Co-operated well with the group. • Contributed to all aspects of the project.	The student: • Co-operated very well with the group and showed well-developed time management skills. • Contributed well to all aspects of the project.	The student: • Co-operated well with the group and showed initiative and well-developed leadership and time management skills. • Contributed fully to all aspects of the project.

Comment:

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Teacher’s signature: ________________________________

Date: ____________________

STUDENT ASSESSMENT OF GROUP PRESENTATIONS

NAMES OF GROUP MEMBERS: ____

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Criterion	Needs improvement	Satisfactory	Very good	Excellent
Voice projection	Most of the group spoke too softly and/ or too quickly.	It was difficult to hear parts of the presentation.	Most of the group's voices were clear and able to be heard.	All the group's voices were clear and projected well.
Engagement with the audience	Most of the group members did not seem confident or enthusiastic or aware of their audience.	Some of the group members did not seem confident or enthusiastic or very aware of their audience.	Most group members appeared confident and enthusiastic and maintained good eye contact with the audience. They made a good effort to interest and involve all the audience.	All group members were confident, lively and enthusiastic and maintained good eye contact with the audience. They made a real effort to interest and involve all the audience.
Response to questions from the audience	The group members did not encourage the audience to ask questions, and found it difficult to answer questions.	The group members did not encourage the audience to ask questions, but answered most questions quite clearly.	The group members encouraged the audience to ask questions, and answered most questions clearly and confidently.	The group members encouraged the audience to ask questions, and answered the questions clearly and confidently.
Use of different communication aids to the presentation	The group used some visual aids in their presentation, but these were sometimes difficult to see or needed more work to be beneficial.	The group used some communication aids in their presentation, but these needed more work to be beneficial.	The group used some well-prepared communication aids to help make their presentation interesting and clear.	The group used a good variety of well-prepared communication aids. Their presentation was interesting, clear and very creative.
Knowledge of material	The group needed to provide a lot more information.	The group provided some interesting relevant facts but needed to explain them more clearly.	The group provided a number of interesting relevant facts and explained the ideas and terms well.	The group provided many interesting relevant facts and explained the ideas and terms very clearly.
Logical development of material	The group tended to jump around with their presentation, making it difficult to follow. Some of the content did not appear to be relevant.	The group needed to organise their material into a more logical order and to give a more balanced coverage of the different aspects. Some of the content did not appear to be relevant.	The group presented the material in quite a logical and balanced way. All or most of the content was relevant to their topic.	The group presented the materials in a very logical , balanced way. All the content was relevant to their topic.

Signed: ____________________________________

Print name: _________________________________

10.2 STELR RENEWABLE ENERGY EQUIPMENT

STELR Student Equipment Kit (Kit #1)	
Description	**Quantity**
Solar panel	1
Testing station	1
Light source 12V 25W	2
Power source 12V. 4A. AC	1
Multimeters	2
Switch	1
Wind turbine rotor & generator	2
Clamping hub for wind turbine	2
150 mm long vanes	15
100 mm medium vanes	15
75 mm short vanes	15
'Cotton reel' racer with band	4
Battery power source	2
Connecting cables	8

STELR Teacher Kit (Kit #2)	
Description	**Quantity**
Hand driven generator base	1
Spare belts for generator	3
Water wheel assembly complete	1
Clear vinyl hose for water feed.	1
Vial of 10 spare lamps	1
Jumping cups	20

Extra equipment	
Description	**Quantity**
Electric fans	6 recommended per class set

Replacement Parts

Purchase spare parts directly from:

INDUSTRIAL EQUIPMENT & CONTROL PTY. LTD.
61-65 McCLURE ST. THORNBURY VIC 3071
AUSTRALIA

Tel: +61 3 9497 2555
Fax: +61 3 9497 2166
Email: iec@iecpl.com.au
Website: www.iecpl.com.au

STELR

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RENEWABLE ENERGY EQUIPMENT ITEMS & PART NUMBERS

Solar cell panel

ST 070-01

Wind turbine

ST 120-01

Clamping hub

ST 110-01

Turbine blades

ST 140-01	red	150mm
ST 140-02	blue	100mm
ST 140-03	yellow	75 mm

Test rig module

ST 080-01

Multimeter

ST 050-05

12V power supply

ST 090-01

50W lamp

ST 100-01

Cable set

ST 020-01

3V battery pack

ST 010-01

Switch

ST 105-01

Cotton reel racer

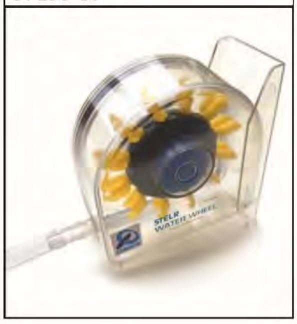
ST 040-01 green, ST 040-02 blue, ST 040-03 red, ST 040-04 yellow, ST 040-06 sticks

Hand crank generator base

ST 225-01

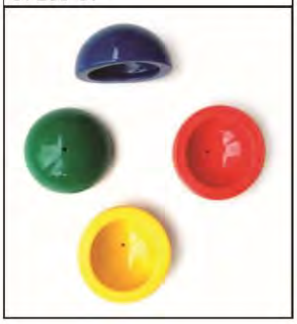
Pelton wheel

ST 290-01



Jumping cup

ST 285-01



Fan

ST 210-01

REPLACEMENT PARTS CODES

DESCRIPTION	CODE NO.
STELR BATTERY P/SUPPLY, 2x'AA', 4mm SOCKETS	ST 010-01
STELR CABLE, 30cm, WITH BANANA PLUGS, YELLOW	ST 020-02
STELR CABLE, 60cm, WITH BANANA PLUGS, BLUE	ST 020-03
STELR CABLE, 60cm, WITH BANANA PLUGS, BROWN	ST 020-04
STELR CABLE, 60cm, WITH BANANA PLUGS, GREEN	ST 020-05
STELR CABLE, 60cm, WITH BANANA PLUGS, GREY	ST 020-06
STELR CABLE, 60cm, WITH BANANA PLUGS, RED/BLACK PAIR	ST 020-07
STELR CABLES, SET/11,WITH BANANA PLUGS	ST 020-01
STELR CARTON FOR KIT#1, WITH SET OF DIVIDERS	ST 030-01
STELR COTTON REEL MOTOR ,BLUE	ST 040-02
STELR COTTON REEL MOTOR ,GREEN	ST 040-01
STELR COTTON REEL MOTOR ,RED	ST 040-03
STELR COTTON REEL MOTOR, YELLOW	ST 040-04
STELR COTTON REEL RODS, WOOD, SET/6	ST 040-06
STELR COTTON REEL RUBBER BAND SET/6	ST 040-05
STELR METER, MULTIMETER, W/BACKLIGHT, AUTO POWER OFF	ST 050-01
STELR MIRROR, PLASTIC, FLAT,160x168mm	ST 060-01
STELR P/SUPPLY, 240/6V/12V. 4A (RUNS 2xLAMPS)	ST 090-01
STELR SOLAR CELL PANEL, 4xCELLS	ST 070-01
STELR SOLAR CELL TEST PANEL,100ohm RHEOSTAT LOAD	ST 080-15
STELR SOLAR CELL TEST PANEL,BUZZER ONLY	ST 080-13
STELR SOLAR CELL TEST PANEL,LAMP,LED,BUZZR,MOTOR	ST 080-01
STELR SOLAR CELL TEST PANEL,MOTOR ONLY	ST 080-05
STELR SOLAR CELL TEST PANEL,PROPELLOR ONLY	ST 080-07
STELR SOLAR CELL TEST PANEL,RED LED ONLY	ST 080-11
STELR SOLAR CELL TEST PANEL,RESISTORS ONLY	ST 080-09
STELR SOLAR LIGHT SOURCE,12V,25W,QI LAMP	ST 100-01
STELR SOLAR LIGHT SOURCE, SPARE LAMP 12V, 25W, REFL.	ST 100-02
STELR SOLAR LIGHT SOURCE, SPARE SOCKET KEEPER	ST 100-05
STELR SWITCH,TOGGLE,SPST IN HOUSING	ST 105-01
STELR WINDMILL FAN HUB ASS'Y,FOR UP TO 12 VANES	ST 110-01
STELR WINDMILL GENERATOR UNIT,2.5:1 GEAR RATIO	ST 120-01
STELR WINDMILL HUB ADAPTOR (OLD TO NEW)	ST 115-01
STELR WINDMILL VANES, LONG, RED, SET/15	ST 140-01
STELR WINDMILL VANES, MEDIUM ,BLUE, SET/15	ST 140-02
STELR WINDMILL VANES, SHORT, YELLOW, SET/15	ST 140-03
STELR, CARTON FOR KIT#2, WITH SET OF DIVIDERS	ST 200-01
STELR, FLOOR FAN,16' HIGH VELOCITY, 220/240V	ST 210-01
STELR, GENERATOR/ MOTOR, DC,HAND DRIVEN, INCL. MAGNET	ST 220-01
STELR, HAND CRANK GENERATOR BASE	ST 225-01
STELR, GENERATOR/MOTOR, DC, LAMP LOAD PCB WITH PLUGS	ST 220-02
STELR, GENERATOR/MOTOR, SPARE BELT	ST 220-03
STELR, GENERATOR MOTOR, SPARE LAMPS,2.5Vx200mA	ST 220-04
STELR, LAMPS,VIAL/10 LAMPS, 3V 50mA	ST 250-01
STELR, LAMPS, VIAL/10 LAMPS, 6V 50mA	ST 250-02
STELR, METER, ANEMOMETER	ST 260-01
STELR, METER, I.R. THERMOMETER (no laser)	ST 270-01
STELR, METER,LUX,TO 50,000	ST 280-01
STELR, TOY, JUMPING JACKS, BAG/10	ST 285-01
STELR, WATER WHEEL ASS'Y,WITH CHUTE, HOSE BARB	ST 290-01
STELR, WATER WHEEL HOSE, VINYL, CLEAR, 8x11mm,1M	ST 290-02

STELR

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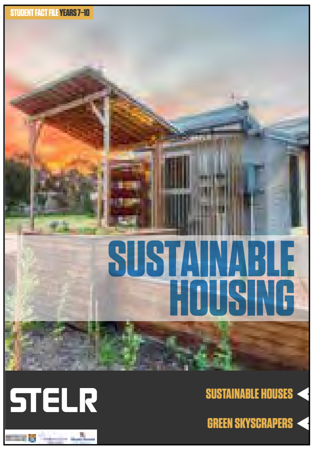
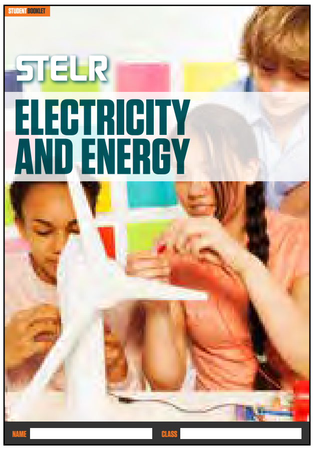
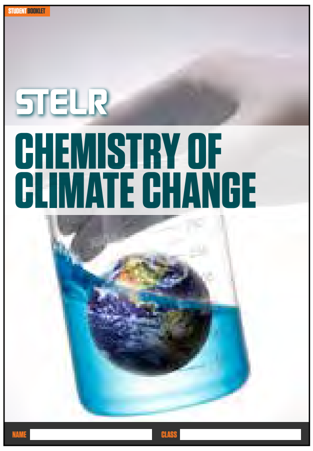
OTHER TITLES AVAILABLE







The Australian Power Insititute (API) proudly supports science, technology, engineering and maths education in Schools.

ENGINEERING THE FUTURE

Engineers in the Energy Industry help to:

- Provide the "bridge" between science & community
- Take up climate change challenges
- Address technological challenges
- Transition to a renewables future
- Implement energy efficiency initiatives
- Continue providing essential service to community
- Raise living standards & tackle poverty in developing countries.

ABOUT API

The API is a not for profit organisation established by the energy industry companies in Australia to facilitate the provision of tomorrow's technical leaders equipped to deliver Australia's energy future through initiatives such as:

- API Bursary Program to support students at university study engineering and technology courses
- Support for programs to encourage young female students to study STEM and pursue engineering and technology careers.

API SOLAR CAR CHALLENGE

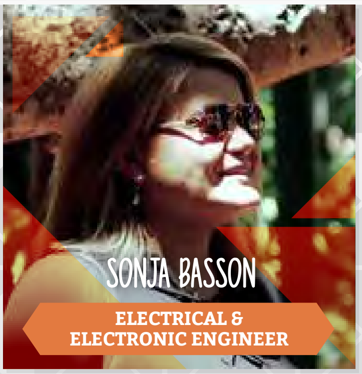
As API is committed to improving STEM education, API provides part funding for STELR, which is an initiative of The Australian Academy of Technological Sciences & Engineering (ATSE). API supports this program by providing class sets of re-usable model solar car kits to over 250 schools Australia wide using the Science and Technology Education Leveraging Relevance (STELR) Renewable Energy Module.

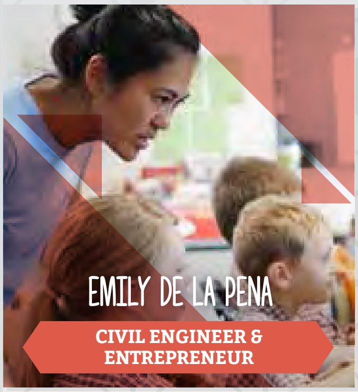
API also encourages involvement between university undergraduate engineering students by sending an API Bursary Holder to a participating high school to deliver a presentation about careers related to the renewable energy and power industry. During these visit the young undergraduate engineers also assist with solar car construction, judge the cars, and award prizes. The API, the high school teachers and students consider the Solar Car Challenge a great program to be invlolved in!

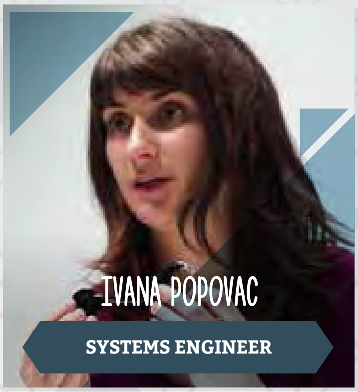
API BURSARY PROGRAM

As The API is constantly working to support the education and professional development of engineers & technologists in the energy industry across Australia, API offers scholarships to engineering & technology students with an interest in areas of engineering relevant to the electric power industry. The bursaries provide financial assistance over 4 years plus the opportunity where available for paid employment with member companies during the univeristy summer vacations.

Applications open February-May 2020 via API website.







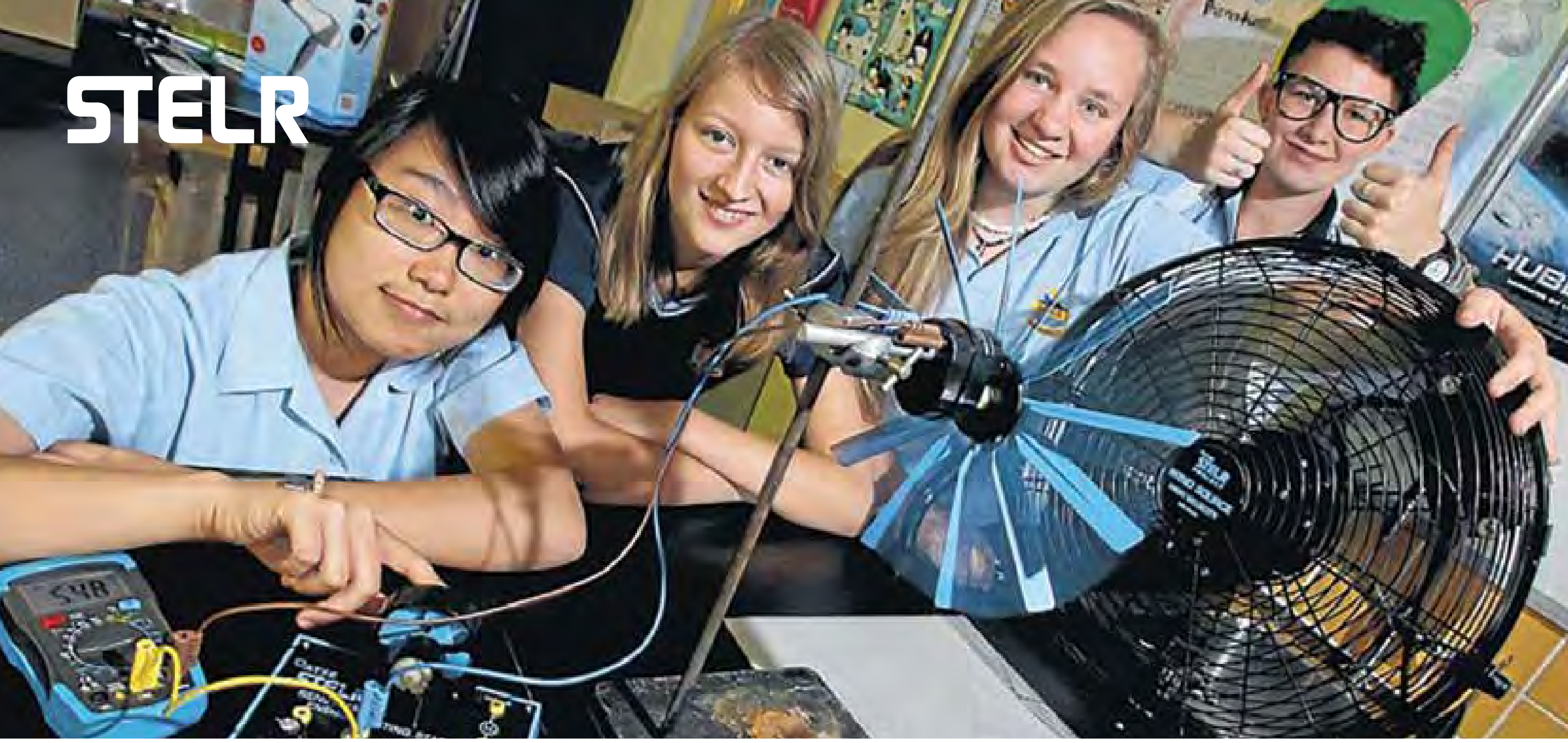
VIDEO PROFILES OF WOMEN IN STEM CAREERS AND ENTREPRENEURSHIP

View them all at www.stelr.org.au/WomenInSTEM

#WomeninSTEM #BeAChangemaker #DoSTEMMakeChange

This project received grant funding from the Australian Government.

ATSE STELR PROJECT



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