LOW-EMISSION TECHNOLOGY SERIES:

Introduction to carbon capture and storage

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Use of resources

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Foreword

This document is designed to introduce teachers and students to carbon capture and storage (CCS), one of a number of low emission energy technologies.

These materials are part of CSIRO's CarbonKids, a program now in over 200 schools around Australia, that helps school communities understand one of the most challenging issues facing the world today – climate change – and the issues around it, including energy technologies, adaption and mitigation.

CarbonKids combines the latest science with inquiry-based education. For more information on the various climate change topics and energy technologies included in CarbonKids, visit www.csiro.au/CarbonKids

Peta Ashworth

Research group leader, CSIRO

Global CCS Institute

The Global CCS Institute (the Institute) is proud to support the CSIRO CarbonKids program in the development and delivery of the education materials, low-emission technology series: Introduction to CCS.

Young people who are active in science, engineering and technology today will become the decision-makers of tomorrow. We are proud to support programs that demonstrate the importance of science and innovation to our young people around the world.

We believe that CarbonKids is an exciting opportunity for students, their schools and their communities to not only understand climate change but learn about climate adaption and mitigation, in particular low-emission energy technologies.

Introduction to CCS aims to help school communities understand a relatively new technology that could potentially help a large part of the Australian energy sector reduce CO_2 emissions and mitigate climate change.

I am sure that your school and the wider community will find CarbonKids rewarding. I look forward to hearing the inspiring stories and actions taking place within your school community as a result of learning about CCS technology.

Brad Page

CEO, Global CCS Institute

Rationale

All major international projections and roadmaps (IEA, USDOE, EU) for reducing carbon emissions show that the lowest cost and most effective means of achieving abatement comprise a portfolio of technology solutions. In every case, CCS is seen as an essential part of the solution.

CSIRO considers that CCS technology will play an important part in Australia's future energy mix, with all our coal and gas fired power stations potentially utilising the technology by 2050[1]. CCS could help us reduce emissions of carbon dioxide (CO_2) from our use of fossil fuels, to help mitigate climate change.

Climate change is one of the most challenging issues facing the world today, with each decade warmer than the previous decade since the 1950s. Australian average temperatures are projected to rise by 1-5 degrees Celsius by 2070 when compared with the climate of recent decades if global greenhouse gases (GHGs) are within the range of projected future emissions scenarios considered by the Intergovernmental Panel on Climate Change.

The international climate science consensus is that it is very likely that most of the surface global warming observed since the mid-twentieth century is due to anthropogenic (human activity) increases in greenhouse gases (GHG)[2].

Even in recent years, fossil fuel CO_2 emissions increased by more than three per cent per year from 2000 to 2010. The main cause of the observed increase in CO_2 concentration in the atmosphere is the combustion of fossil fuels since the industrial revolution.

We need to reduce our CO_2 emissions to reduce the impact human activity has on atmospheric GHG concentrations. Low-emission fossil fuel energy, renewable energy and energy efficiency technologies, together with behavioural changes will be needed to do this.

This is where CarbonKids comes into play. We want to address climate change, and in this document help encourage students to understand low-emission options – of which CCS technology is one.

How can teachers be part of the process?

This resource has been developed to help teachers and students understand CCS. Furthermore it combines the latest science from around the world with inquiry-based learning to support increased knowledge and understanding.

Using this cutting-edge subject matter CarbonKids aims to bring science to life for students to potentially inspire future study and career options.

For the full range of CarbonKids education materials on a range of topics visit, www.csiro.au/CarbonKids

This resource provides information in three parts.

SECTION 1 – Scope of this resource
Contains information about the resource, unit structure and unit descriptions.

SECTION 2 – Background notes for teachers
Contains information to assist in building students' understandings of energy, climate change and CCS technology.

SECTION 3 – Teaching units
Provides units of work for primary and secondary school-aged students.

[1] Jennifer A. Hayward, Paul W. Graham and Peter K. Campbell, 2012 *Projections of the future costs of electricity generation technologies: An application of CSIRO's Global and Local Learning Model (GALLM).*

[2] *State of the Climate*, CSIRO, Bureau of Meteorology, 2012

SECTION 1
Scope of this resource

Teaching unit structure

The teaching units offer a range of ideas and activities for the primary and secondary years of schooling and have been developed to:

- provide resources and a wealth of cross-curricula activities to support teaching and learning
- develop scientific skills
- promote a scientific-inquiry and action-based approach to learning
- be teacher and student friendly
- introduce and improve understanding of CCS technology.

The units are designed to be integrated into learning areas in the curriculum in Science, Technology, Geography, English, and the Arts.

The units use inquiry learning as the basis for unit organisation and implementation. The model was developed by Hamston and Murdoch in their text, *Integrating Socially: Planning Integrated Units of Work for Social Education*.

Each unit begins by ascertaining students' own experiences and understandings about the topic. A series of investigative activities is suggested to enable students to gather new ideas and information. A range of activities is then outlined to help students to sort out and make sense of this new information. In the latter stages of each unit, activities are suggested to help students reflect on, generalise and analyse their new understandings and to put them into action in some way.

The units can be used in a number of ways.

The seven inquiry stages

Seven inquiry stages contain choices so that teachers can select, adapt, add to or modify their approach to suit local needs:

Tuning in

- provide students with opportunities to become engaged with the topic
- ascertain students' initial curiosity about the topic
- allow students to express their personal experience of the topic.

Preparing to find out

- establish what students already know about the topic
- provide students with a focus for the forthcoming experience
- help in the planning of further experiences and activities.

Finding out

- further stimulate the student's curiosity
- provide new information, which may answer some of the students' earlier questions
- raise other questions for students to explore in the future
- challenge the students' knowledge, beliefs and values
- help students to make sense of further activities and experiences that have been planned for them.

Sorting out

- provide students with concrete means for sorting out and representing information and ideas arising from the 'finding out' stage
- provide students with the opportunity to process the information they have gathered and present this in a number of ways
- allow for a diverse range of outcomes.

Going further

- extend and challenge students' understanding about the topic
- provide more information in order to broaden the range of understandings available to the students.

Making connections

- help students draw conclusions about what they have learnt
- provide opportunities for reflection both on what has been learnt and on the learning process itself.

Taking action

- assist students to make links between their understanding and their experience in the real world
- enable students to make choices and develop the belief that they can be effective participants in society
- provide further insight into students' understandings for future unit planning.

About the units and resources

Units begin with activities that ascertain student knowledge and beliefs about a particular topic. This is followed by a series of investigative activities designed to assist students to gather information and further develop their ideas. Students are encouraged to make sense of this new information, act and then reflect on their new understandings.

There are a number of activities provided for each stage of the inquiry. The activities provided are diverse in an attempt to meet the different interests and abilities of students in the same class. However, they all explore the focus question for that stage. Teachers are invited to choose activities appropriate to their purpose and context. There is no expectation that every activity in each stage will be used. Teachers are invited to substitute activities of their own or students' devising at any stage.

However, maintaining continuity of purpose will ensure that teaching and learning is structured, sequential and worthwhile.

Resource sheets are provided for some activities. Most are for photocopying and distribution to students. They are identified within units by the following icon:

☑ Resource 1.2

The resource sheets are designed to assist teachers to facilitate learning without necessarily having access to many other resources.

Similarly, use of the internet is also encouraged as a resource. Opportunities to use a number of websites are identified using hyperlinks.

Many of the activities contain the following icons offering a suggestion on how many students should be involved:

Suggested for individuals

Suggested for pairs or small groups

Suggested for larger groups or entire classes

The two units outlined on the next page – *Investigate CCS* and *Explore CCS* – are listed as being aimed at different years of schooling, but teachers are encouraged to make their own judgements about when to use each component. The units are not grouped into year levels but are listed according to topics.

While it is possible to use any of the units on their own or to incorporate any of the activity suggestions into an existing framework or syllabus, the two core units contain suggestions and ideas that should be considered as vital to the success of these education materials.

Unit descriptions

Investigate CCS (primary)

In this unit students investigate the chemical properties of carbon and carbon dioxide (CO_2). We then investigate the role and movements of CO_2 in the atmosphere.

Using a range of strategies across learning areas, this unit introduces students to the issue of climate change and CO_2 emissions. Students explore the different types of emission sources that contain CO_2.

Further to this, they investigate and simulate CCS technologies, for example:

- capturing CO_2 from power plants
- compressing and transporting CO_2
- storing CO_2.

The inquiry approach is built around the investigation of CCS, broadening student experiences and understandings during the investigation, and then consolidating and presenting these understandings to an audience following the study.

Explore CCS (secondary)

During this unit, students will investigate new and existing technologies and actions that may stabilise and reduce global emissions of CO_2. Students assess the impact of these technologies on climate change while evaluating strategies for coping with potential changes to the climate.

Students are given an insight into ways industries could reduce their CO_2 emissions by using processes designed to separate CO_2 out of the flue stream produced by coal, natural gas and petroleum fired power plants, in addition to processes in industry.

Students design research investigations, learn about innovations that reduce CO_2 emissions from industries and power plants, and inform their wider community about how these might impact climate change.

The units: how to use them most effectively

Each of the units follows a similar sequence. The sequence is an inquiry-based one that encourages students to gather and process information and to reflect and act upon what they have learned.

Should I do all the activities?

At each stage of a unit, a number of activities are listed. You would not be expected to do them all. Instead, the units are designed so that a selection of activities can be made at each stage. You should select the activities according to the needs and interests of your students and the time and relevance to the existing school curriculum and resources available to you.

While you are encouraged to follow the suggested inquiry sequence for each unit, it is quite possible to pick and choose from the range of activity ideas throughout the two units. These may also be used in conjunction with other programs you use.

How do these units fit into my weekly program?

Although these units integrate a range of key learning areas, they are not designed to be a total program. It is assumed that regular routines that operate in your classroom will continue to run alongside your unit of work. For example, you may have regular times for use of the library, for maths, physical education etc. These things don't change – although student's writing topics or choice of topics to research in the library or in ICT classes may be influenced by the units.

How long should each unit run?

This will of course depend on your particular circumstances but generally, six weeks to a term is suggested.

I don't know much about CCS or climate change myself – will I be able to teach it effectively?

Yes! The units are designed in such a way that you, as the teacher are a co-learner and you are provided with teacher notes, plus the resources are mainly web-based and are readily available. Most importantly, you will find that you learn with the students and make discoveries with them.

SECTION 2

Background notes for teachers CCS education program

Introduction

These background teacher notes are intended to provide a brief introduction to CCS in the context of climate change. By no means are they exhaustive and we recommend engaging with the students in learning more about these topics.

Although each unit can be taught discretely, we suggest reading the background teacher notes in their entirety to gain a more holistic appreciation of the concepts, themes and issues.

CCS is a technology that researchers around the globe are investigating as a way to reduce CO_2 being emitted into the atmosphere from power plants. It is a new technology to many people and can be controversial. New technologies, even well established technologies, lead to many different opinions and it is often difficult to know which sources to trust, what actions are most effective or what challenges we should expect in the future. These notes provide a stepping stone for you and your students to begin your journey to better understanding CCS.

Carbon chemistry

FAST FACT

In chemistry, the term 'organic' is used to describe chemistry based on chains of carbon.

To understand CCS technology you first need to understand carbon and CO_2. In this section we provide an introduction to both.

Carbon is an element, or a type of atom. Like all elements, it can be found on the periodic table. It has the atomic number '6', meaning the nucleus of each carbon atom contains six protons and there are six electrons surrounding the atom's nucleus. The arrangement of these electrons means carbon can form up to four links or 'bonds' with other atoms to form a molecule. It's this special arrangement of its electrons and carbon's relative abundance in the universe that allows this element to have a key role in the chemistry of life on earth.

Carbon's special arrangement of electrons means it can make a diverse number of highly complex molecules with itself and other elements. It's the diversity of carbon chemistry that has allowed life to gradually evolve out of a mix of simpler chemical solutions hundreds of millions of years ago.

CO_2 is made up of two oxygen atoms bonded to one carbon atom.

Carbon-based molecules such as CO_2 were abundant on earth as it formed. While the details are unclear, life is thought to have developed out of a mix of chemical reactions. Carbon-based molecules are the basic constituents of the many types of sugars, proteins and fats from which cells are made. All modern living things share this fundamental chemical recipe.

Molecules have various reactions. Some react readily with other molecules, others are very stable and do not react readily. CO_2 is a particularly stable molecule which generally does not react readily with other molecules, in the absence of significant external or applied energy. An example of external energy is from the sun (see photosynthesis below). The low reactivity of CO_2 is the reason that it cannot be readily or economically converted to useful products and must therefore be captured and stored to reduce emissions to the atmosphere.

Meaning of 'life'?

FAST FACT

Currently, about 0.039 per cent (390 parts per million, or ppm) of our atmosphere is CO_2. This is much higher than the natural range of 170-300 ppm during the past 800,000 years. There is 50 times more CO_2 dissolved in the oceans than in the atmosphere.

One way we can define a living thing is by its ability to grow and reproduce by absorbing chemical nutrients from the environment and changing them by using energy from the sun or other chemical reactions.

Given a limited supply of such chemical resources, living things typically find themselves in competition with one another. Organisms which survive and reproduce more effectively replace those which are less effective. Environments contain a diversity of organisms using whatever nutrients and energy they can to stay in the game. Typically, this results in a balance where organisms survive by occupying a 'niche'.

We can classify organisms into groups by their energy source. For example, plants are organisms that absorb radiation from the sun. This process, called 'photosynthesis', captures the sun's energy and uses it to convert CO_2, into other higher energy forms, by first making glucose, and then going on to make very high energy content molecules such as fats and oils.

Animals, on the other hand, consume other organisms and break the chemicals down to release energy for their own growth in a process called 'respiration'; this breakdown is like low temperature burning and involves the use of oxygen. Plants also respire, breaking down the glucose they made in photosynthesis. In breaking the chemical bonds for energy, animals release CO_2 and water back into the environment. This forms the backbone of the carbon cycle, where carbon compounds are released into and absorbed from the environment.

Riding the carbon cycle

Carbon can exist in a number of forms in the environment. At one moment, it might be nestled in a glucose molecule, stored away in the roots of a plant in anticipation of a dark winter. It could then be digested in the belly of a herbivore, changed into a molecule of fat and built into the membrane of one of its skin cells. These cells might be swallowed by a carnivore, where the fat molecule is used for energy in respiration before being exhaled into the atmosphere as CO_2. Then, after a period, another plant might absorb it, turning it once more into glucose, and starting the cycle once more.

Carbon Count
(in billion tonnes)

Atmosphere	750
Vegetation	610
Soils	1580

Yet there are far more possibilities. It might stay in the plant's roots as glucose and become buried, where over time it decays into soil organic matter. Bacteria can break this down and release the carbon as CO_2, or as methane in conditions without oxygen.

Or, our humble carbon atom in the form of CO_2 might instead be dissolved in our oceans as carbonic acid. It's possible that within the sea water, it might be taken up by various sea creatures and turned into calcium carbonate, forming shells or bones. In such cases, these shells and bones could also be buried, where over time they form layers of limestone.

Fossil fuels

This movement of carbon through the biosphere (living things), the hydrosphere (oceans and water), the lithosphere (rocks and soil) and atmosphere (air above the ground) depends on a range of environmental factors, and therefore constantly varies. The flows of carbon from one sphere to another are referred to as carbon fluxes.

360 million years ago during the early Carboniferous period, the concentration of atmospheric CO_2 was as high as 1500 parts per million (ppm). The rapid growth of plants trapped much of this CO_2 over tens of millions of years, where it gradually became buried in fossils in the form of hydrocarbon molecules.

This is how fossil fuels are made. Coal, oil and natural gas were formed from the burial of organic matter over long periods of time and placed under huge amounts of pressure. Burning these fossil fuels releases the CO_2 and water that went into making them, together with a large amount of energy. It often also releases sulphur oxides, nitrous oxides and particles such as ash and soot.

FAST FACT

Australia's population is 0.3 per cent of the world's total.

We contribute about 1.3 per cent of the world's total CO_2 emissions.

Our modern world relies greatly on the energy released from burning fossil fuels. We use it to drive our cars, make electricity to light our homes and power our factories. Fossil fuels give us a good quality of life. However, the CO_2 currently being released into the atmosphere from burning fossil fuels is returning to the active carbon cycle after being locked away for tens or hundreds of millions of years. Not only are we depleting our limited fossil fuel resource, we are now faced with more CO_2 in the atmosphere, a factor causing climate change.

Carbon Chemistry information adapted from CSIRO CarbonKids, the Carbon Trust and Queensland Resources Council.

Climate change

CO_2 and climate change

Increased concentrations of CO_2, methane and other greenhouse gases (GHGs) in the atmosphere can reduce the efficiency with which heat is radiated back into space from the earth's surface, causing surface temperatures to increase and weather patterns to change.

About half of our global CO_2 emissions are currently absorbed by the natural carbon sinks in oceans and on land. The other half remains in the atmosphere and is responsible for the enhanced GHG effect and much of global warming. Human activity, such as deforestation and the burning of fossil fuels are the main contributors to higher GHG concentrations in the atmosphere. Cultivating soil also releases CO_2 from organic matter in the soil.

Increases to the amount of CO_2 in our atmosphere is causing the world's climate to change, resulting in higher temperatures, rising sea levels and threats to ecosystems globally. Thirteen of the past fifteen years have been the warmest years globally since records began and in Australia each decade has been warmer than the previous one since the 1950's (State of the Climate, 2012).

Many types of activity undertaken by people in their daily lives at work, home, school and play are sources of CO_2 and other GHG emissions. On the other hand, the right kinds of action by individuals, families, industries and communities can help greatly to reduce emissions.

Energy and CO_2

CO_2 is by far the most influential GHG, followed by methane and nitrous oxide. CO_2 emissions from human (anthropogenic) sources account for about 60 per cent of all GHG. These global CO_2 emissions are mostly from burning fossil fuels for energy (more than 85 per cent), land-use change, mainly associated with tropical deforestation (less than 10 per cent), and cement production and other industrial processes (about 4 per cent).

Energy use and generation in Australia and throughout the world continues to climb and is dominated by fossil fuels, suggesting CO_2 emissions will grow for some time yet.

Measures to reduce CO_2 emissions

Reducing our CO_2 emissions while maintaining our quality of life is no easy task. In summary it is up to governments, industry, and households to do their parts. To reduce CO_2 emissions from energy production, we can:

- Reduce the energy we use: This can happen in a number of ways, for example, using energy efficient technologies and through changing the way we use electricity.
  For example, a household may decide to buy a six-star rated, energy efficient, clothes dryer and also make the choice to only use it when needed, and use the outdoor clothes line at all other times.
- Reduce CO_2 emissions from energy production: develop renewables such as solar, wind and biofuels and invest in low-emission fossil fuel energy technologies (such as CCS).

It is important to keep looking for new and better ways of reducing CO_2 emissions from energy production and other human activities. There is not a 'one size fits all' solution, but providing information on the portfolio of solutions is an important step towards reducing GHG emissions on a global scale.

A low-emissions future

We live in a power hungry world. From the moment we get out of bed in the morning we seek ways to feed our appliances, our vehicles and our buildings with energy.

Energy: the universe's currency

Energy and money have a lot in common. Like money, energy is passed on from a source. It can sit for a time before passing on again. Both can make things happen – the more you have, the bigger the event!

While we have to work hard to keep stock of our world's currency, the universe keeps track of every joule of its energy. No energy is lost and none is created. With every transaction there is an amount of energy lost as heat. This heat is a bit like the five cent pieces you get in change when you go shopping. Small and not easily spent and that can add up.

To carry the analogy further, energy transactions in our world also have banks – places where energy accumulates. These 'banks' include the radioactive elements present in the earth's crust and the globe's crushing pressure that manifests in earthquakes and volcanoes.

The biggest source of energy for earth is the Sun. Nuclear reactions release energy in the form of electromagnetic radiation that rains down on our surface. Or, in simpler terms, sunlight.

Energy sources with interest?

When making a withdrawal from the bank, we have options. Do we pull out a few fifties? A cheque? Do we use EFTPOS? A money order? Some choices come with steep fees. But there is always the decision between convenience and cost.

Energy sources provide similar decisions. Sunlight is stored in the carbon building blocks of growing plants. This chemical storage can be buried as plants die, be passed on to other organisms as it is consumed, or released as CO_2 into the atmosphere as the chemicals decompose.

Lengthy geological processes can compress plant matter into a concentrated form of mineral we call coal. Similar processes create natural gas and oil from organic matter as well. In each case, these fossil fuels provide a convenient source of concentrated energy which we have discovered works well as a means of powering our world. Yet this convenience has a price.

Fossil fuels simply aren't being produced at the same rate they're being consumed. Guesses on how much money is in our account also vary, making it hard for most people to know when we'll run out.

In addition, turning fossil fuel into the energy that powers our lights, heating, iPods and combustion engines frees the chemicals that held it for so long. The CO_2 produced by burning fossil fuels affects the temperature of our atmosphere.

This leaves us with an important question; is it time to change banks, or use multiple banks and make efficient withdrawals?

Demand lower fees!

In the future Australia will have a diverse energy mix, made up of renewable energy sources and fossil fuels. But we need lower emissions from that fossil fuel. One option to consider in countering the release of CO_2 involves capturing it before it is released, transporting it to a storage site, and storing it away from the atmosphere, this is called carbon capture and storage (CCS).

CCS would allow us to continue to use fossil fuels without emitting CO_2 into the atmosphere. It could also be used to capture and store CO_2 from other industrial processes that are large point source emitters, such as steel or cement producers.

Change banks

For all of their convenience, fossil fuels aren't always the most suitable source of energy.

For many needs, enough electricity can be produced directly from sunlight in a process called photovoltaics. Steam can be produced through focusing the Sun's energy onto water or oil via strategically placed mirrors or through passing water through naturally hot rocks deep under the earth's surface.

The Sun's heating of the land and atmosphere also results in currents of wind and water that can be considered as sources of energy. For instance, the Snowy Mountains Hydro scheme releases dam water through pipes and into a water driven turbine.

There is also the matter of distance – losing heat energy as those inconvenient 'five cent pieces' adds up as electricity is transported through vast networks of power lines. Each resource needs to be in the right environment to reduce its impact on the ecosystem and to make efficient use of their energy source.

Efficient spending

New technologies in energy production are an important part of the story for a low-emission future, but they are only part of the story. Through clever building design and reducing energy-consuming behaviour, resources can be conserved and emissions are reduced. Energy efficient light globes in homes, factories and office blocks, solar panels for heating water, extended eaves in homes and factories for cooling are just some of the solutions. Furthermore, cars have become much more efficient over the last decade, while cleaner hybrid cars (having both a combustion and electrical engine) are becoming more common.

Industry and the energy sector play a role in reducing and conserving energy through the use of energy efficient equipment, installing more efficient engines in equipment and being self sufficient in the energy they require. Some industries are planting trees and grasses to absorb carbon, thereby offsetting the CO_2 generated by their use of fossil fuels.

Renewable energy, new low-emission fossil fuel energy technologies and energy efficiency are all essential elements to a low-emission energy future.

CCS technology

What is CCS?

These education materials focus on CCS as one option that could be used to reduce the CO_2 emissions in energy production. CCS is part of a suite of fossil fuel low emissions coal (LEC) technologies.

There are three parts to a LEC technology:

1. A series of energy transformations in which energy in the fossil fuel is transformed into electricity (and CO_2 is produced).
2. Separation and capture of CO_2 by one of several technologies.
3. Compression and transport of CO_2 (usually by pipeline) and sequestration (storage) of it underground.

CCS is a technology chain that involves the capture of CO_2 emissions from power generation and other industrial processes. The CO_2 is then transported and stored in stable underground formations (such as depleted oil and gas reservoirs or saline aquifers).

The capture stage has been tested at pilot plants overseas and in Australia and has been shown to be technically viable.

However, there is not yet any large scale integrated and complete CCS technology operating at any coal fired power station anywhere in the world.

The challenge to CCS capture plants being introduced at power stations is the cost of the infrastructure and the resulting decrease in plant efficiency that results from the installation of the capture technology.

In addition, there are also challenges around the integration of the technology and reduction of the cost of the infrastructure, together with the resulting decrease in plant efficiency that results from the installation of the capture technology.

CCS research

Current research activities focus on making the three stages of the process as efficient and reliable as possible:

Capture

Seeking alternative options for capturing CO_2 from power plants, such as:

- Pre-combustion capture – turning the fuel into hydrogen and CO_2 gases; separation, capture and storage of the CO_2; and then using the hydrogen to generate power.
- Oxy-fuel combustion – burning the fuel in an oxygen rich gas to create a stream of CO_2 that can be captured more easily for storage.
- Post-combustion capture – absorbing the CO_2 emitted in combustion from the flue gas.

Transport

Transporting the CO_2 to the storage site will involve building new infrastructure:

- Pipelines – to transport the CO_2 to the storage sites, both on and off shore.
- Ships – to transport the CO_2 to offshore storage sites if no pipelines exist or the transportation distances are too large.

Storage

There are a number of options for storing CO_2, each with its own risks and benefits:

- Deep saline aquifers (porous rock formations which hold salty water) – the underground store with the largest potential storage capacity.
- Depleted oil and gas fields – the second largest storage capacity comes from injecting CO_2 into an underground store that is well understood and monitored because it is where oil and gas have been extracted from for years.

- Enhanced oil recovery sites – a comparatively smaller-capacity underground store which has been developed first in places like Texas in the USA as the CO_2 injection improves the economics of the oil field by increasing oil extraction and so creating a revenue for small levels of CO_2; however, this benefit only lasts until the oil field is depleted, and some of the CO_2 is extracted with the oil.
- Enhanced coal bed methane recovery – a developing area in which CO_2 is used to enhance the release of methane (natural gas) from coal seams.
- CO_2 mineralisation – occurs naturally in nature over millions of years; CO_2 is 'locked' up in stable minerals such as chalk and limestone. Research is focusing on mixing CO_2 with crushed minerals, chemically binding CO_2 to the mineral.

A number of pilot plants are in operation today testing many of these processes. Large-scale demonstrators are planned in Europe, North America, Australia and China over the next five years. Storage of CO_2 in excess of one million tonnes per year is taking place at Sleipner in the North Sea off Norway, Weyburn in Canada and In-Salah in North Africa. One of the largest CCS projects in the world – in terms of tonnes of CO_2 stored per year – is currently under construction in Australia. The Gorgon CO_2 Injection Project expects to store between 3.4 and 4 million tonnes of CO_2 each year at a depth of approximately 2.3km into a deep saline formation below Barrow Island.

One million tonnes of CO_2 is only 0.01 per cent of total GHG emissions, however it represents a proof of concept for CCS technology.

Challenges

The technologies that makes CCS possible exist; yet making it happen on a large-scale takes more than just know-how. There are three main challenges to the deployment of large-scale CCS:

- Cost of the infrastructure
- Reduced efficiency of power plants by about 20 to 25 per cent.
- Uncertainty and proximity of storage sites.

All of the above are likely to result in electricity price increases.

There are also questions to be asked and answered. For example, what impact would CCS technology have on CO_2 emissions? Presented with a way to reduce CO_2 emissions, would it make it more difficult to pursue renewable energy and reduce our dependence on fossil fuels? What if something goes wrong in the process? CO_2 leaking into groundwater may lead to acidification, while a release of pressurised CO_2 into the atmosphere may create a dangerous 'low oxygen' zone. What if the technologies don't work as expected? Could funding for CCS be put to better use elsewhere?

A piece of the puzzle

Reducing CO_2 in the atmosphere is vital for mitigating climate change. Commercial development of large scale CCS is one way that would allow us to continue to burn fossil fuels for energy without increasing CO_2 in the atmosphere.

CCS is not a complete solution in its own right, but is a piece of a puzzle. What role it will play will depend largely on whether its potential benefits outweigh its risks.

SECTION 3
Teaching units

Investigate carbon capture and storage (primary/elementary)

Main idea

In this unit students investigate some of the chemical properties of carbon dioxide (CO_2) and investigate its roles and movements in the atmosphere.
Using a range of strategies across learning areas, this unit introduces students to the issue of climate change and CO_2 emissions. Students explore the different types of emission sources that contain CO_2.

Further to this, they investigate and simulate CCS technologies for:

- capturing CO_2 from industrial sources or power plants
- compressing and transporting CO_2
- storing CO_2.

The inquiry approach is built around the investigation of CCS, broadening student experiences and understandings during the investigation, and consolidating and presenting these understandings to an audience following the study.

Key understandings

By the end of this unit, students should understand:

- Carbon is an element present in all living things
- Carbon is exchanged between the atmosphere, biosphere, hydrosphere and rocks and soils in a cycle
- Carbon stored as fossilised plant matter is released as CO_2 following the combustion of fossil fuels
- Changes to the carbon cycle contribute to changes in the climate
- Many activities undertaken by people in their daily lives at work, home, school and play are sources of GHG emissions, which includes CO_2 emissions
- Burning fossil fuels for energy and processes in industry releases CO_2 emissions
- CCS is a process that separates CO_2 out of the flue stream of power and industrial plants. The CO_2 is transported and stored in deep geologic formations. The technology is still being developed.

Focus questions

- What is carbon?
- How does carbon cycle through the environment?
- What is carbon dioxide (CO_2)?
- Who and what produces CO_2 emissions?
- How does increasing the amount of atmospheric CO_2 impact climate change?
- How can emissions be cut while meeting demands for energy and products like cement, steel, iron and aluminium?
- What technologies are being developed to reduce emissions of CO_2?
- What can power plants and industry do and why is it important to get involved?
- Why is it important to keep looking for new and better ways of reducing our contribution to climate change?

Key literacy terms

Absorb, action, alternatives, atmosphere, atom, behaviour, capture, carbon, carbon cycle, carbon dioxide (CO_2), change, climate, communities, consequences, conservation, decisions, ecosystem, efficiency, emissions, energy, exhausts, fossil fuels, geosequestration, global warming, greenhouse gases, impacts, implementation, industry, innovation, investigate, pollution, renewable, resource, responsibilities, scientists, sequester, sources, storage, sustainability, technology, transport.

Sample unit sequence and activity ideas

Tuning in

An overview of carbon

Required: ☑ Internet

Ask students to develop a concept map describing what they know about carbon, what it is, what it comprises, what it affects, and who and what produces carbon emissions that can affect the earth's climate. Share with students some facts about CO_2 emissions as is currently understood.

Surf the following websites and read and discover more about carbon and the carbon cycle.

See:

Chem4Kids – carbon
www.chem4kids.com/files/elements/006_speak

Climate change kids website
www.epa.gov/climatechange/kids/index

CCS Education Centre – What is the problem with CO_2?
www.geos.ed.ac.uk/sccs/public/

Geography4Kids – carbon cycle
www.geography4kids.com/files/cycles_carbon

NASA earth observatory – carbon cycle
www.earthobservatory.nasa.gov/Features/CarbonCycle/

Web elements online periodic table
www.webelements.com/carbon/contents

Makin' molecules

Required: ☑ **Resource 1.1**

Talk with the students about the amazing carbon atom and its remarkable ability to bind with other carbon atoms to form chains, rings and complex structures. Introduce the term 'molecules' and explain how they are made up of two or more atoms joined by shared electrons.

Explain that carbon can form different molecules with other elements, such as oxygen and hydrogen.

Source: CSIRO CarbonKids Carbon Chemistry Curriculum Unit page 6

Make CO_2

Required: ☑ **Resource 1.2**

Carbon moves throughout the atmosphere (air), biosphere (living things), hydrosphere (water) and lithosphere (rocks and soil) in different forms. It does this because it forms molecules that react with other chemicals.

Explore with the students how a reaction between two different substances – a solid (bicarbonate soda) and a liquid (vinegar) – can create a third new substance such as CO_2 gas.

Invite students to contrast the differences between the compound 'acetic acid' (vinegar), the compound sodium bicarbonate and CO_2 gas. Ask where the gas came from and where it would go once it was released.

Source: CSIRO CarbonKids Carbon Chemistry Curriculum Unit page 7

Clarifying different types of substances that are emitted to the air

Required: ☑ Recording materials

Ask students to express their personal experience of substances that are emitted to the air. Consider using the following questions:

- What do we mean by substances that are emitted?
- How many different types of substances can you think of that are emitted to air, land and water? (Industry sources, point and diffuse sources, natural sources, transport sources, consumer products etc.)
- What sort of impacts do these substances have on human health and the environment?

List students' ideas on a medium for further reference.

Preparing to find out

Learning Log

Required: ☑ Exercise book

Begin a Learning Log where students record their understandings. This might form part of an assessment plan.

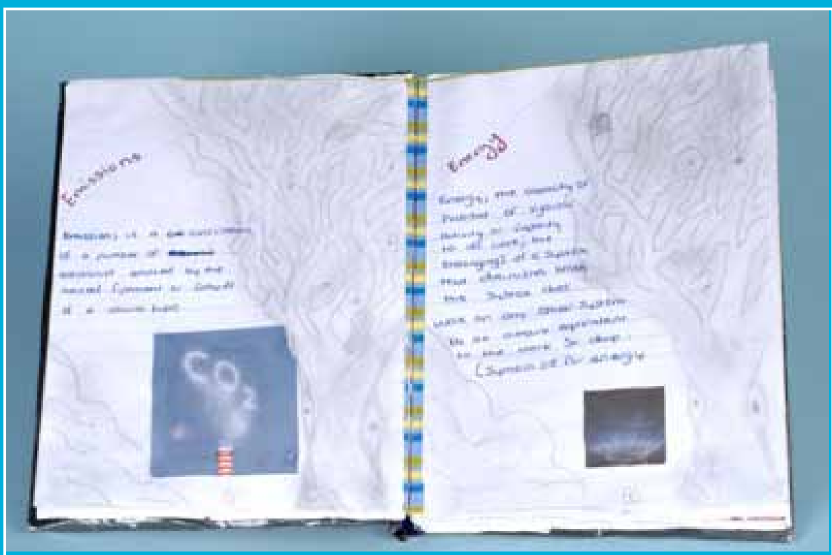
Introduce the Learning Log and model a procedure for maintaining it. The whole class might jointly construct the first entry. Students can then make individual entries based on the activities they do and the questions they come up with.

Initial focus questions could include:

- Who and what produces CO_2 emissions that can affect the earth's climate?
- What impact does my perception of CO_2 emissions have on my use of technology and energy?
- What technologies am I aware of that can reduce CO_2 emissions to the atmosphere?
- Are we going to produce more or less CO_2 emissions in the future?
- What answers might there be to meeting the challenge of climate change and reducing CO_2 emissions?

Note this!

Contribute to a Learning Log by writing down questions and reflections about what they already know, what they would like to know and interesting facts or information.



Counting CO_2

Required: ☑ Yellow dried peas
☑ Green dried peas
☑ Resource 1.3
☑ Internet

Gases such as CO_2 are often represented as 'parts per million'. This can be a difficult term to visualise.

Ask students what 'parts per million' might mean? Start with nine yellow peas and ask students to add one green pea, to make a total of ten peas. Explain that this is 'one green pea per ten peas', or 'one part per ten'. Scale this up to 99 yellow peas and one green pea, to make 'one part per hundred'.

What might one part per million look like if you had one green pea per million yellow peas? What volume would make up one millionth of your local harbour or lake? Use other examples of 'one part per...' such as cars, people or even school buildings. Compare this figure with percentages (per hundred).

Research and translate the percentage of oxygen in the atmosphere into parts per million (ppm).

Critical graphing

Present a copy of **Resource 1.3**, which shows a graph of global carbon emissions over time. Ask students to search the internet for a graph demonstrating temperature changes over a similar time.

Discuss whether it's reasonable to assume one causes the other. Ask what additional information might be required to gain a better understanding of the relationship. Can we assume based on the graph that temperatures and CO_2 emissions might continue to increase into the future? Why/why not?

Source: CSIRO CarbonKids Carbon Chemistry Curriculum Unit page 8

Extend yourself!

Divide the population of your country of origin into your national CO_2 contribution to determine what your country produces 'per capita'. Compare this with the global total. How does your country compare? What creates this difference?

Connections between emissions of CO_2 and climate change

Required: ☑ Internet

Ask students to develop a concept map describing what they know about connections between CO_2 emissions and the earth's climate. Share with students some facts about CO_2 emissions as is currently understood.

Consider that:

- CO_2 from anthropogenic sources represents up to 60 per cent of total GHG emissions
- By studying air bubbles trapped in ice-core samples from the Antarctic, scientists know that the concentration of CO_2 was stable between 180-300 (ppm) for the past 650 000 years
- Since the Industrial Revolution, however, levels of CO_2 have risen to 389 ppm in 2010.

Questions, questions…

Use the following 'Question Grid' to encourage students to devise additional angles to their questions.

What is?	Where/when is?	Which is?	Who is?	Why is?	How is?
What did?	Where/when did?	Which did?	Who did?	Why did?	How did?
What can?	Where/when can?	Which can?	Who can?	Why can?	How can?
What would?	Where/when could?	Which could?	Who would?	Why would?	How would?
What will?	Where/when will?	Which will?	Who will?	Why will?	How will?
What might?	Where/when might?	Which might?	Who might?	Why might?	How might?

For example: What is a low-emission technology? What is CCS? Where is CCS happening? Which parts of the world are developing CCS? Who is researching CCS? What did scientists most recently report on? Apply these same questions to complementary technologies that are zero emission or can reduce CO_2 emissions.

Source: CSIRO CarbonKids Understanding Climate Change Curriculum Unit page 7

Research task: Part 1

Assessing prior knowledge

Invite students to choose from one of the three topics:

- Carbon dioxide (CO_2) as a greenhouse gas (GHG)
- CO_2 underground
- Carbon in the living world

Ask them to create three lists for their topic.

Prepare for the inquiry

Ask students why they think it is important to understand the role of carbon in our environment. List the student's responses on cards and put aside this list for a later activity.

Use the following list to focus the student's responses:

- Carbon in natural systems
- The carbon cycle
- Carbon and volcanic eruptions
- Human use of carbon
- CO_2 emissions and GHG
- CO_2 emissions and climate change

Sort responses and ask students to give reasons for their choices. Students can also sort and categorise information using a Venn diagram to show how one item may belong in two or more categories.

Explain to the students that in later stages of the unit they will be investigating CCS, a technology that can separate CO_2 emissions out of emissions produced by some industries and power plants.

Encourage students to brainstorm ways that they think this might be possible.

Source: CSIRO CarbonKids Carbon Chemistry Curriculum Unit page 10

Finding out

Research task: Part 2

Required:
- ☑ **Resource 1.4**
- ☑ Research materials (library, internet)
- ☑ **Resource 1.5**
- ☑ Research materials (library, internet)

Fossil fuels

Fossil fuels have become a resource we depend upon. Geologists play a vital role in our search for new fossil fuel sources and in understanding how and where these deposits form.

In class, discuss with students what they understand about society's use of the fossil fuels – oil, coal and gas. Students then create a list of potential resources that could provide more information on each fossil fuel, e.g. library research, contacting different industry bodies, using the internet, contacting research organisations.

In their research, they should endeavour to come to a conclusion on the following points:

- What uses does each fossil fuel have?
- How is each fossil fuel formed? What is the geology of its formation?
- For each use, what happens to the fossil fuel's carbon?
- How vital is each use to our way of life?
- Are there alternatives to each use?
- Is there new technology being developed which could address any of the above points?

In groups, students decide upon resources they can use to learn more about the uses and alternatives regarding fossil fuels. Read the Student Fact Sheet in **Resource 1.5** about energy and varying sources that could reduce CO_2 emissions.

Of particular importance, encourage students to find out more about technologies being developed or explored which could reduce CO_2 emissions to the atmosphere from processes involved in using fossil fuels.

Each group might:

- Prepare questions to help them find out relevant information
- Prepare a record sheet for answers
- Check these with another group to ensure that they are comprehensive.

Invite students to use the following web-based source materials to find additional information about CCS as a technology being developed to reduce CO_2 emissions from industries and power plants.

See the Queensland Resources Council website to find and explore CCS technological processes.
www.oresomeresources.com/resources_view/resource/link_carbon_capture_and_storage_movie

View a video and animation on climate change and CCS.
www.egfi-k12.org/whats-new/e-tube/carbon-sequestration
www.ccs-education.org/keeping-co2-out-of-the-atmosphere-by-sequestering-it-underground/

Investigate how CCS works via a YouTube video.
www.youtube.com/watch?v=ROEFaHKVmSs&NR=1

Hear from a Scottish expert on how CCS works.
www.ccs-education.org/

Look at a large number of reports and video footage on CCS:
www.globalccsinstitute.com/

View excerpts and, in groups, explore the issues presented and list ideas on a class retrieval chart documenting understandings about CCS as a low-emission technology.

Adapted from: CSIRO CarbonKids Carbon Chemistry Curriculum Unit page 11

Note this!

Retrieval charts are tables or charts that categorise information, making it easier to understand. This is important as students will begin to see patterns emerging.

Investigation: CCS

Required: ☑ **Resource 1.6** and **Resource 1.7**
☑ Exercise book

Improve understandings about CCS. Talk with the students about the first stage of the process where the CO_2 is captured before or in some cases after fossil fuels are burned and compressed into a liquid form.

Hand students a copy of **Resource 1.6** and **1.7**. Challenge them to investigate and simulate how CO_2 can be captured and stored deep underground.

Invite students to record their understanding of how CCS works. This might include a flow chart or diagram with associated captions. Encourage students to reflect on the processes involved and their associated challenges and opportunities.

Ask students to incorporate understandings from this simulation into their Learning Logs for future reference.

Investigation: Transporting CO_2

Required: ☑ **Resource 1.8**
☑ Exercise book

Once CO_2 is captured, the next step required is transportation to a storage site. In most cases, CO_2 is compressed into a liquid and transported to locations where the geology can hold and store large quantities of this liquefied gas.

Use **Resource 1.8** to explore pumping, compression and pressurisation and to simulate the processes in CCS where the CO_2 is moved from where it is collected at the power station or industry, to where it is stored in an underground reservoir.

Ask students to record their understandings about the transportation of CO_2 and the processes involved in CCS in their Learning Logs.

Investigation: Storing CO_2 underground

Required: ☑ **Resource 1.9**
☑ Exercise book

Review the two stages of CCS that have been investigated by the students in the earlier hands-on activities. Explain to the students that in the final stages of the process, CO_2 can be stored in some geological formations under the ground. The goal of storage is to find locations where CO_2 can be stored safely in large quantities for an indefinite period of time.

Brainstorm different types of geological formations that could possibly store carbon dioxide. (i.e. oil and gas fields, deep saline formations and unmineable coal seams).

Extend the brainstorm and ask students:

- At what depth might the CO_2 need to be stored?
- How might scientists make sure the seal is good enough for the CO_2 to stay underground?

Using the activities in **Resource 1.9** engage students in simulating the storing of CO_2 in underground storage sites.

Sorting out

Ask students to record their understandings about the storage of CO_2 in their Learning Logs.

Concept mapping

Draw conclusions about what has been learned. Develop concept maps using key words. Students draw connecting lines between words and indicate how they believe their words relate to each other.

From the concept maps, students come up with statements about CCS as a technology that reduces the amount of CO_2 emissions from industries and power plants. Share and prioritise statements.

Research Task: Part 3

Required: ☑ Internet

Our changing climate is prompting us to limit our emissions of CO_2 to the atmosphere. How industry and power plants work towards developing technologies and methods to mitigate the release of CO_2 is part of an emerging story.

Engage students individually or in pairs to reflect on the research and hands-on activities undertaken about CCS as one type of low-emission technology.

Ask students to consider how they are going to bring their information together and present it so that the main processes involved in CCS can be communicated to an audience at the school, within the local community or via social media outlets like YouTube.

As a class, list the main processes involved and the main messages to be given about CCS and decide on ways to share this information.

Ask students to decide on a way of representing the processes and main messages, data and research collected from their investigation about CCS. It could be a poster, a presentation, a pamphlet or a documentary. Invite them to justify their choice of media and explain its advantages and disadvantages.

See Google Images or the ICO_2N Library for graphics that students might use in their presentations.

www.iCO₂n.com/library/graphics

If students are interested in using animations as part of their presentation see 'Carbon Underland' an animated short film on carbon sequestration for ideas.

www.youtube.com/watch?feature=player_embedded&v=gr9cznZFuIc

Additional CCS images, maps and slides can be found at the website of the Global CCS Institute, Slidefinder and the National Energy Technology Laboratory.

www.globalccsinstitute.com/

www.slidefinder.net/c/carbon_management_sustainable/development_examination_potential/276062 and

www.netl.doe.gov/technologies/carbon_seq/core_rd/CO2_web12.exe

Going further

Additional demonstration: CO_2 compression and geosequestration

Required: ☑ **Resource 1.10**
☑ Exercise book

Explain to the students that CO_2 storage is possible in a number of ways, including injecting CO_2 into depleted and depleting oil and natural gas fields, coal beds, deep saline aquifers, and salt caverns.

Scientists study the rocks deep beneath the surface in order to determine which formations might be good for sequestering (storing) CO_2.

Use **Resource 1.10** to see what happens in an oil reserve when CO_2 is pumped into it. Note there are two parts to this activity – a teacher demonstration using a chemical reaction to create CO_2 and a student component involving the pumping of CO_2 into a simulated oil deposit.

Invite students to reflect on the processes simulated in the hands-on activity in their Learning Logs for future reference.

Additional demonstration: CO_2 storage and ocean acidification

Required: ☑ **Resource 1.11**
☑ Exercise book

Talk with the students about scientists who are thinking about other ways we can store CO_2 in the oceans safely. Some scientists have thought about pumping CO_2 directly into the oceans, but very deep down.

Using **Resource 1.11** simulate this component of carbon capture and storage that is still very much in the exploratory stages of research.

De Bono's six hat thinking

Students explore issues raised using de Bono's Six Thinking Hats technique to explore CCS as a developing technology that can address climate change in more depth. Students, in six groups, each with a different hat, discuss and document the issues according to their given perspectives and come together at the end to share their ideas.

Red Hat	White Hat
Feelings *What are the emotions and feelings associated with CCS? How do you feel?*	**Information** *List the facts that you know about carbon capture and storage as it is used by industry and power plants and how it affects the environment.*
Blue Hat	Green Hat
What thinking is needed *What has happened so far?* *What should happen next?* *What questions should we consider?*	**New ideas** *How could the problems related to GHGs be solved?* *What needs to be done?*
Black Hat	Yellow Hat
Weaknesses *What are some of the negative aspects and outcomes of seeking new low-emission technologies?*	**Strengths** *What are some of the positive aspects and outcomes of seeking new low-emission technologies?*

Making connections

Review understandings

Required: ☑ Internet

Review key understandings about carbon, CO_2 emissions and CCS. Assist students to draw conclusions about what they have learnt by playing 'The Adventures of Carbon Bond'. See www.southwestcarbonpartnership.org/kids/carbon_mcs

This game was developed by the National Energy Technology Laboratory (NETL) at the U.S. Department of Energy (DOE). Carbon Bond is a rehabilitated CO_2 molecule who has been given a chance to pay his debt to society by becoming a secret agent. His mission is to save the planet by capturing as many rogue CO_2 molecules as possible and putting them safely behind bars. Invite students to play the game and take the National Energy Technology Laboratory (NETL) Entrance Exam to review what they know about carbon, CO_2 emissions and CCS.

Likewise invite students to play 'The CO_2 Connection' developed by Science Alberta. This video game centres on building a giant pipeline capable of transporting vast amounts of CO_2. See www.incubatorgames.com/index.php/20110323/CO_2-connection/ or www.wonderville.ca/asset/CO_2-connection.

Considering consequences

Required: ☑ Resource 1.12

All actions – or lack of action – carry a range of potential consequences. Ask the class to consider a range of consequences for not reducing CO_2 emissions at power plants and industry sites. Place the consequences on a scale of severity, from 'minor' to 'major'. Have students give their opinion on the likelihood of each consequence, and discuss the significance of the scale.

Use a consequence wheel (**Resource 1.12**) to examine first, second and third order consequences.

Adapted from: CSIRO CarbonKids Carbon Chemistry Curriculum Unit page 15

Reflection

Ask students to complete a self-assessment and reflection activity. Complete one yourself and role model it for the students.

Use the following questions as a guide:

- What is the most useful thing I have learned about industry and power plants using CCS as a way for reducing CO_2 emissions?
- How might I help others to understand there is no one 'solution' to climate change?
- What would I still like to find out about industries and power plants working more sustainably?
- What piece of work am I most satisfied with?

References

International Energy Agency, *Technology Roadmap*, Carbon Capture and Technology, Paris: OECD 2009

CSIRO, *The CSIRO Home Energy Saving Handbook*, J. Wright, P. Osman, P. Ashworth, Pan Macmillan Australia 2009.

Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds),

Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

CSIRO, (2010), *CarbonKids Carbon Chemistry Curriculum Unit*, CSIRO Education

Dalton, J., (1985), *Adventures in Thinking*

De Bono, E. (1992) *Six Thinking Hats for Schools*, Books 1 and 2, Hawker Brownlow Educational.

Websites

Andrea Hazard

www.ahazard.com/kidsbooks/kids/ocean_acid

CCS Education Centre

www.geos.ed.ac.uk/sccs/public/

CCS Education Initiative

www.ccs-education.org

Chem4Kids

www.chem4kids.com/files/elements/006_speak

CO2CRC

www.co2crc.com.au

CSIRO

www.csiro.au

CCS101

www.ccs101.ca/teachers-page

eGFI

www.students.egfi-k12.org

Geography4Kids

www.geography4kids.com/files/cycles_carbon

Global CCS Institute

www.globalccsinstitute.com

Google Images

www.google.com.au/images?q=carbon+storage&hl=en&rlz=1T4SUNC_enAU373AU374&prmd=ivnsu&wrapid=tlif130083777134710&um=1&ie=UTF-8&source=univ&sa=X&ei=iTWJTdnIKY_uuAOJ0bDMDg&ved=0CHMQsAQ4Cg&biw=1328&bih=502

Integrated CO_2 Network

www.ico2n.com/library/graphics

NASA Earth Observatory

www.earthobservatory.nasa.gov/Features/CarbonCycle/

National Energy Technology Laboratory

www.netl.doe.gov/technologies/carbon_seq/core_rd/CO2_web12.exe

Queensland Resources Council

www.oresomeresources.com

Science Alberta

www.incubatorgames.com/index.php/20110323/co2-connection/

Science News For Kids

www.sciencenewsforkids.org/2011/04/sea-changes/

Slidefinder

www.slidefinder.net/c/carbon_management_sustainable/development_examination_potential/276062

United States Department of Energy

www.blog.energy.gov/blog/2011/05/26/move-over-american-idol%E2%80%A6

United States Department of Energy

www.southwestcarbonpartnership.org/kids/carbon_mcs

United States Environmental Protection Authority

www.epa.gov/climatechange/kids/index

Web Elements online periodic table

www.webelements.com/carbon/contents

Western Michigan University

www.wmich.edu/corekids/CarbonDioxideSequestration

Woods Hole Oceanic Institution

www.whoi.edu/oceanus/viewArticle.do?id=65066

YouTube

www.youtube.com/watch?v=ROEFaHKVmSs&NR=1

Name:

Molecule models

You will need

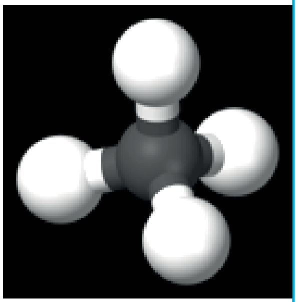
- Fimo (white, red, black)
- Toothpicks
- Scissors
- Protractor
- Aluminium foil
- Small, strong magnets
- Strong glue (super glue or hot glue)

What to do

CARBON DIOXIDE: CO_2

1. Mould one black ball and two red balls 2cm in diameter.
2. Gently poke two closely parallel toothpicks halfway into each of the red balls.
3. Line up one red ball on either side of the black ball.
4. Gently poke the toothpicks halfway into the black ball.
5. Jiggle the toothpicks gently to widen the holes, as they will eventually shrink, then remove the toothpicks.
6. Bake the balls on a foil-lined tray in the oven for 30 minutes at 110 degrees Celsius. Leave to cool.
7. Cut the toothpicks in half and glue one into each hole, joining the balls together.
8. Glue a magnet to the back of the black ball.

METHANE: CH_4



1. Mould four small white balls (1cm diameter) and one red ball (2cm diameter).
2. Gently poke a toothpick halfway into each of the white balls before pulling it out again.
3. Form a V-shape with the white balls at the top and the red ball at the bottom in such a way that no matter which way the molecule sits, it has three ‘legs’ that form a perfect triangle. Use the protractor to adjust the toothpicks to 109.5 degrees apart.
4. Gently poke the toothpicks halfway into the red ball.
5. Repeat Steps 5–7 as for the carbon dioxide molecule.

What’s happening?

The balls that you’ve moulded represent atoms, while the toothpicks represent covalent bonds. The bonds are at different angles in each molecule because the electrons that surround the atoms hold them together differently in each case.

CO_2 is best known as a GHG in the earth’s atmosphere. It is produced by all animals, plants, fungi and microorganisms during respiration — the process that harnesses the energy needed to live. CO_2 is taken up from the atmosphere by plants during photosynthesis — a process that stores the Sun’s energy. There is great concern that humans’ daily activities are causing the release of too much CO_2 into the atmosphere, contributing to global warming.

Methane is the simplest ‘hydrocarbon’, formed from carbon and hydrogen. It is the main component of natural gas, and is also released as a waste product by bacteria.

Source: CSIRO CarbonKids Carbon Chemistry Curriculum Unit page 20

This resource is part of the Introduction to Carbon Capture and Storage education materials.
Supported by the Global CCS Institute and delivered by CSIRO Education.

Name:

Make carbon dioxide

You will need

- Empty small soft drink bottle
- Vinegar
- Bicarbonate of soda
- Balloon

What to do

- Place 100 mL of vinegar into the bottle.
- Half fill the balloon with bicarbonate of soda. Break up any lumps of bicarb first so they don't get stuck.
- Carefully stretch the balloon over the mouth of the bottle, being careful not to spill bicarb into the bottle or tear the balloon.
- Hold the balloon upright and shake the bicarb into the bottle – the balloon should start blowing up quickly.
- Liquid may bubble up into the balloon, if so hold it upright to drain into the bottle.
- Observe what is happening in the bottle – the bubbles of gas filling the balloon are carbon dioxide.

What's happening?

When vinegar and baking soda mix together, there is a fast chemical reaction. There are several products of the reaction, although it is the carbon dioxide gas (CO_2) that inflates the balloon. We'll have a look at the whole reaction later. As more and more CO_2 is produced, the bits of carbon dioxide (called molecules) are squashed together and begin to push, or apply a force, on all the inside surfaces thus inflating the balloon.

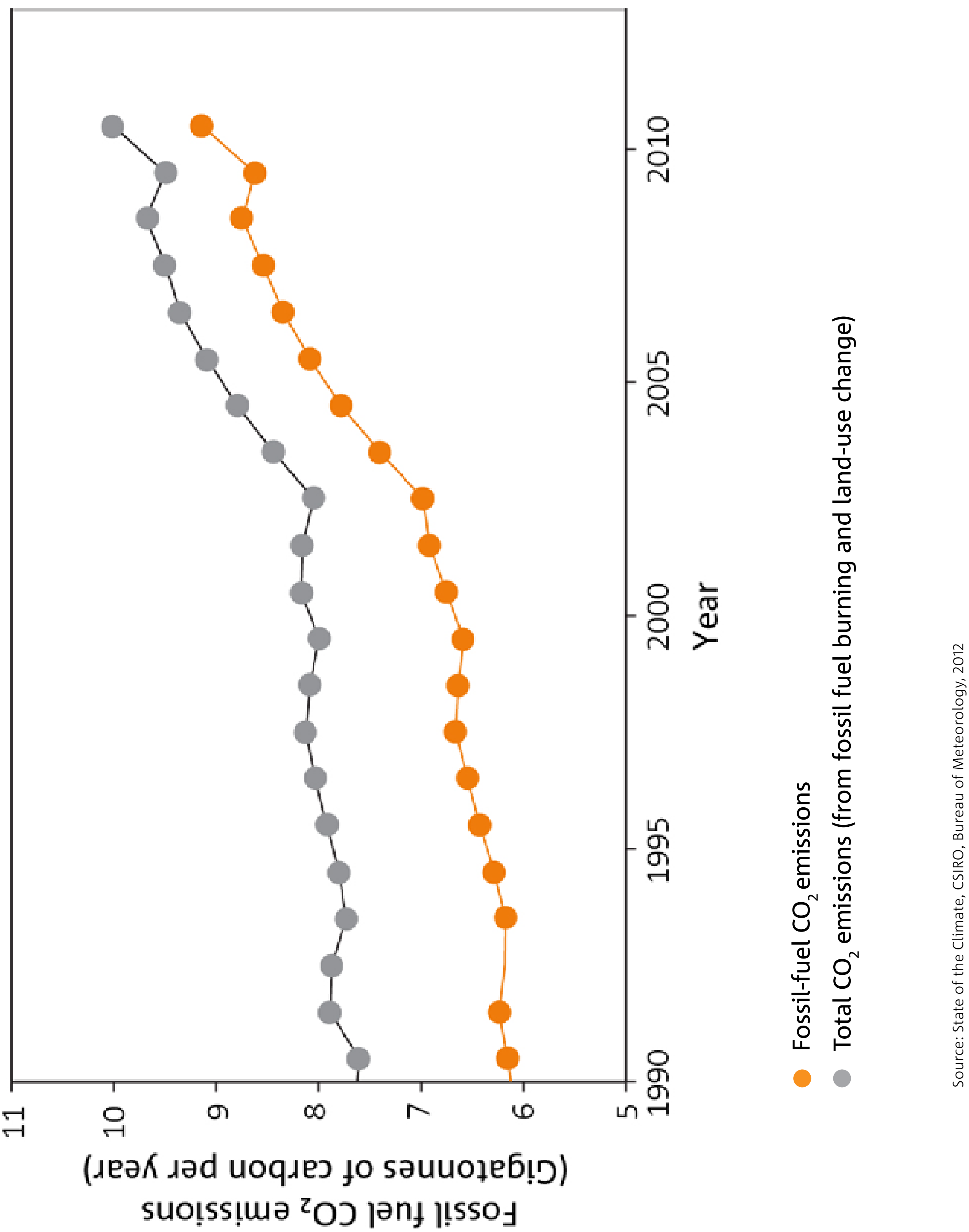
As vinegar (dilute acetic acid) is a weak acid and baking soda (sodium bicarbonate) is a weak base, it is an example of an acid-base reaction. The equation is shown below:

$$\mathbf{CH_3COOH + NaHCO_3 \rightarrow NaCH_3COO + H_2CO_3}$$

Acetic acid plus sodium bicarbonate makes sodium acetate plus carbonic acid

This resource is part of the Introduction to Carbon Capture and Storage education materials.
Supported by the Global CCS Institute and delivered by CSIRO Education.

Name:



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Name:

The research process

In science, researching what other people have written about a concept is called a 'literature review'.

To do a literature review, go through the following steps:

Choose a topic	My topic:
Define key words that might be associated with that topic.	Key words:
List all of the possible places that information might be found on that topic, and decide how to search through them.	List of resources:
Search for the key words and decide whether the text might be useful or not. Keep a record of the text, including: author's name, the name of the text, the year it was written, the name of the publisher and the pages you found most useful.	Author's name: The name of the text: The year it was written: The name of the publisher: The pages you found most useful:
Photocopy or write out the information you think is important.	

Source: CSIRO CarbonKids Understanding Climate Change Curriculum Unit page 20.

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STUDENT FACT SHEET 1

Energy resources overview

What is energy?

Energy makes the world go round. Its classical definition is the capacity to do work which is usually explained by a force moving a mass. This is obvious in kinetic energy, which is possessed by a moving object like a car or rocket, or potential energy, which an object acquires because of its position (e.g., a compressed spring or a lifted mass). But energy exists in other forms as well - heat is thermal energy which has the capacity to do work on and change the state of materials; radiation including light is radiant energy held in electromagnetic fields that fill space and time; the petrol in the tank and the battery under the bonnet of a car contain chemical energy; and so on.

The first human beings relied on the power of their own bodies which were fuelled by the food they ate. When they discovered fire, the energy stored in wood and similar fuels gave them a source of heat and light they could control and use as they wanted. In time they also learned to harness (literally) the muscle power of other animals and to tap into the power of wind and water.

Our use of energy has accelerated in the last 300 years with the invention of the steam engine and then the internal combustion engine. These new machines created an enormous demand for energy resources, the implications of which we have only now started to realise. Whether we continue to rely on finite supplies of fossil fuels or learn to harness renewable sources such as wind, water, and sunshine will have serious implications for our survival.

Energy has many different sources. It can be stored in a fuel such as wood or coal or collected by the sails of a windmill or the photovoltaic cells of a solar array. Some sources of energy such as fossil fuels are very useful but once used are gone forever. Others tap into an effectively limitless resource such as solar energy but are not as concentrated as fossil fuels. Whatever the source of energy, significant capital investment is required to develop resources and convert the energy into a form that we can use.

Energy resources

Australia has a variety of energy resources including coal, natural gas, oil, wood, wind, geothermal, sunshine, waves, tides and uranium. Some of these are currently used as energy sources while others remain undeveloped. We are fortunate to be very rich in nearly all of these resources, and Australia is already the world's largest exporter of coal and a significant exporter of liquefied natural gas and uranium.

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STUDENT FACT SHEET 2

Different sources of energy

Coal

What is it?

Coal is a fossil fuel formed by the accumulation and decomposition of plant material over millions of years. The energy of the sun is used by plants to extract carbon from carbon dioxide (CO_2) gas in the air. The plants then grow by turning that carbon into leaves, wood and flowers. The plants die, are buried and sometimes turn into coal. When we burn the coal the carbon combines with oxygen to form CO_2 and it is returned to the air. The quality of coal reserves is variable, with black coal having the highest energy content by mass.

How is it used?

Coal has a number of uses. Coal is used in power stations where it provides most of the world's electricity. It is sometimes used for heating in homes, or for district heating in cold climates, and often as a source of heat for industry. Metalurgical coal is used in the process of making steel. Other uses are to produce fertilisers, drugs, dyes, soap, tar, gas, creosol, disinfectant and pesticides.

Australia exports 82 per cent of its black coal production. Of the coal used in Australia, about 80 per cent generates electricity, 12 per cent is used in metal smelting and the remainder is used in manufacturing.

Challenge

The high reliance on coal for power generation has resulted in the production of large quantities of carbon dioxide, one of the emissions generally understood to be responsible for the enhanced greenhouse effect – the increase in the world's temperature due to the increased insulating effect of the earth's atmosphere.

Petroleum

What is it?

The word 'petroleum' comes from two words 'petra' (Greek for rock) and 'oleum' (Latin for oil). It was so called because oil is found in porous sedimentary rocks, trapped along with layers of gas, under layers of impervious rocks. In its widest sense, petroleum includes all the hydrocarbons found in the earth. In its narrower commercial sense, it usually just refers to the liquid deposits (crude oil).

How is it used?

Petroleum gas, or 'natural gas', is used in houses for heating and cooking and in factories as a source of heat energy. Petroleum liquid and gas are used to fuel our transport needs, large power stations, and also small electricity generators that provide local power to homes and businesses.

Challenge

In Australia, consumption of petroleum products produces CO_2 emissions (the principal GHG). Nevertheless, natural gas is regarded as a cleaner alternative to coal for generating electricity, because it produced approximately half the amount of CO_2 for the same energy output.

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Different sources of energy continued

Liquefied natural gas (LNG)

What is it?

LNG is natural gas that has been chilled to -161 degrees Celsius at normal atmospheric pressure to form a liquid. It may be transported long distances in ships and heated (re-gasified) to turn it back into a gas for use. Australia's natural gas consumption is predicted to significantly increase as Australia transitions to a lower carbon economy through greater use of gas for electricity generation purposes, as well as rising energy demands associated with increased population and economic growth.

How is it used?

One important use of natural gas is for generating electricity in gas-fired power stations. Gas-fired power stations offer a lower GHG emission alternative to coal-fired plants because they generate less CO_2 for the same amount of electricity generated. Reducing our dependency on coal for electricity production means that there is a need to increase natural gas production to meet future energy demands.

Challenges

Considerable energy must be expended to firstly chill natural gas to a liquid, keep it in a liquid form during transport and then re-gasified at its destination. Consequently the GHG intensity of LNG used for power generation is higher than that of (locally sourced) natural gas.

Solar

What is it?

Solar energy is energy from the sun as a result of nuclear fusion. This fusion typically involves two hydrogen atoms being compressed together by the enormous pressure and temperature of the sun to form one helium atom. During the conversion some of the mass of the two hydrogen atoms disappears as it is converted into a large amount of energy. The heat and light we experience everyday are obvious examples of solar energy. A solar cell converts sunlight into electrical or thermal energy. A solar battery contains solar cells, usually mounted in panels.

How is it used?

There are two main ways to convert sunshine into energy:

- **Solar thermal:** When concentrated using mirrors, solar thermal energy can replace burning fossil fuels as a source of heat. This is called concentrating solar thermal (CST) and several large power stations of this kind have been in service since the global oil crisis of the 1970s. More advanced CST technologies are now being developed and tested, such as power towers surrounded by fields of tilting mirrors that reflect the sunshine to a single collector, producing temperatures as high as 1000 °C.
- **Solar electrical:** Solar energy produces electricity directly through solar cells, more formally known as photovoltaic (PV) cells, which are assembled into PV arrays of any size from rooftops to solar farms. Solar photovoltaic energy can be used in stand-alone and grid-connected situations.

In grid-connected circumstances, where utility-supplied electricity is available, clean energy from the sun can be harvested to add to the existing grid supply. Homes and businesses can install solar PV arrays and receive payment for the electricity they generate. Large generating companies can create solar farms and operate as a major supplier.

Challenge

An obvious limitation of solar systems is that the sun only shines during the day and may be intermittent even then due to cloud cover. Some means of providing power when the sun is not shining or storing the energy generated during the day is therefore essential when using solar energy.

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STUDENT FACT SHEET 2 continued

Different sources of energy continued

Although the energy generated is sometimes referred to as free, because no fuel is required, the cost of solar photovoltaic cells is high and their useful lifetime of 15-20 years is less than half the typical lifetime of a coal-fired or gas-fired power station. Presently, government subsidies are helping to increase the amount of solar energy, and large-scale manufacturing has led to dramatic decreases in costs in recent years.

Solar thermal power stations and solar PV arrays have different costs and benefits, so in the near future there is likely to be strong growth of both technologies.

Wind

What is it?

Wind energy is in fact a form of solar energy – but then, when you think about it, so is almost every form of energy! (The exception is geothermal energy – see below.) Heating the earth's surface creates rising air in some places, to be replaced by air from elsewhere, causing both local winds like sea breezes and trade winds that cross oceans. Wind energy represents an estimated 0.25 per cent of the Sun's energy reaching the lower atmosphere.

How is it used?

Traditional images of Australian rural life show small windmills pumping water out of the ground in a dry landscape. Nowadays, however, most wind energy is harvested by rotating wind turbines that can be as large as football fields turned sideways. Mounted high up behind the turbines are generators that convert the mechanical energy into electricity, contributing to the grid supply.

Wind turbines are usually clustered into wind farms at locations where the wind is reliable and strong enough to operate the turbine efficiently. They are also installed by some energy users who would like to make their own clean-energy contribution. In general, though, good winds are found far from cities and towns. This contrasts with solar energy, because the quality of sunshine can be very good in urban regions, so it is much more common to see rooftop PV arrays than rooftop wind turbines.

Choosing sites for wind farms requires at least one year of wind-speed data to be collected, and preferably more: interannual variations in wind should be understood because there can be significant differences between years. Wind turbines can be designed for higher or lower wind speeds, and often the main issue is the wind's reliability.

Challenge

The cost of electricity from wind turbines is an issue, like the cost of solar PV cells. In a good location wind energy is more closely competitive with electricity generated by fossil fuels. Due to the remoteness of many good locations, connecting wind farms to the electricity grid is a significant expense, and this is preventing the construction of a lot of wind farms that would otherwise be economic.

There are sometimes community concerns about the visual impact of wind farms on the Australian countryside and coastline, about potential health problems due to the noise of wind turbines, and about birds being killed by fast-moving turbine blades. These are being addressed by planning controls and, in some cases, by operating procedures.

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STUDENT FACT SHEET 2 continued

Different sources of energy continued

Ocean

What is it?

Ocean energy resources include wave, tidal, current and thermal energy; thermal energy depends on ocean temperature varying with depth, and there are limited technologies and trials for extracting this energy, so it will not be further discussed here.

How is it used?

- **Tidal:** In recent years, new technologies have been developed to extract tidal energy, they consist of tidal turbines which can be located individually or in an open fence configuration. As the water flows through the turbine it turns the blades, just like a wind turbine.
- **Wave:** Technologies that harness the power of waves including using floatation devices to extract energy directly from the surface motion of ocean waves or from pressure fluctuations below the surface.
- **Currents:** Ocean water is in continuous motion and this motion can be captured much like wind currents are with wind turbines.

Challenge

The technology is very new and there are many questions that need to be answered. There are many areas that could be impacted by ocean energy developments (either negatively or positively), including marine protected areas, Indigenous land (native title and land rights), shipping, tourism, recreation and real estate values, aquaculture and fisheries, mineral exploration and mining, defence and security. In addition, there are many knowledge gaps on the performance, cost of maintenance and the logistics of full-scale ocean energy power stations.

Biomass

What is it?

Biomass is biological material (plant and animal) that can be used for fuel. Using biomass is an indirect use of solar energy which was absorbed in the process of photosynthesis and in supporting animal life. Decomposing plant and animal matter produces methane which is helpful to burn as a fuel, and rubbish dumps with domestic waste also provide methane.

How is it used?

Biomass feedstock from a variety of crops can be used as fuel for direct heating or thermal electricity generation. In doing so they replace fossil fuels – and the same amount of CO_2 generated during combustion is recaptured by photosynthesis as the plants grow again.

A major effort for scientists is to find ways in which biomass can be grown without taking up valuable farmland for growing crops. For example, they are looking at using wood and farm waste such as straw to make the biofuels. Scientists are even experimenting with growing algae on ponds to produce oil and biomass while cleaning up the water. They are also experimenting with using the CO_2 from power stations to grow algae so that the carbon from the CO_2 goes into the algae and the oxygen is released into the air. The hard part is doing this at a competitive cost without using too much energy in the machinery that is used to grow the algae.

Challenge

Growing, harvesting, and transporting biomass is expensive if a reliable supply is to be sustained. For this reason, the major biomass generators in Australia are all in the sugar-cane growing region, where there is a regular supply and existing transport infrastructure. Once collected into one place, electricity generation from biomass is similar to using fossil fuels, with some additional cost depending on the type of crop.

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Different sources of energy continued

Loss of natural habitats and food-growing areas when they are replaced with biomass crops has become a major issue in all countries where biomass energy is significantly used. The net GHG footprint associated with biomass production, transport and use is biomass specific and requires careful consideration. It may not always be positive. Careful planning and management should involve representatives of all affected sectors of society, which requires adequate government processes.

Hydro-electric

What is it?

The potential energy held by water stored at a height is available to be converted to kinetic energy when the water is allowed to fall. The kinetic energy of naturally flowing rivers may also be harnessed directly for electricity production. The water evaporates (solar energy again) and rises high into the air where it falls back as rain and flows into dams.

How is it used?

Hydro-electric power stations are usually associated with water storage schemes to ensure that a reliable supply of electricity can be generated whenever it’s required. Mountainous regions are especially suited to hydro-electric power, for example the highlands of Tasmania or the Snowy Mountains, although run-of-river systems can involve multiple dams along the length of a river, as along the River Derwent. Household- or village- scale micro-hydro generation is also possible when there is a suitable stream nearby.

Challenge

The environmental impact of damming areas for hydro-electricity generation is large and irreversible. Entire ecosystems are destroyed, cultural sites can be flooded and at times humans also need to be resettled. Introducing new water storage has impacts on fish breeding, land use, and wildlife habitat, water flow, and river ecosystems. Interestingly, large fresh-water lakes are also significant producers of methane, a potent GHG, through the decomposition of plant matter.

Large hydro-electric schemes are also very costly compared to fossil-fuel generators.

Geothermal

What is it?

Geothermal energy is heat energy created by natural radioactivity occurring in rocks deep within the earth or from areas where the earth’s molten core is near to the surface. Some of this heat finds its way to the surface in the form of hot springs or geysers. Other schemes tap the heat energy by pumping water through zones of hot rocks several kilometres beneath the earth’s surface.

How is it used?

In some locations, concentrated and accessible geothermal energy makes it possible to use this energy source in a cost effective way. Geothermal energy is commercially used for the generation of electricity and for space and water heating in a small number of countries.

Challenge

Only concentrated and accessible geothermal energy makes it possible to use this alternative energy source in a cost effective way.

In Australia, the best reserves of geothermal energy are deep and usually far from population centres, and the technical difficulty of extraction has not yet justified the construction of large-scale plants and of grid expansion to transport the generated electricity.

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STUDENT FACT SHEET 2 continued

Different sources of energy continued

Nuclear

What is it?

Nuclear energy is the energy released when atoms are either split (fission) to make lighter atoms or joined together (fusion) to make heavier atoms. In both cases a small amount of mass is lost while a large amount of energy is created. Nuclear reactors allow these nuclear reactions to happen in a controlled way and harness the heat released. The heat is used to produce steam which drives a turbine. The turbine, in turn, can drive an electricity generator in a power station or provide direct mechanical power in a ship or submarine.

How is it used?

The heat released by the nuclear reactor is taken out using a circulating fluid which in turn is used to produce steam. The steam turns turbines to generate electricity, as in other forms of thermal generation such as fossil-fuel or solar-thermal power stations. Nuclear power stations have large output, like the largest fossil-fuel power stations, and work better if they are operated at a constant level of output. Therefore, other kinds of power station or energy storage are required to match nuclear power to the varying demand for electricity. This may change in the future if small flexible power reactors become commercially available.

Challenge

At each stage of the fuel cycle, the nuclear industry produces various types of waste which must be carefully managed and safely stored for many thousands of years. Uranium itself is a heavy metal which is poisonous as are its by-products. Processed uranium can pose a security threat which needs to be managed. Safe trading partners, transport routes, and disposal sites need to be found.

Presently there is no serious consideration of nuclear power generation in Australia.

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Name:

Capturing carbon dioxide from a soda water bottle

In this activity we'll look at how carbon dioxide can be captured from a soda water bottle.

Any soft drink may be used for this activity.

DO NOT INHALE THE CONTENTS OF THE BALLOON.

You will need

- Balloon
- Small soda water bottle with screw top lid

What to do

- Secure the balloon over the neck of the screw top soda bottle.

- Note the size and formation of the balloon. Gently unscrew the lid.
- Note down any observations. You should be able to see something happening in both the liquid and the balloon.
- Observe what is happening in the bottle – the bubbles of gas filling the balloon are carbon dioxide.

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Name:

What's happening?

Images source: CO2CRC

Carbon dioxide (CO_2) is found in soda water and other soft drinks. The CO_2 cannot be seen as it is dissolved in the water at room temperature. The bottle is pressurised and sealed. This keeps more CO_2 in the water than would normally be possible. When the lid of the bottle is unscrewed a pressure change is created, pressure is released. This causes the CO_2 to come out of solution and appear as the bubbles that we see. These bubbles rise up out of the solution. If there was no balloon on the bottle the CO_2 would be released out into the atmosphere. However, here we have captured the CO_2.

The CO_2 gas quickly inflates the balloon, but is 'captured' rather than being released into the air. The idea of CCS is similar to this, but requires a number of chemical processes to capture the CO_2.

In your experiment, the CO_2 was a gas. When a power station makes CO_2 it's also a gas, which is usually just emitted into the air where it adds to our GHG emissions. Before the CO_2 can be stored underground, it has to be turned into a liquid so it takes up less room. This takes lots of energy. Pipes connect the power station to the underground reservoir and the liquid CO_2 is pumped underground.

So far this technology is still being tested. While it has been proven to work and is being used in a few places round the world, most power stations don't use carbon capture – yet. In a test project, Australian scientists have so far injected 65,000 tonnes of CO_2 into a reservoir in the Otway Basin. Part of their research has involved carefully checking no gas is leaking. You can find out more at www.co2crc.com.au/otway/index.

Like many new low-emission technologies, there is still lots more we need to learn about CCS. Ideally we want to reduce the CO_2 produced in the first place by using less energy (becoming more energy efficient) and using more renewable sources of energy.

Source: www.co2crc.com.au/imagelibrary2/vid_handson.html

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Name:

Carbon capture and storage (CCS) activity

In this activity we'll look at how carbon dioxide can be captured and stored deep underground.

You will need

- Empty 1.25l soft drink bottle
- Vinegar
- Bicarbonate of soda
- Balloon
- Small funnel or homemade cardboard cone

What to do

- Fill the bottle 1/3 full with vinegar.
- Using the funnel, 2/3 fill the balloon with bicarbonate of soda. Break up any lumps of bicarb first so they don't get stuck. Shake or flick the funnel to help the bicarb through.

- Carefully stretch the balloon over the mouth of the bottle, being careful not to spill bicarb into the bottle or tear the balloon (careful of fingernails).

- Hold the balloon upright and shake the bicarb into the bottle – the balloon should start blowing up quickly.
- Liquid may bubble up into the balloon, if so hold it upright to drain into the bottle.

- Observe what is happening in the bottle – the bubbles of gas filling the balloon are carbon dioxide.

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Name:

Carbon capture and storage (CCS) activity
continued

What's happening?

When vinegar and bicarb soda mix together, there is a fast chemical reaction. One of the things we make in the reaction is carbon dioxide (CO_2). To learn more about the chemistry involved, visit

www.csiro.au/helix/sciencemail/activities/CanisterRocket.

In a power station using coal or gas, different chemical reactions (burning) also produce CO_2.

The CO_2 gas quickly inflates the balloon, but is 'captured' rather than being released into the air. The idea of CCS is similar to this, but requires a number of chemical processes to be undertaken.

Applications: How does this relate to climate change?

CCS is a way to trap CO_2 rather than let it go into the atmosphere. One idea scientists are looking at is putting CO_2 deep underground. This is called 'geosequestration' – 'geo' means earth and 'sequestration' means to store, so together 'geosequestration' means to store in the earth.

Imagine your bottle is a power station making CO_2, and your balloon is a place to safely trap the CO_2. In real life, this balloon would be replaced with a large underground reservoir – an area deep under the ground with specific types of rock that can safely store CO_2. This is often the same type of rock that has held oil or gas for millions of years. It is not a big empty cavity.

It's really important these reservoirs won't let any CO_2 leak, so it cannot be stored anywhere underground. Scientists look for places with special rock formations with really strong impermeable rock above them which seals the CO_2 in. CO_2 can leak through some porous rocks (see activity on Resource 1.9 to learn about porous rocks), while other rocks might have cracks that let it escape. Scientists have to be careful to find places where no leaks can happen, usually where thick solid rock 'caps' the reservoir – like a lid on a jar.

In your experiment, the CO_2 was a gas. When a power station makes CO_2 it's also a gas, which is usually just emitted into the air where it adds to our GHGs. Before the CO_2 can be stored underground, it has to be separated from other gases and turned into a liquid so it takes up less room. This takes lots of energy. Pipes connect the power station to the underground reservoir and the liquid CO_2 is pumped underground and it is stored.

Before you read on, have a good think and discussion about anything that could go wrong. If you thought about the CO_2 escaping, full points. Even tiny holes or cracks in your reservoir could let the CO_2 out and eventually back into the atmosphere. What would happen if you had a tiny hole in the balloon?

But such sealed reservoirs do exist. Think about all the petroleum products, including gas, that are currently in use. They are all supplied out of geological reservoirs where the oil or gas has been trapped for millions of years before being tapped into by man.

So far this technology is still being tested. While it has been proven to work and is being used in a few places round the world, most power stations don't use CCS – yet. In a test project, Australian scientists have so far injected 65,000 tonnes of CO_2 into a reservoir in the Otway Basin. Part of their research has involved carefully checking no gas is leaking.

You can find out more at www.co2crc.com.au/otway/index

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Name:

Carbon dioxide (CO_2) transport activity

In this activity we'll explore how gases can be transported under pressure.

You will need

- Electrical or duct tape
- 4 or more metres of garden hose or similar
- Foot pump (as used for cars, airbeds, etc.)
- Balloons
- Thick rubber bands

What to do – transport activity

- Attach the tube to the pump and seal with lots of electrical or duct tape so you have an airtight seal.
- Attach the balloon to the other end of the tube, securing with the rubber band.

- Separate the group into two teams. Team 1 will do the pumping of the gas, while Team 2 will monitor the reservoir (the balloon).
- Arrange the two teams so you can hear, but can't see each other. i.e. around a corner or with a divider between you – and no peeking!

- Team 1: slowly start pumping, sending gas through the tube into the balloon (which you can't see).
- Team 2: communicate with Team 1, letting them know the gas is getting there, listening for any leaks, and anything else you think is helpful.
- When you think the balloon reservoir is full, Team 2 should tell Team 1 to stop pumping – don't pop your balloon reservoir!
- Carefully slide the balloon off the tube making sure no gas escapes and tie it off – did any gas leak from your balloon reservoir?

What's happening?

When we use a pump, we squash or compress the air slightly – we increase the pressure. Gases and liquids always move from areas of high pressure to areas of lower pressure, to balance out the pressure. This is why the balloon inflates. Basically we squash the air in the pump and it gets pushed along the tube and into the balloon.

Applications

In carbon capture and storage (CCS), a similar process is used to move CO_2 from where it is collected at the power station to where it is stored in the underground reservoir. The big difference from what you've done is the amount of pressure used. By using massive amounts of pressure – over 73 times more than in the air around us – we can squash CO_2 so much that it turns into a liquid. At normal pressure like in our atmosphere, there is lots of room between the CO_2 molecules, but as we squash them more and more the space between molecules get smaller and smaller until the CO_2 eventually turns into a liquid. For CCS, the CO_2 is squashed until it turns into a 'supercritical liquid', which is just in-between a gas and a liquid.

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Name:

Carbon dioxide (CO_2) transport activity
continued

This process of building up so much pressure uses a lot of extra energy, so more CO_2 is produced. With any technology, we need to look at the whole picture to make sure that overall we are still reducing CO_2 emissions. That is, the amount of energy used to reduce the emissions is not more than the actual emissions we reduced.

The huge pressures that CO_2 is transported and stored at means we have to be very careful there are no leaks. Did you have any leaks while pumping or tying up your reservoir balloon? Probably! Scientists have to ensure that no CO_2 escapes, both in the pipes used to transport the liquid CO_2 and from the reservoir where it is stored. High pressures make leaks more likely – imagine a garden hose with a little hole in it... what happens to the amount of water leaking as we turn the tap on higher, increasing the pressure? Exactly, the higher the water pressure, the more will escape out the hole – the same is true for liquid CO_2.

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Name:

Carbon storage and porosity activity

In this experiment you will test how much liquid can soak into different materials. For the activity we will use water, but in carbon capture and storage, liquid carbon dioxide is used instead.

You will need

- 3 jars the same size and shape. It works best if they are tall and thin
- 3 different material samples – sand, small rocks, larger rocks
- A measuring jug
- Water (a few drops of food colouring make it easier to see)
- A permanent marker

What to do

1. Use the permanent marker to mark all three jars at the same height, around halfway.
2. Fill each jar with one different material up to the mark, so each jar has the same amount of material in it.

3. What do you think will happen if you pour water into the jars – will it go all the way to the bottom? Where does the water go? Which material do you think will hold the most water?
4. Use the measuring jug to pour the same amount of water into each jar. Make sure you have more water than the amount of material in there but not enough to fill the jar. Wait to make sure the water has filtered all the way through the materials and the bubbles have stopped.

5. Compare the water levels in the jars.

What's happening?

When you fill the jars the water works into the gaps between the sand and rocks, even the ones that are too small for us to see. The water is heavier than air so it pushes the air up and out as bubbles.

The different sized materials let more or less water through, depending on how well they fit together. If more water gets into the gaps, there will be less left up the top of the jar. So the jar with the lowest water level has the most porous material and the highest water level has the least porous material.

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Name:

Carbon storage and porosity activity
continued

Applications

Tiny holes between and inside rocks are called pores, so the measure of how much water, gas or oil can be held in a rock is called porosity. This is important in storing carbon dioxide (CO_2) underground after it has been transported.

Oil and gas were formed from the remains of sea creatures and plants that settled to the bottom of lakes and oceans millions of years ago. They built up and were covered in layers of mud called sediment. As they were covered more and got deeper, they were under increasing pressure and heat. The sediments were slowly cemented together into porous sedimentary rocks. As the sea creatures and plants decompose under heat and pressure, they turn into the coal, oil and gas that we use today. Because these rocks were formed of tiny grains like the sand grains you used in the jars, they tend to have tiny gaps or pores in the cement between the grains. These pores are where the oil and gas we use today are stored.

These underground reservoirs have caps of rock over them – like a lid on a jar – that will not let things through, which is why the gas and oil have stayed there. This could make the perfect conditions for holding CO_2, which can replace the natural gas and oil we have taken out and used.

Basically, we put the CO_2 into the space left after taking out the gas or oil or by replacing the water in saline aquifers, but first the CO_2 is turned into a liquid and we have to make sure none leaks. Many places where scientists are experimenting with CO_2 storage in underground reservoirs are old oil and gas reservoirs, such as the Otway Basin in Victoria, Australia.

Links

Otway basin project in Victoria, Australia – storing CO_2 in an old gas reservoir
www.co2crc.com.au/otway/index

Western Michigan University
www.wmich.edu/corekids/Geology-and-Natural-Resources

Thirsty rocks activity
www.windows2universe.org/teacher_resources/teach_thirsty

This resource is part of the Introduction to Carbon Capture and Storage education materials.
Supported by the Global CCS Institute and delivered by CSIRO Education.

Name:

Carbon compression and geosequestration activity

In this activity you will see what happens in an oil reserve when carbon dioxide (CO_2) is pumped into it. There are two parts to the activity – your teacher will demonstrate using a chemical reaction to create CO_2. You can model pumping gas into an oil deposit.

You will need

- 1 small container or bottle
- 1 medium bottle
- 1 container to catch water
- Plasticine to seal the mouths of the bottles
- 2 bendable straws or flexible tubes
- Sodium bicarbonate (bicarb soda)
- Vinegar
- (Coloured) water
- A large syringe.

What to do

1. Mostly fill the medium bottle with coloured water.
2. Use the plasticine to create a lid for this bottle with two straws going into it. One has the short end going into the bottle to stay above the water level and the other has the long end in the bottle going into the water. Mould the plasticine to make it as airtight around the straws as possible.
3. Carefully bend the straw from the water over to drain into the third bottle.

FOR STUDENTS:

4. Blow gently into the long straw that ends above the water.

FOR TEACHERS:

5. Put a generous amount of sodium bicarbonate into the small container.
6. Use the plasticine to create a lid for the small container with the long end of the second straw from the water bottle going through it. Make it as airtight as possible.
7. Draw as much vinegar into the syringe as you can.

8. Gently work the syringe through the plug on the small container and seal any gaps, checking that all seals remain airtight.
9. Squirt the vinegar into the container keeping hold of the syringe. The sodium bicarbonate and vinegar will begin reacting and you need to make sure the gas goes into the straw, not out around the syringe.
10. If necessary repeat step 9, blocking the hole in the plasticine lid while you are refilling the syringe.

This resource is part of the Introduction to Carbon Capture and Storage education materials.
Supported by the Global CCS Institute and delivered by CSIRO Education.

Name:

Carbon compression and geosequestration activity continued

What's happening?

The bottle filled with water is a model of an oil and gas deposit deep underground. It formed there over millions of years and is trapped under a cap of rock, like the lid of the bottle is trapping the water. When extra gas is pumped in, either by blowing or from the reaction, it takes up space in the bottle and pushes down on the water. It is very hard to compress or squash the water, but it has a way out and is pushed up and out through the second straw.

The system is under pressure and will release it at the weakest point. It takes a lot of effort to push the water up through the straw and out, which is why you could get lots of bubbles coming out of a weak seal instead.

In the chemical reaction, the vinegar reacts with the sodium bicarbonate to produce bubbles of carbon dioxide (CO_2) gas. If your seals are airtight the new gas will travel up the straw and into the bottle of water, pushing some water out.

Vinegar is a weak acid called acetic acid and sodium bicarbonate is a weak base, so this is an acid/base neutralisation reaction. There are actually two reactions happening.

First:

CH_3COOH + $NaHCO_3$ -> $NaCH_3COO$ + H_2CO_3

Acetic acid + sodium bicarbonate -> sodium acetate + carbonic acid

Then the carbonic acid breaks down:

H_2CO_3 -> H_2O + CO_2

Carbonic acid -> Water + Carbon dioxide

Applications

Underground oil and gas are two of our most important energy sources. The oil is refined into fuel for cars, trucks, aeroplanes, ships, etc. It is also used to make plastics and many other things and both oil and gas are burnt in power stations to make electricity. Unfortunately burning oil and gas produces CO_2. We need to decrease the amount of CO_2 we produce and stop it getting into the atmosphere. One of the ways we can do this is by catching it at power stations and burying it underground.

To get oil and gas from the earth we drill down to them with an enormous tube like the straw, but a bit more complicated. When we take them from a reservoir it leaves room to pump in the CO_2 caught at power stations.

Used oil and gas deposits are a good place to store CO_2 because we already know they can contain it – they have kept natural gas securely for millions of years so they should be able to trap the CO_2 as well. CO_2 is actually pumped in as a liquid because of the high pressure underground. A bonus is that it can push out more of the oil in the reservoir like our gas pushed out the water, which is called Enhanced Oil Recovery (EOR).

Links

Flash interactive sequestration model
www.netl.doe.gov/technologies/carbon_seq/core_rd/CO₂_web12.exe

CO_2 sequestration
www.wmich.edu/corekids/CarbonDioxideSequestration

This resource is part of the Introduction to Carbon Capture and Storage education materials.
Supported by the Global CCS Institute and delivered by CSIRO Education.

Name:

Carbon storage and ocean acidification activity

In this activity you will see that extra carbon dioxide increases the acidity of the oceans.

You will need

- Two small containers
- Plasticine
- A bendable drinking straw
- A syringe
- Sodium bicarbonate (bicarb soda)
- Vinegar
- A pH indicator – bromothymol blue, phenol red or you can make your own red cabbage indicator
- A tiny amount of laundry detergent if you are using red cabbage indicator.

What to do

IF YOU ARE MAKING RED CABBAGE INDICATOR:

1. Roughly chop some red cabbage and boil it for around 10 minutes.
2. Drain and keep the liquid.

FOR THE ACTIVITY:

1. Put a couple of spoons of sodium bicarbonate into one container.
2. Make a cover to seal the container using the plasticine, with the short end of the bendable straw going into the container. Make sure it is well sealed.
3. Put some water with a little indicator in the second container.
4. If you are using red cabbage indicator, mix in a tiny amount of laundry detergent to make the mixture slightly basic and change the colour to green. This will give you a more obvious colour change when you do the experiment.
5. Trim the long end of the bendable straw so it goes into the container of indicator and down to the bottom.
6. Draw up a syringe full of vinegar and carefully work it through the plasticine seal on the first container, use the plasticine to make an airtight seal around it.
7. Being careful of all your seals push the vinegar down into the container. Watch the end of the straw in the water to see what happens.
8. To do it again, gently work the syringe out and put your finger over the hole while you refill it, then repeat step 7.

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Name:

Carbon storage and ocean acidification activity

continued

What's happening?

Indicators are chemicals that change colour when they are in acids or bases. Many plants with strong purple or red colouring can be made into indicators. Red cabbage indicator goes green in a base or red in an acid. bromothymol blue is green in neutral solutions like water and yellow in acids, while phenol red goes from yellow in neutral solutions to pink in acids. What you are seeing in the experiment is the change from the neutral or slightly basic water to acidic when carbon dioxide (CO_2) bubbles through it.

When you mix the vinegar and sodium bicarbonate together you produce CO_2 gas through two reactions. The vinegar acts as a weak acid and the bicarbonate is a weak base, they react together to neutralise each other.

First:

$$CH_3COOH + NaHCO_3 \rightarrow NaCH_3COO + H_2CO_3$$

Acetic acid + sodium bicarbonate -> sodium acetate + carbonic acid

Then the carbonic acid breaks down:

$$H_2CO_3 \rightarrow H_2O + CO_2$$

Carbonic acid -> Water + Carbon dioxide

When the CO_2 goes through the straw and bubbles up through the water, it reverses the second reaction and produces some carbonic acid again.

$$H_2O + CO_2 \rightarrow H_2CO_3$$

Water + Carbon dioxide -> Carbonic acid

This carbonic acid changes the colour of the indicator, eventually it will turn the whole solution acidic.

Applications

Much of the increasing levels of atmospheric carbon dioxide (CO_2) will be absorbed into the oceans, but this will take several centuries. More CO_2 in the ocean will make it more acidic – this is called ocean acidification. Some researchers are investigating carbon capture and storage (CCS) technologies that will inject CO_2 deep into the oceans, which will remove it immediately and may stop it mixing with the surface water and making it more acidic. Currently the ocean is very slightly alkaline: making it more acidic is dangerous – for example, it can stop many animals from being able to make shells.

In the deep oceans there is very high pressure and low temperatures. Researchers are investigating the theory that if CO_2 pumped is down there, whether it would stay as a liquid rather than a gas and not move much. However we don't know much about how it interacts with the water around it. There is some evidence that it forms carbonic acid and affects some of the sea creatures around it.

We also don't know how rising global temperatures will affect this type of storage – as the oceans become hotter it may melt the hydrates and make the liquid CO_2 more likely to mix with the water around it.

We need to learn more about how the oceans will react to increasing amounts of CO_2, both from the atmosphere and direct injections of captured CO_2.

Links

Ocean acidification for kids
www.ahazard.com/kidsbooks/kids/ocean_acid

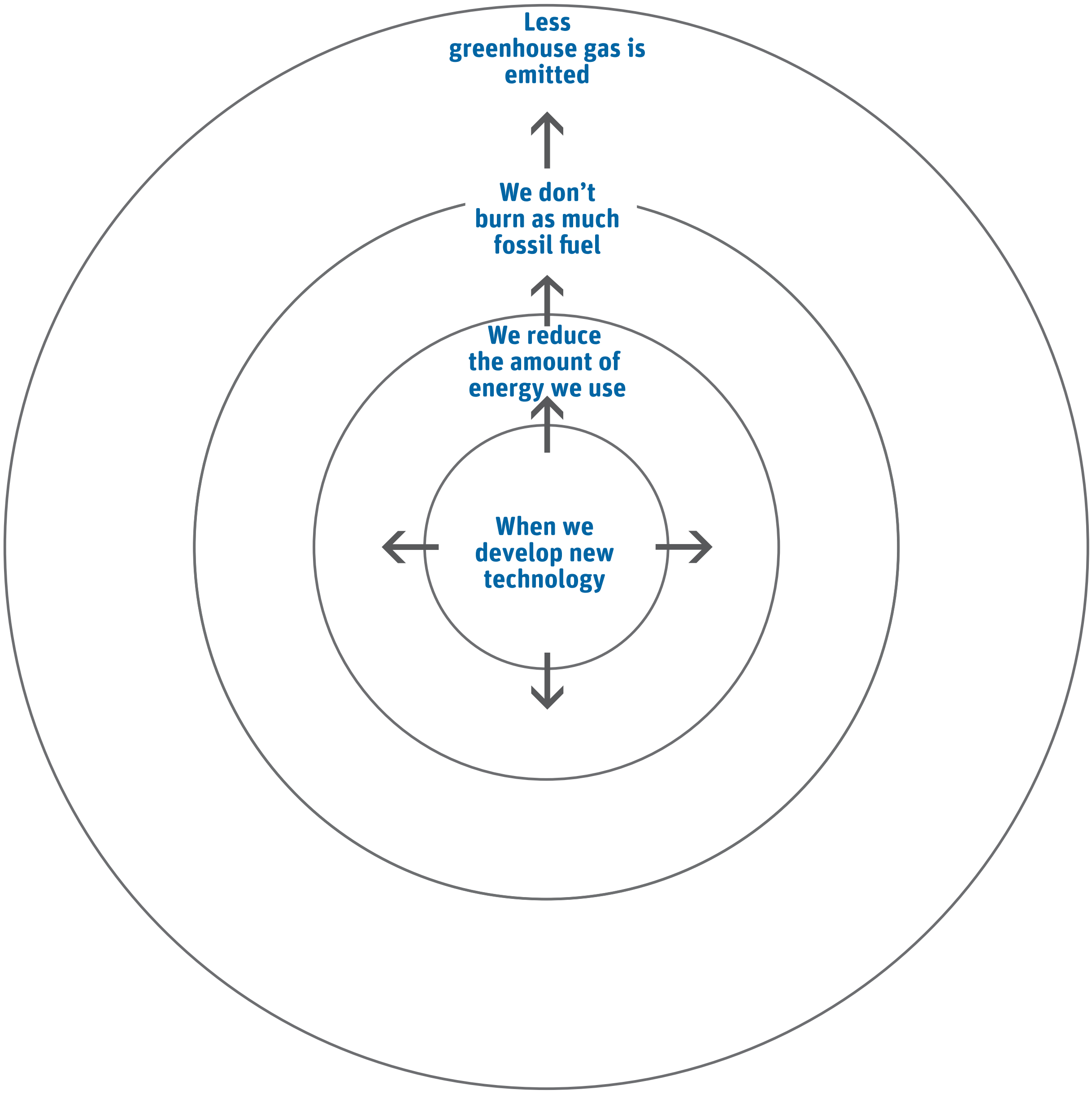
Deep injection of CO_2
www.whoi.edu/oceanus/viewArticle.do?id=65066

This resource is part of the Introduction to Carbon Capture and Storage education materials. Supported by the Global CCS Institute and delivered by CSIRO Education.

Name:

Consequence wheel

Consequence wheels are used to explore wide ranging consequences that can follow from actions, issues or trends in the present. Look at the example below.



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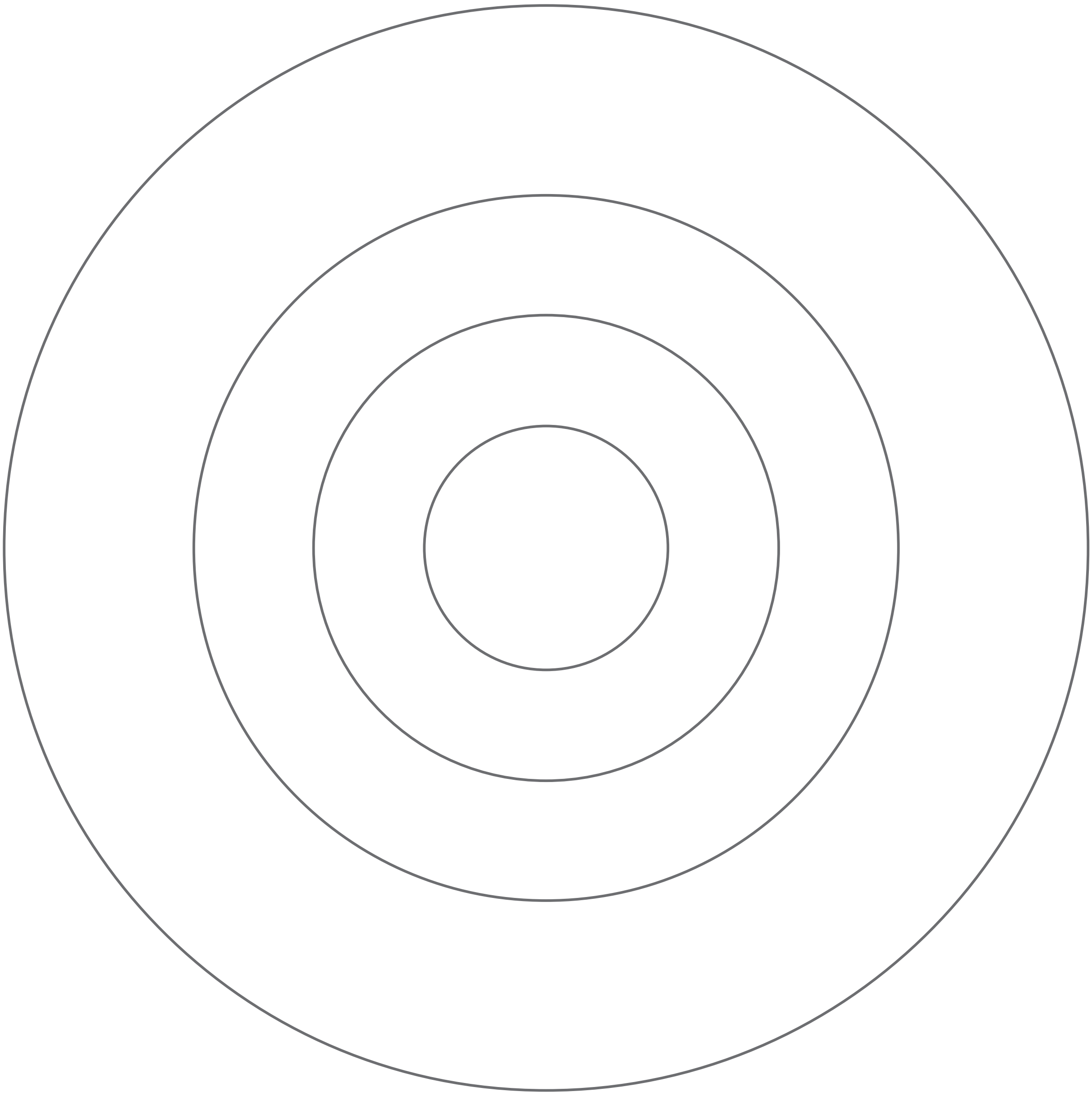
Name:

Consequence wheel continued

Decide on an issue that is part of understanding the use of carbon capture and storage (CCS) as a low-emission technology. Place the focus in the centre of the consequence wheel. Then, explore the focus by asking the question “What are the immediate consequences?”

Write the immediate consequences in the inner ring around the main idea. Link each consequence to the main idea with a single line. This indicates that they are first order consequences. Continue exploring second, third and fourth order consequences using the outer circles.

Use the four concentric circles below to explore the consequences of an action, issue or trend relevant to the emission of GHGss and/or the sustainable management of CO_2 emissions in industries or power plants today.



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SECTION 3
Teaching units

Exploring carbon capture and storage (secondary)

Main idea

During this unit, students in the secondary schooling years will investigate new and existing technologies and actions that may stabilise and reduce global emissions of CO_2.

Students are also given an insight into some ways industries are minimising their impact on global change by using processes designed to separate CO_2 out of the flue stream produced by coal, natural gas and petroleum fired power plants, in addition to processes in industry.

Students design research investigations and learn about renewable energy and CCS technologies that could reduce CO_2 emissions from industrial processes and power plants. Schools are encouraged to learn from scientists, industry, researchers and their community.

Key understandings

By the end of this unit, students will understand that:

- no single technology can alone deliver deep cuts in CO_2 emissions
- burning fossil fuels for energy contributes to climate change
- CO_2 emissions from energy can be reduced by burning less fossil fuel and by using more renewable energy sources such as solar or wind
- new technologies and actions will be required to stabilise and reduce global emissions by 2050
- CCS is a technology that can reduce CO_2 emissions from power plants and other industrial processes
- working towards a sustainable future requires planning to meet human needs, together with the responsible use and disposal of resources
- action is already being taken on local and global levels.

Focus questions

- Why and how is climate changing?
- How do we view our future?
- What do we want environment, industry and society to be like in the future?
- How is industry's creation of products and energy use connected to climate change?
- What are the impacts of industry's transport choices and resource consumption on climate change?
- How can CO_2 emissions be cut while meeting demands for energy and products like cement, steel, iron and aluminium?
- What choices can industry make to reduce CO_2 emissions?
- What are the renewable and innovative technologies being developed to reduce emissions of CO_2 and tackle climate change?
- What can industry do and why is it important to get involved?
- Why is it important to keep looking for new and better ways to mitigate climate change?

Key literacy terms

Action, alternatives, behaviour, calcification, capture, carbon, change, climate, communities, consequences, conservation, decisions, dependence, ecosystem, efficiency, emissions, ethics, flue stream, fossil fuels, geosequestration, global warming, government, GHGs, impacts, implementation, innovation, maintenance, photovoltaics, policy, protect, renewable, resource, responsibilities, scientists, sequester, solar, sources, storage, sustainability, technology, thermal, transport, values, wind.

Sample unit sequence and activity ideas

Tuning in

An overview of climate change

Required: ☑ Internet

Ask students to develop a concept map describing what they know about climate change, what it is, what it comprises, what it affects, its potential impacts on living things in a variety of ecosystems, and who and what produces emissions that can affect the earth's climate. Share with students some facts about climate change as is currently understood.

Refer to reference books and websites for support material. See:

A student's guide to climate change
www.epa.gov/climatechange/kids/index

Cool the globe
www.cooltheglobe.com/index

CSIRO
www.csiro.au/science/Changing-Climate

PEW Centre on Global Climate Change
www.pewclimate.org/climate-techbook

UK Met Office Climate Change
www.metoffice.gov.uk/climate-change/guide

United Nations environment program
www.unep.org/climatechange/Introduction/tabid/233/Default.aspx

United States global change research program
www.globalchange.gov/resources/educators/toolkit/materials

Class discussion – in the news

Required: ☑ News stories

Ask students to bring in news clippings or notes from news broadcasts that mention climate change. Ask them what they understand about the story, including what aspects of the climate it discusses, its effects and future consequences with respect to themselves and others in the world.

List their ideas on a chart or whiteboard. Invite students to talk about global changes in weather patterns or climatic conditions. Ask students if they think their news stories are accurate. Discuss the language being used. Is it positive or negative? Encourage students to think, reflect and share ideas with others.

Clarifying the confusion

Required: ☑ Art materials

Issues surrounding climate change can have many confusing terms and technical jargon.

Ask students what they think the difference is between:

- Carbon pollution and GHG emissions
- Global change and climate change
- Greenhouse effect and enhanced greenhouse effect
- Climate and weather

Why is it important to make distinctions between these terms? Present them with a range of resources. Ask them to compare their research with their original ideas.

Ask students to create simple graphic representations – in the manner of a road sign or warning signs – to represent each term.

Note this!

Contribute to a Learning Log by writing down questions and reflections about what they already know, what they would like to know and interesting facts or information.

Imagine

Ask students to imagine that they were born today. In 20 years time, when they have grown into adulthood, many of the world's ecosystems will have changed.

Consider the following two scenarios:

Scenario one
Many ecosystems now provide fewer natural resources for humans. Due to climate change, excessive use of fossil fuels, high emissions of CO_2 and poor uptake of renewable energy technologies, the natural resources we grew dependent on have been depleted. Technologies and actions to stabilise and reduce CO_2 emissions have not been implemented globally.

Scenario two
Many ecosystems provide more natural resources for humans. Climate change has slowed and is better understood, and appropriate low-emission technologies ensure we use our resources efficiently with minimal impact on the environment. A broad suite of technologies and actions have been used to stabilise and reduce emissions.

Support students to reflect on how our understanding of the use of the earth's resources might differ to that of our parents' and grandparents' generation. Also, consider what factors have contributed to our changing understanding of the environment and sustainable living.

Ask students to discuss the differences between the two scenarios. Which would they prefer? What factors need to be considered for each to be considered realistic? Ask them to create a third scenario based on what they believe is a realistic goal for the future.

Read the poem *The Seventh Generation* and reflect on the writer's perspective on the importance of ecological sustainability.

The Seventh Generation

"Will it benefit the seventh generation?"

Was the question that the Hopi dwelt on.

"Will it help the future people who will walk on this Earth

Long after you and I are dead and gone?"

And if the Hopi saw that the answer was "No"

They would drop that new idea.

They thought not only of themselves

But future generations as well.

I speak now for that seventh generation,

For the seventh generation from now on.

I speak for the people who will walk upon this Earth

Long after you and I are dead and gone.

Will they reap a bitter harvest from the things that we have done?

Will they thank us for the healing that in our time has begun?

Will there even still be people seven generations on?

For I fear for the seventh generation.

(The Gap, Issue 5, 1994, p.7, Global Education Centre, Australia)

Brainstorm the many factors that may have caused the situation described in the poem, or that might result from it. Ask students to rank the 10 factors that they consider are the most important.

Adapted from: CSIRO CarbonKids in Action Curriculum Unit page 6

Picturing the future

Required: ☑ **Internet**

Explore how youth globally see climate change, low-emission technologies and sustainable futures. Working in small groups, ask students to focus on the artwork from India, China, Brazil and Qatar. Have students distinguish between those that may stabilise and reduce global emissions of CO_2. See www.bit.ly/c2Nopa

Discuss how climate change, low-emission technologies and sustainable futures messages are communicated within the artwork, asking students to focus on what they think the young artists are trying to say.

Engage them in a hypothetical continuation of the artists' stories, encouraging students to evaluate these strategies for coping with potential changes to the climate. In groups, students discuss the types of decisions needed if these preferable futures are to eventuate.

Adapted from: CSIRO CarbonKids Agriculture in a Changing Climate Curriculum Unit page 6

Preparing to find out

Learning Log

Required: ☑ Exercise book

Begin a Learning Log where students record their understandings. This might form part of an assessment plan.

Introduce the Learning Log and model a procedure for maintaining it. The whole class might jointly construct the first entry. Students can then make individual entries based on the activities they do and the questions they come up with.

Initial focus questions could include:

- What impact does my perception of climate change have on my use of technology and energy?
- What other technologies do I know of that can reduce CO_2 emissions being released to the atmosphere?
- If we know about technology and conservation techniques that can limit CO_2 emissions, why don't we use them in all instances?
- Are we going to rely on energy more or less in the future?
- What answers might there be to meeting the challenge of climate change and reducing GHGs?

Ask students to come up with their own questions they hope to have answered by the end of the unit and instruct them to write them into their log.

Energy everywhere

Energy is big news in today's media, especially when it comes to its impact on the environment or sustainability. Whether it's about new types of solar cells or the opening of a wind farm, or a debate over 'clean coal' or opinions on nuclear energy, it's easy to find stories covering our search for ways to provide our society with cheap, sustainable energy sources that reduce emissions to the atmosphere.

Brainstorm ideas with the students including what you already know about different energy technologies. Discuss what words such as 'renewable', 'low-emission', 'clean' and 'sustainable' might refer to. Ask the students to use those keywords you come up with to do a media search over the following week to find examples of social media, newspaper clippings, magazine articles or stories on the television or radio covering current affairs in energy technologies that can address climate change.

With the students, arrange these examples into categories. Some might be relevant to scientific research, for instance, while others are about politics or economics or are opinion pieces.

Find common words between them and list them in a 'common words' box.

Source: CSIRO CarbonKids Powering into the Future Curriculum Unit page 10

Evaluating science information with thinking routines

Required: ☑ Internet

☑ Resource 2.1

During the unit, the students will ask many questions. Answers can be found in many different places.

Discuss the types of people who might present a good understanding of low-emission technologies that are being used to address climate change. They might include teachers, librarians, researchers, parents and authors of books or web sites. Of course, each of these people would have different sources for their own information. Sources could include internet sites, magazines, science journals, social media sites, personal experiences (anecdotes), newspaper articles and television programs.

Discuss how the students might evaluate their sources. They might ask

- Who is the source's author?
- Where did they get their information from?
- Why might they be writing this source?
- What language are they using (i.e. is it emotional or informative)?

Ask them to produce a rating system, to describe how reliable or useful their source is, otherwise use the rubric in **Resource 2.1**.

Questions, questions...

Use the following 'Question Grid' to encourage students to devise additional angles to their questions.

What is?	Where/when is?	Which is?	Who is?	Why is?	How is?
What did?	Where/when did?	Which did?	Who did?	Why did?	How did?
What can?	Where/when can?	Which can?	Who can?	Why can?	How can?
What would?	Where/when could?	Which could?	Who would?	Why would?	How would?
What will?	Where/when will?	Which will?	Who will?	Why will?	How will?
What might?	Where/when might?	Which might?	Who might?	Why might?	How might?

For example: What is a low-emission technology? What is CCS? Where is CCS happening? Which part of the world is experiencing CCS? Who is researching CCS? Why is CCS important? How is what we know about CCS changing? What did scientists most recently report on? Apply these same questions to complementary technologies that can address climate change.

Source: CSIRO CarbonKids Understanding Climate Change Curriculum Unit page 7

Wheel of consequences

Required: ☑ **Resource 2.2**

Invite students to develop a 'consequence wheel' to explore the consequences of decisions and choices relating to CO_2 emissions from industrial or power plants. In groups, encourage students to decide what issue they wish to explore.

The issue is written in the centre of a sheet of paper and a series of concentric circles are then drawn lightly around it. The first question asked is "What are the immediate consequences?"

See **Resource 2.2** for an example.

Ask groups to discuss what the repercussions might be and briefly write them around the first circle. Ask groups to link each statement to the central point by a single line. Next, students discuss what consequences may follow on from the first ones. Following on, third and fourth order consequences can be explored and marked in a similar way.

Share consequence wheels and explore the difference between intended and unintended consequences for a range of issues.

Encourage the students to ask critical questions of one another's work. For example:

- What do you feel, hope and fear in relation to this particular issue?
- Do you think everybody agrees?
- Why might other people think and feel differently?
- How did the issue come about?
- Who do you think influenced your opinions?
- Who gains and who loses?
- Who has power in this situation and how do they use it?
- Is it used to the advantage of some and the disadvantage of others?
- What values can we use to guide our choices in the way the environment is used, managed and conserved?
- What are the possible courses of action open to us?
- What are others already doing?
- How might industry and power plants implement a plan of action to stabilise or reduce emissions of CO_2?
- How might we work together?
- Whose help might we need?
- How do we measure our success?

Adapted from Education For The Future – a practical classroom guide, D.Hicks, WWF, 1994, p.10

Probable or preferable?

Read the following quote to the class:

> "The world is on the edge of a new age... We are now in one of those rare points of history – a time of great change, a time when change is as unpredictable as it is inevitable. No one can say with certainty what the New World will look like. But if we are to fashion a promising future for the next generation, then the enormous effort required to reverse the environmental degradation of the planet will dominate world affairs for decades to come."

Source: L. Brown, (1991), State of the World, Earthscan Publications, London

Point out to students that this was written back in 1991. In hindsight, do they think the author was correct?

Encourage students to outline their impressions of what "the world on the edge of a new age" might mean today. Do they think it might be much different to the vision of the author back in 1991?

Ask students to record the issues and changes that they feel are most important. Do they think the author recognised the significance of GHG emissions? Have concerns changed over the past two decades?

Encourage them to use the terms 'probable' and 'preferred' to describe the futures they are describing, i.e. what they expect the future to be and what they hope the future to be. Motivate a discussion to explore how they might expect GHG emissions to be reduced, secure and sustainable energy to be provided, and global environments to be protected and conserved in future years.

Source: CSIRO CarbonKids in Action Curriculum Unit page 7

Research task: Part 1

Required: ☑ **Resource 2.3**
☑ Research materials (library, internet)

Make available a copy of the following statement to the class and have somebody read it aloud:

> There is no single answer to meeting the challenge of climate change and reducing GHGs. A variety of technologies will be needed, including those providing low-emissions and greater energy efficiency.

Adapted from "What's the solution?" NewGenCoal, www.newgencoal.com.au/climate-change.aspx

Explain that their task is to start with this statement and find relevant text to supplement it. They must undertake research using available texts that address low-emission, renewable and energy efficient technologies. Their resources could focus on one of the following five themes:

- how CCS technology is being used in the petroleum, chemical and power industries in order to reduce atmospheric CO_2 emissions.
- how the fossil fuels we rely on now for power, and may continue to rely on, produce significant CO_2 emissions, requiring applications of low-emission technologies, like CCS.
- how although CCS is promising, there are a number of challenges that must be resolved before the technology can be deployed as a global CO_2 emission control option.

- how renewable technologies have experienced double-digit annual growth rates for the last 10 years, and worldwide, the renewable share of global power generation climbed from 5 per cent in 2003 to 23 per cent in 2008.
- how currently, reliability of renewable energy is a critical issue: wind and solar resources are naturally impacted by weather fluctuations and how this is being addressed.

Have students collect these references for all of the class to use. Use brainstorming to guide the investigation and suggestions as to where relevant information might be found.

Have students record all resources in a central class bibliography, together with a rating system describing how relevant they think their source is to their investigation.

Students work in pairs to prepare for their investigation. The ongoing research should be shared with the class, asking for additional suggestions before proceeding.

See **Resource 2.3** to support personal or group investigations.

Note this!

Assessment idea: Use a checklist to record student contributions to the research database. This might include their capacity to evaluate their resources as well as provide information. This will indicate a student's skill in collecting, evaluating and recording information appropriate to the task.

Finding out

Scoping out CCS

Required: ☑ Internet

View and listen to communicators, scientists and people sharing knowledge about CCS as one low-emission technology that can reduce CO_2 emissions from industrial and power plants.

Investigate how CCS works.
www.youtube.com/watch?v=ROEFaHKVmSs&NR=1

Find out about the role that CCS can play in achieving reductions in CO_2 emissions in order to mitigate global climate change.
www.youtube.com/watch?v=BOAWpW652zE and

www.oresomeresources.com/resources_view/resource/powerpoint_low_emission_technologies

View a video and animation on climate change and CCS.
www.ccs-education.org/keeping-co2-out-of-the-atmosphere-by-sequestering-it-underground/

Examine the challenges involved in CCS.
www.geos.ed.ac.uk/sccs/public/teachers/

Hear from a Scottish expert on how CCS works.
www.ccs-education.org/

Find out about CCS.
www.globalccsinstitute.com/

Find out about the potential of CCS to reduce emissions.
www.egfi-k12.org/whats-new/e-tube/carbon-sequestration

Find out about the development of CCS technological processes.
www.oresomeresources.com/resources_view/resource/link_carbon_capture_and_storage_movie

View excerpts and in groups, explore the issues presented and list ideas concerning understandings about carbon capture and storage as a low-emission technology. Create a fact sheet that could be used to supplement one of the multimedia presentations viewed.

See fact sheets about carbon capture and storage at:

www.ccs101.ca/ccs-basics/co2-capture

www.oresomeresources.com/resources_view/resource/fact_sheet_carbon_capture_and_storage

View excerpts and in groups, explore the issues presented and list ideas concerning understandings about CCS as a low-emission technology. Create a fact sheet that could be used to supplement one of the multimedia presentations viewed.

www.ccs101.ca/ccs-basics/co2-capture

www.oresomeresources.com/resources_view/resource/fact_sheet_carbon_capture_and_storage

www.bgs.ac.uk/education/carboncapture/

www.csiro.au/science/CO2-geosequestration

www.cslforum.org/education/index

What's an alternative?

We know that our fossil fuel supply has a limit, and our demand is rapidly increasing. It is also impossible to know with much precision whether we should measure our fossil fuel reserves in decades or centuries. One thing is certain, fossil fuels will one day be all but depleted. Combined with our understanding of how CO_2 emissions cause climate change, it's hard to ignore the need for alternative energy and low-emission technologies in the future.

There are two ways of thinking about this situation. One is to hope future generations will develop such innovations. The second way is to get a head start now and invest time and effort into addressing the problems we face in finding alternative energy sources.

Divide the class into small research groups, or use those that were allocated in Research Task 1. Explain that their task is to:

a) Choose from the following list of alternative energy options;

   i. wind
   ii. hydro/tidal/wave
   iii. geothermal
   iv. nuclear
   v. solar
   vi. biogas/biomass
   vii. fossil fuels with CCS.

b) Provide response to the following points regarding their technology:

   i. Where does the energy in the resource come from?
   ii. Which countries currently use it? What percentage of their energy comes from it?
   iii. What are its strengths as an energy resource?
   iv. What are its limitations as an energy resource?
   v. What part do you think it could play in the world's energy mix?

Discuss with students what it would take to address the limitations and increase the strengths. Encourage them to think outside the box – remind them that their solutions don't have to be scientifically possible at this point in time to be discussed.

Change Source: CSIRO CarbonKids Powering into the Future Curriculum Unit page 14

Web search

Required: ☑ Internet

Use the CSIRO website to answer the following questions:

Question 1: What are some new emerging energy technologies?
www.csiro.au/science/Climate-Change-Mitigation

Question 2: Is the community's attitude to climate and energy changing?
www.csiro.au/news/Table-talk-climate-change

Question 3: How do we know that cost effective, clean coal technologies are being developed?
www.csiro.au/science/Low-Emission-Electricity

Question 4: Who is working on sustainable and efficient energy solutions?
www.csiro.au/org/Energy-Transformed-Flagship-Overview

Question 5: Are future energy needs and alternative fuel sources being researched?
www.csiro.au/org/Energy-Overview

Question 6: Are scientists researching low-emission electricity, low-emission transport, distributed energy and energy futures?
www.csiro.au/org/Energy-Overview

Try other sites too.

Stabilising CO_2 emissions

Required: ☑ Internet

Invite students to stabilise CO_2 emissions in a game by using existing technologies, increasing energy efficiency and conserving natural resources. Play the 'Stabilisation Wedge Game' at www.princeton.edu/~cmi/resources/stabwedge

Sorting out

Research task: Part 2

Required: ☑ **Resource 2.3**

☑ Research materials (library, internet)

Remind students of their research investigation on one of the following topics:

- How CCS technology is being used in the petroleum, chemical and power industries in order to reduce atmospheric CO_2 emissions.
- How the fossil fuels we rely on now for power, and may continue to rely on, produce significant CO_2 emissions, requiring applications of low-emission technologies, like CCS.
- How although CCS is promising, there are a number of challenges that must be resolved before the technology can be deployed as a global CO_2 emission control option.
- How renewable technologies have experienced double-digit annual growth rates for the last 10 years, and worldwide, the renewable share of global power generation climbed from 5 per cent in 2003 to 23 per cent in 2008.
- How currently, reliability of renewable energy is a critical issue: wind and solar resources are naturally impacted by weather fluctuations and how this is being addressed.

Present students with the resource list they compiled and ask them to find facts and opinions within them. Remind them that 'facts' cover details that can be directly observed and measured, while 'opinions' are statements that are extrapolated from facts.

Ask students to consider how they are going to bring their information together and present it so that the main points come across clearly.

As a class, list the main messages to be given about climate change and decide on ways to share this information. Consider using:

- 3-dimensional models and dioramas
- Visual displays
- Timelines
- Videotaping
- Plays and dialogues
- PowerPoint and multimedia presentations
- Murals
- Flowcharts
- Effects wheels
- Posters

Extend yourself!

Teach students these new keywords:

Objective – refers to any statement that describes something that can be directly observed or measured. Facts should be objective in nature e.g. *that man's height is 2.2 metres.*

Subjective – refers to any statement that relies on a context or personal experience. Opinions are typically subjective in nature e.g. *that man is tall.*

Compass rose

Required: ☑ **Resource 2.4**

Introduce the compass rose as a simple tool that enables thinking about complex issues according to different contexts.

As a class, talk about each axis and what each compass point represents. Discuss the diagonal 'in between' points and types of questions these imply.

Talk about the environmental, social, economic and political factors that influence the various ways in which global energy needs are met now and into the future. Discuss industries, power plants and businesses and how they are taking steps to limit GHGs from their activities, possibly by implementing CCS, renewable energy or energy efficient technologies and strategies. This can have a number of impacts:

- Saving them money that they would otherwise have spent on excess energy
- Costing them money to implement the technology
- Being publicly recognised
- Reducing CO_2 emissions to the atmosphere
- Reducing environmental impacts
- Offsetting carbon on CO_2 trading schemes
- Reducing any carbon price exposure.

Refer to the compass rose in **Resource 2.4**.

Explain each context involves different priorities and needs. For example, while GHG emissions are highly significant for the environment, they might not be as important as costs for the economy. Politicians might be primarily concerned about delivering energy exports to other countries, while social groups would have the reduction of energy demands as a high priority.

Offer the statement 'Investing in low-emission technologies and alternative energy is investing in our future'. Brainstorm a list of ideas discussing what this sentence might mean. Identify key questions or statements for each of the compass rose points and the diagonal points (NE, SE, SW and NW).

Adapted from: CSIRO CarbonKids Changing Climate Curriculum Unit page 11

PMI

'PMI' stands for 'Plus, Minus, Interesting', and is a useful way of exploring an issue in terms of its positive and negative aspects and those that provoke deeper thought.

Use the PMI technique to identify different directions students' conclusions could be taken. Ask them to discuss their key findings in terms of the benefits they could provide, the costs or risks involved and any new questions that the conclusions have given rise to.

De Bono's six hat thinking

Students explore issues raised using de Bono's Six Thinking Hats technique to explore the issue of complementary technologies that can address climate change in more depth. Students, in six groups, each with a different hat, discuss and document the issues according to their given perspectives and come together at the end to share their ideas.

Red Hat	White Hat
Feelings *What are the emotions and feelings associated with low-emission and renewable technologies? How do you feel?*	**Information** *List the facts that you know about present technology used by industry and power plants and how it affects the environment.*
Blue Hat	**Green Hat**
What thinking is needed *What has happened so far?* *What should happen next?* *What questions should we consider?*	**New ideas** *How could the problems related to GHG be solved?* *What needs to be done?*
Black Hat	**Yellow Hat**
Weaknesses *What are some of the negative aspects and outcomes of seeking new low-emission and renewable technologies and new behaviours?*	**Strengths** *What are some of the positive aspects and outcomes of seeking new low-emission and renewable technologies and new behaviours?*

Going further

Cost benefit analysis

Required: ☑ **Resource 2.5**

Ask students to undertake a cost-benefit analysis to identify all the costs and benefits of implementing a range of renewable and low-emission technologies to reduce CO_2 emissions in our society, environment and economy. If the benefit exceeds the cost, the cost-benefit is said to indicate an overall gain to society, or vice versa.

Using the 'Argument Map for CCS' in **Resource 2.5** and found at http://www.argumentenfabriek.nl/argument-map-carbon-capture-and-storage-ccs explore the arguments for and against CCS for the Netherlands. Complete a cost-benefit analysis on the low emission technology that can reduce CO_2 emissions.

Info graphic – Global CCS developments

Required: ☑ Internet (with Google Earth)

Info graphics are graphical representations of collections of information. They can take the form of posters, signs or even digital graphics on web pages. See www.coolinfographics.com/ and www.informationisbeautiful.net for some inspirational ideas.

Present students with some example info graphics and explain that they are to design their own on the topic of fossil fuel-based energy using low-emission technologies or complementary technologies that can address climate change.

They are to research a range of facts and figures on global mining of fossil fuels, their use as an energy resource and their use of low-emission or renewable technologies. This information is to be presented graphically, either as a poster or a digital graphic.

The following websites will be a useful start in their search for information:

Worldwide energy sources
www.geos.ed.ac.uk/sccs/public/teachers/SNH_Fig_3.JPG

Global overview of CCS projects
www.globalccsinstitute.com/projects/map

CCS Atlas of the United States and Canada
fossil.energy.gov/news/techlines/2010/10058-Third_Edition_of_Carbon_Sequestrat

Renewable Energy Locations
www.earth.google.com/outreach/showcase.html#kml=Renewable_Energy_Locations

Google Images
www.google.com/search?hl=en&biw=1259&bih=688&gbv=2&tbm=isch&sa=1&q=carbon+capture+and+storage&oq=carbon+ca&aq=1&aqi=g10&aql=undefined&gs_sm=e&gs_upl=10922l13328l0l9l9l0l0l0l0l360l2422l2-4.4l8

Slidefinder
www.slidefinder.net/c/carbon_management_sustainable/development_examination_potential/276062

Making connections

Blue hat thinking

Required: ☑ Internet

Once students have explored issues using de Bono's Six Hat Thinking method from above, ask the whole class to extend their discussion on the 'blue hat' line of inquiry.

This hat encourages the students to consider the context, or 'big picture' of the range of renewable and low-emission technologies that can reduce CO_2 emissions and actions that industry and power plants can take. For example, start with the question:

How might industry and power plants reduce CO_2 emissions?

Ask students to think of the contexts this question demands before it can be answered. This might involve economics, social decisions, cultural values and technological progress. Write several of these contexts as headings above columns. In each column, provide other factors that need to be considered.

e.g. How might industry and power plants reduce CO_2 emissions?

Economically	Scientifically	Culturally
Which choices are more cost efficient?	What is our current technology?	Who thinks the benefits outweigh the risks?

Adapted from: CSIRO CarbonKids in Action Curriculum Unit page 15

What's my value?

Ask students to consider the things they find most valuable in life and make a list. Point out to them that every decision they will ever make in life is between outcomes they potentially would find valuable. The choices we make are based on our personal values.

However, it is never easy making these decisions because values are often relative. We might value money and also value a tasty meal. However, if you're starving, food is more important. If you've just eaten, money might be more valuable.

Invite students to consider other people's values and compare them with their own. Remind them that values have no objective (absolute) quality, however for decisions to be made together we must respect shared values while accepting that some values will be different.

Students consider the values of future generations and discuss what is happening at the present that might mean that the next generation inherits less sustainable environments than those of today. Discuss with them the meaning of the term 'rights' with respect to values.

Students consider the values of industries and power plants involved in taking steps to limit CO_2 from their activities, including by implementing CCS, renewable energy or energy efficient technologies and strategies. Discuss their 'rights' with respect to values.

Adapted from: CSIRO CarbonKids in Action Curriculum Unit page 15

Taking action

Share research investigation and info graphic outcomes

Encourage students to share their research investigation or info graphics about low-emission and renewable technologies used in industry and power plants with other classes or to submit either project to their local Science Teacher's Association awards program. Students could consider sharing their work with the Global CCS Institute.

Student work samples can be submitted to education@globalccsinstitute.com

At school and in the home

Tackle a specific GHG emission source that has been found to be of interest in your local area or state/territory. Record responses to the following questions:

- Are you particularly concerned about a specific issue and want to take action?
- Is something happening in the local area or state/territory that you would like to change?
- Are there any groups that are already working on the issue?
- Are there any technologies or is there any research you're aware of that addresses emissions?
- Is there a particular aspect of the issue that you think would be appropriate for a group to work on?
- What can be found out about the issue?
- Who can I empower with the information?

Reflection

Ask students to complete a self-assessment and reflection activity. Complete one yourself and role model it for the students.

Use the following questions as a guide:

- What is the most useful thing I have learned about industry and power plants reducing CO_2 emissions?
- What is one thing I have learned about my own values when it comes to low-emission and renewable technologies being applied globally in an effort to provide society with cost-effective and secure energy and address CO_2 emissions?
- How might I help others to understand there is no one 'solution' to climate change?
- What have I learnt about innovation and low-emission and renewable technologies?
- What would I still like to find out about industries and power plants working more sustainably?
- What piece of work am I most satisfied with?

The Global CCS Institute would like to know what students have learnt from this program. You could encourage students to submit their thoughts and feedback to education@globalccsinstitute.com.

References

CSIRO (2010) CarbonKids in Action Curriculum Unit, CSIRO Education

CSIRO (2012) CarbonKids Powering into the Future Curriculum Unit, CSIRO Education

CSIRO (2010 CarbonKids Understanding Climate Change Curriculum Unit, CSIRO Education

CSIRO (2010) CarbonKids Changing Climate Curriculum Unit, CSIRO Education

CSIRO, Bureau of Meteorology (2012) State of the Climate

Dalton, J. (1985) Adventures in Thinking

De ArgumentenFabrik. (2010) Argument Map CO_2 Capture and Storage. CATO2.

De Bono, E. (1992) Six Thinking Hats for Schools, Books 1 and 2, Hawker Brownlow Educational.

Hamston, J. and Murdock, K. (1996) Integrating Socially: Planning Integrated Units of Work for Social Education, Curtain Publishing, Eleanor.

Hayward, J. Graham, P. and Campbell, P.K. (2012) Projections of the future costs of electricity generation technologies: An application of CSIRO's Global and Local Learning Model (GALLM)

Hicks, D. (1994) Education for the Future – a practical classroom guide, WWF.

Hicks, D. and Steiner, M. Making Global Connections; A World Studies Workbook, Longman/ Harlow, 1989.

Gerber, T. (2006). National Science Education Standards Correlated to Inquiry into Life

(Eleventh Edition). Online Learning Centre: Madder.

The Gap, (1994), Issue 5, Global Education Centre, Australia, 1994.

Websites

Carbon Sequestration Leadership Forum
www.cslforum.org/education/index

Carbon Trust
www.carbontrust.co.uk/emerging-technologies/technology-directory/pages/carbon-capture-storage.aspx

CCS101
www.ccs101.ca/ccs-basics/co2-capture

CCS Education Centre
www.geos.ed.ac.uk

CCS Education Initiative
www.ccs-education.org

Climate Change-Ask an Expert
www.abc.net.au/science/expert/realexpert/climatechange

Climate Change Science Quiz
www.abc.net.au/science/quizzes/climatechange

Cool Info graphics
www.coolinfographics.com

Cool the globe
www.cooltheglobe.com

CSIRO
www.csiro.au

eGFI
www.egfi-k12.org/whats-new/e-tube/carbon-sequestration

European Technology Platform for Zero Emission Fossil Fuel Power Plants
www.zeroemissionsplatform.eu/projects/global-projects

Global CCS Institute
www.globalccsinstitute.com

Google earth renewable energy locations
www.earth.google.com/outreach/showcase.html#kml=Renewable_Energy_Locations

Google images
www.google.com/search?hl=en&biw=1259&bih=688&gbv=2&tbm=isch&sa=1&q=carbon+capture+and+storage&oq=carbon+ca&aq=1&aqi=g10&aql=undefined&gs_sm=e&gs_upl=10922l13328l0l9l9l0l0l0l0l360l2422l2-4.4l8

Information Is Beautiful
www.informationisbeautiful.net

NewGenCoal
www.newgencoal.com.au/climate-change and www.youtube.com/watch?v=ROEFaHKVmSs

PEW Centre on Global Climate Change
www.pewclimate.org/climate-techbook

Queensland Resources Council
www.oresomeresources.com

Princeton University
www.cmi.princeton.edu/wedges

Slidefinder
www.slidefinder.net/c/carbon_management_sustainable/development_examination_potential/276062

UNPEP Bayer Partnership
www.unep.bayer.com/en/International-Children_s-Painting-Competition-18.aspx

US Department of Energy
www.fossil.energy.gov

US Environment Protection Authority
www.epa.gov/climatechange/kids/index and www.youtube.com/watch?v=ROEFaHKVmSs

Name:

The evaluation rubric

In science, examining and discussing what other people have written about a concept is called an 'evaluation'.

To do an evaluation of sources that are about low-emission technologies that are being used to address climate change, go through the following steps:

- Evaluate one source at a time
- Examine and discuss each source with a partner
- Use the rubric below for each source, filling in details to support your judgements.

Resource title	Criteria	Not met	Adequate	Good	Exemplary
	The resource increases knowledge and understanding of low-emission technologies that are being used to address climate change.				
	The resource is engaging for students.				
	The resource has a clear purpose and is well organised.				
	The resource gives a balanced account of an issue, and accurately reflected the broad range of informed opinion on the subject.				
	The resource encourages the reader to ask questions.				
	The visual representations accurately depict the scientific concepts being examined.				
	The visual representations provide an alternative way for the reader to examine the concepts being discussed in the text.				
	Captions accompanying each visual representation follow the above criteria.				
Other Notes					

These criteria are based on the official SB&F award criteria by Timothy Gerber. (2009). 'Mock SB&F Prize for Science Books Election'.

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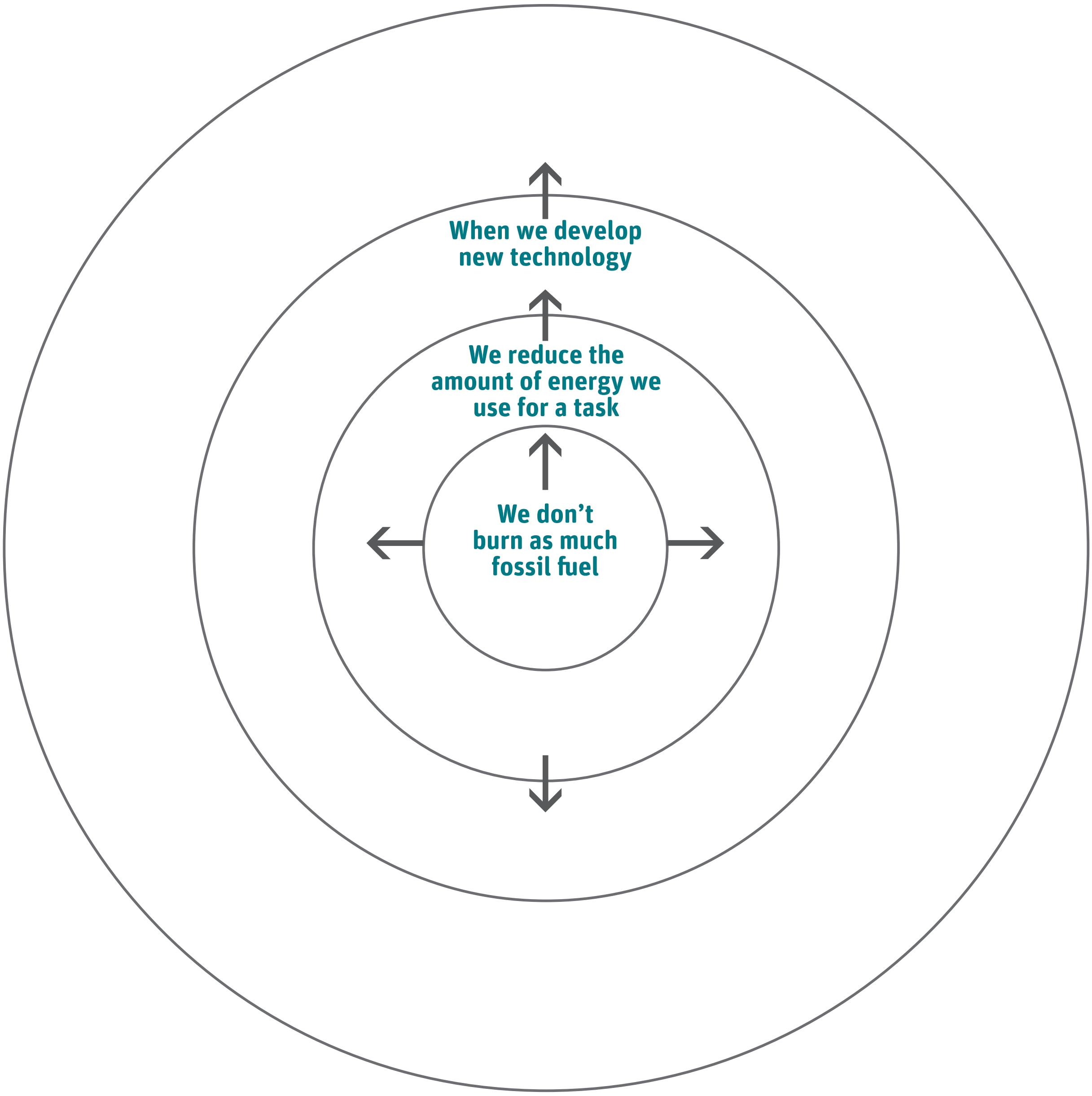
Name:

Consequence wheel

Consequence wheels are used to explore wide ranging consequences that can follow from actions, issues or trends in the present. Look at the example below.



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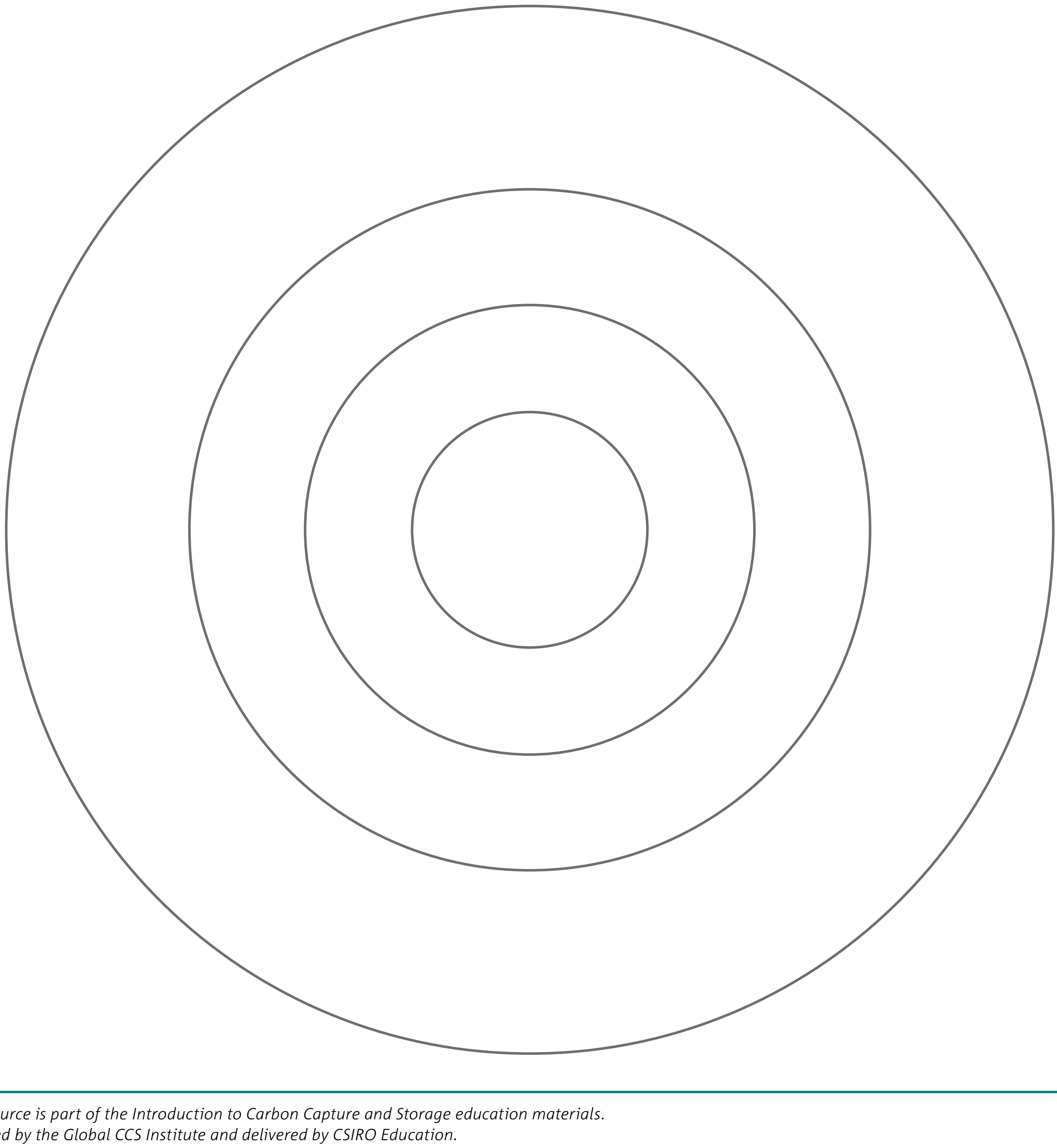
Name:

Consequence wheel continued

Decide on an energy sustainability issue that is part of understanding the use of a low-emission technology. Place the focus in the centre of the consequence wheel. Then, explore the focus by asking the question "What are the immediate consequences?"

Write the immediate consequences in the inner ring around the main idea. Link each consequence to the main idea with a single line. This indicates that they are first order consequences. Continue exploring second, third and fourth order consequences using the outer circles.

Use the four concentric circles below to explore the consequences of an action, issue or trend relevant to the emission of GHGs and/or the sustainable management of carbon dioxide emissions in industries or power plants today.



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Name:

The research process

In science, researching what other people have written about a concept is called a 'literature review'.

To do a literature review, go through the following steps:

Choose a topic	My topic:
Define key words that might be associated with that topic	Key words:
List all of the possible places that information might be found on that topic, and decide how to search through them	List of resources:
Search for the key words and decide whether the text might be useful or not. Keep a record of the text, including: author's name, the name of the text, the year it was written, the name of the publisher and the pages you found most useful	Author's name: The name of the text: The year it was written: The name of the publisher: The pages you found most useful:
Copy and paste or write out the information you think is important	

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Name:

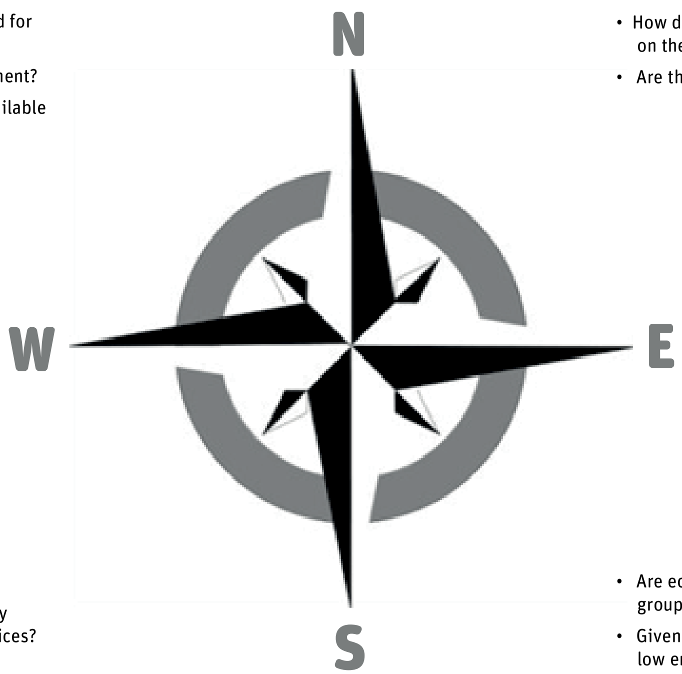
Compass rose

Natural

- What natural resources does your country have?
- How do using different energy resources impact on various ecosystems?
- What policies have been developed to meet the needs of the world's future energy needs?

- Will our plants and animals be protected for future generations?
- What will be the impact on the environment?
- Will the same animals and plants be available to future generations?

- How does your country's export industry impact on the world's use of energy resources?
- Are the economic activities sustainable?



Who decides?

- Who has access to decision making?
- Who decides and by using what criteria?
- What is the local policy on decision making?
- Who has an interest in the decision making?
- Why are decision making structures likely to become more important?
- How can I influence decisions?

Economic

- Is funding for low emission technologies and alternative energy likely to become more important to the economy in future years? Why?
- What investment opportunities are there in low emission technologies and alternative energy?
- How effective are current incentives to use 'green' energy?
- Can most industries afford to adopt low emission or renewable energy technology as a part of their domestic budget?

- What are the political implications?
- How can the industry and the community influence its leaders to make better choices?

- Are economic opportunities accessible to all groups?
- Given a choice between paying more or investing in low emission and alternative energy resources, which do most industries choose?

Social

- How are the various voices in industry and the community heard?
- What attitudes do industry and people have towards this environment?
- In what ways are industry and people organising to influence change?
- What motivates industry and people in choosing their energy sources?
- What influences industry and people's attitude on climate change?

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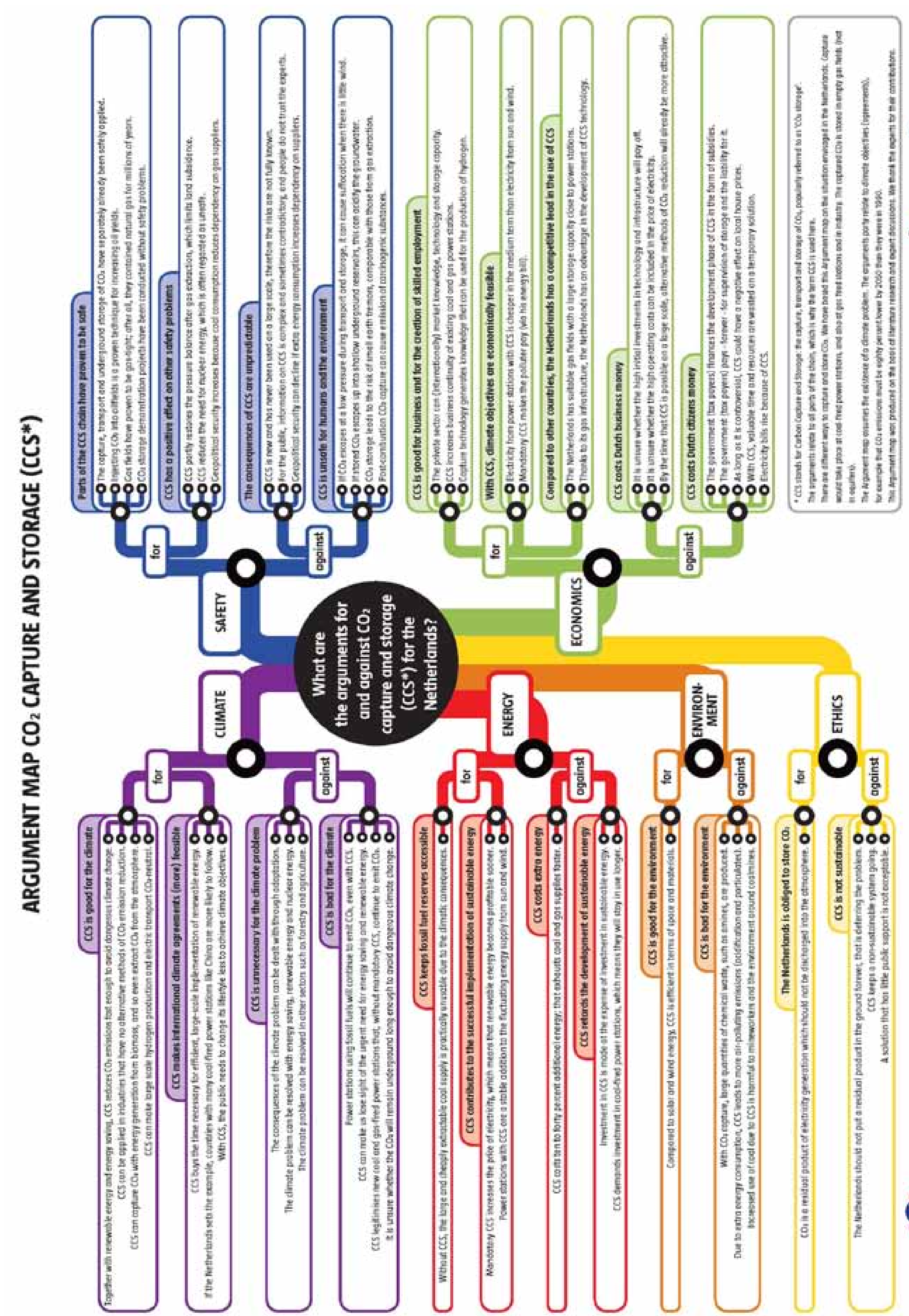

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