CCUS – Teacher Resource

Intended Use of Resources

This project has been designed so that teachers from different STEM areas can pick and choose sections relevant to their subject area to work on. All activities in this package do not need to be completed to get value from the package – each activity can be completed as a stand-alone or can be approached, as a team, as a larger project. The package has potential to be extended into a much longer project to include curriculum points from different STEM subjects.

There are three **student workbooks - Open, Guided and Scaffolded,** that go alongside this resource; all have the same suggestions for activities, however, they have been written and edited to provide differentiated learning options to support good teaching practice**.** Teachers may pick and choose which versions they give which students, and may wish to edit them further to address their learning needs. Due to the differentiation of the workbooks, the **Open** activities will enable more syllabus links to be addressed, which is why each activity has its own syllabus links key. However, if you wish to give a truly open ended investigation then you could just give the students the challenge and background information section of the Student Booklet.

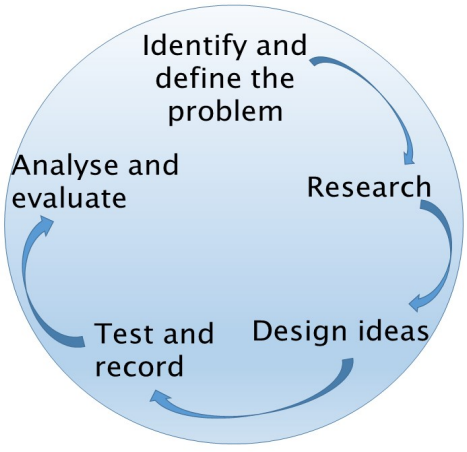
The Woodside Australian Science Project (WASP) STEM resources aim to be accessible and supportive for teachers and students, please contact us if you have questions, feedback, require assistance or would like to arrange an incursion or a professional development workshop - www.wasp.edu.au.

The Student Challenge

In a world where our understanding of the impacts of carbon dioxide (and other greenhouse gases) on our climate is expanding but our demand for energy is higher than ever, it is vital that energy production becomes more efficient and environmentally friendly. While there are renewable sources of energy, many of these are still expensive and/or inefficient. This means that for the foreseeable future, fossil fuels will play a role in our energy mix.

One of the key ideas to minimise the amount of carbon dioxide, associated with fossil fuels, being released to the atmosphere is through using carbon capture utilisation and storage (CCUS) methods.

Your job is to investigate the advantages and difficulties of CCUS and try to come up with a solution to minimise carbon release into the atmosphere.



Background Information

Carbon dioxide is a greenhouse gas in our atmosphere. There are many ways in which carbon dioxide can enter the atmosphere including; respiration of living things, volcanic eruptions, and in the production and burning of fossil fuels. Since the industrial revolution, the amount of carbon dioxide released into the atmosphere has increased (Figure 1), and climate scientists attribute much of this increase to the burning of fossil fuels to produce energy.

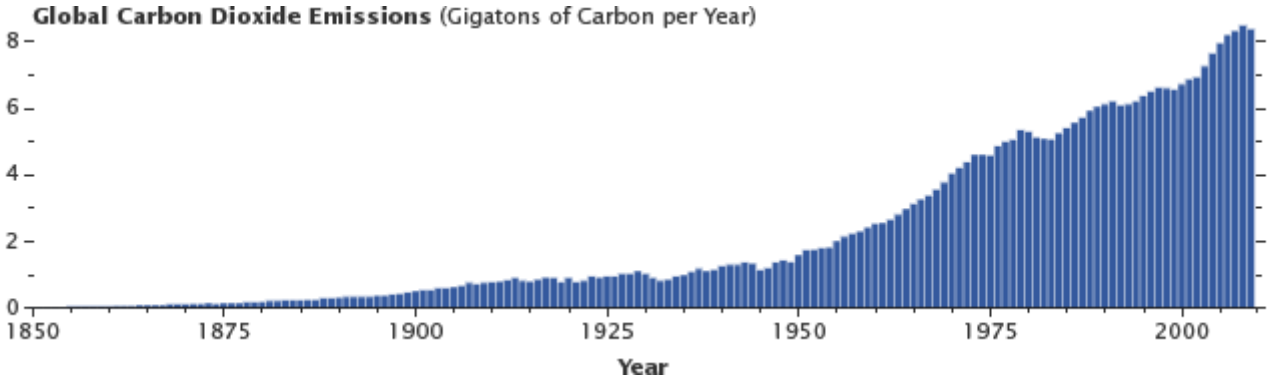


Figure 1. Global carbon dioxide emissions (gigatons of carbon per year) (Earth Observatory, 2011)

Carbon dioxide plays a vital part in the greenhouse effect, as illustrated in Figure 2. Without the greenhouse effect the Earth would be too cold to support life as we know it (like Mars) but higher levels of greenhouse gases can make a planet too warm (like Venus). Having the right amount of greenhouse gases in the atmosphere is vital to the survival of life on Earth. The increase in the amount of carbon dioxide in the atmosphere has been linked to an increase in global temperatures, which is causing polar ice to melt and sea levels to rise, among other problems.

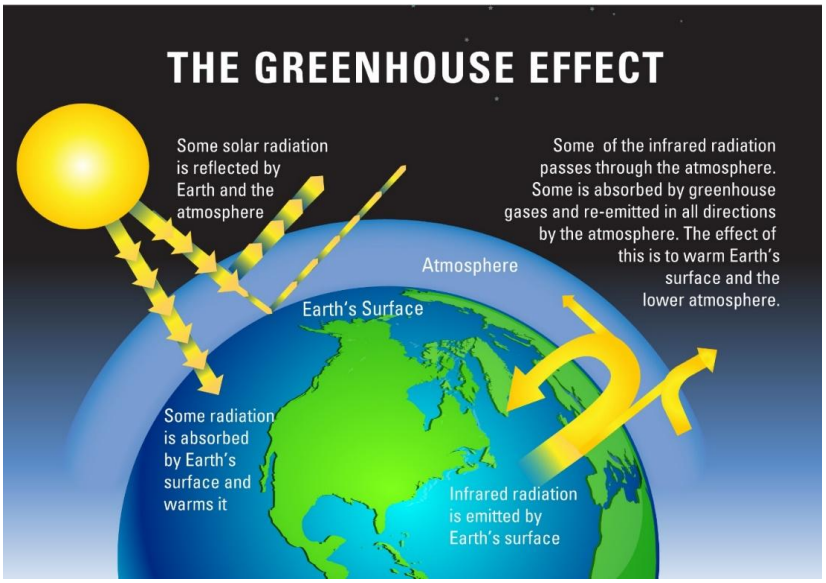


Figure 2. The greenhouse effect helps to keep the planet warm, but higher levels of greenhouse gases can lead to too much heat energy being trapped, causing an increase in global temperatures (The Royal Society, 2019).

The carbon cycle is a natural, global cycle which, when in balance, allows life on Earth as we know it to thrive. One of the largest carbon sinks is the ocean, which removes carbon dioxide from the atmosphere. It currently absorbs about one third of the carbon dioxide released by the burning of fossil fuels (NOAA, 2017). When carbon dioxide absorbs into the ocean its pH levels decrease. This is known as acidification. Acidification of the oceans has been linked to coral bleaching and thinning of shells of marine organisms, which in turn has damaged some marine ecosystems.

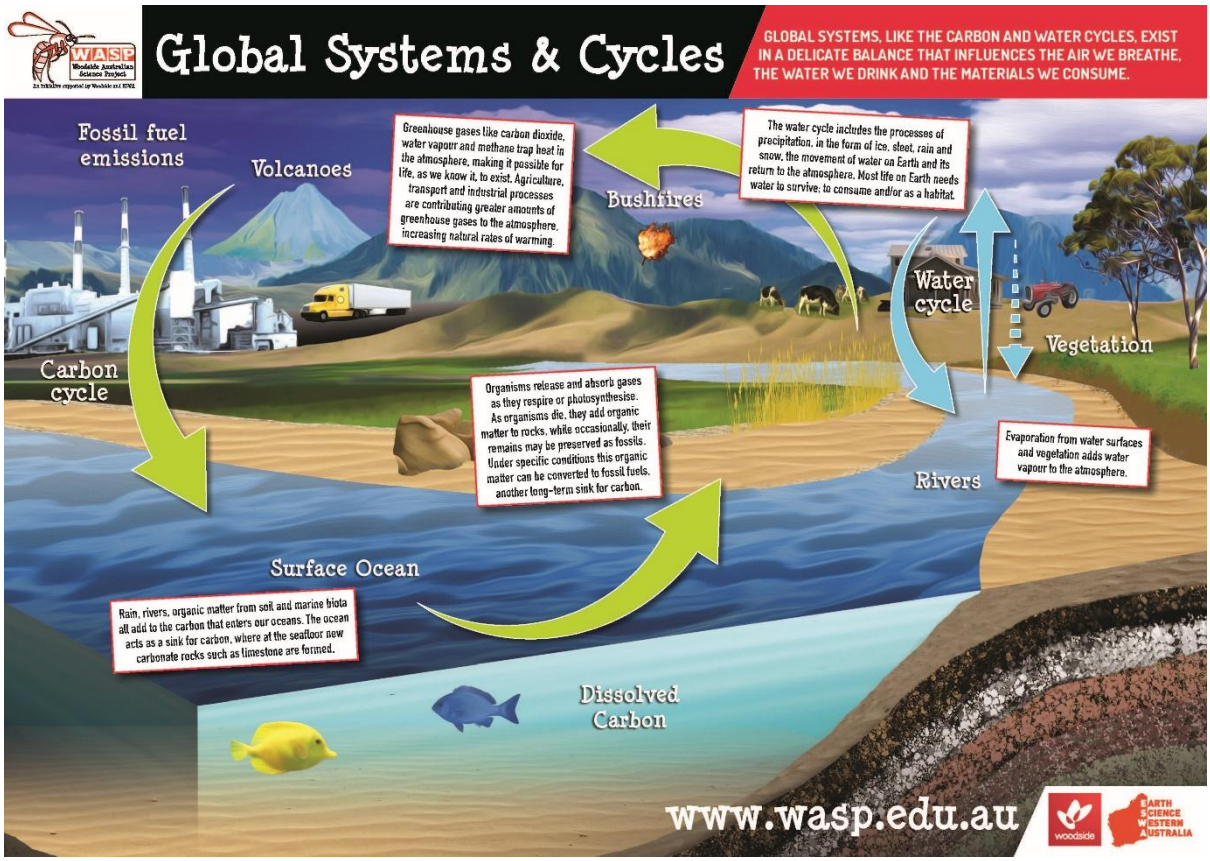


Figure 3. The carbon cycle has natural and manmade inputs. The ocean is a major sink for carbon.

As a global priority, industry and government are investigating how to minimise the amount of carbon dioxide which is released into the atmosphere through human activities. There are some companies using carbon capture and storage methods, however, at present this is very costly. Companies who aim to be both more environmentally friendly and economically competitive are investing in research to look at means of using the carbon dioxide, these processes are known as Carbon Capture, Utilisation and Storage (CCUS).

Activities

This booklet contains extra information on each activity, including syllabus links the overall activity objective, suggestions for recommended equipment or alternative ways to run investigations as well as useful resources and website links*.
The syllabus links have been colour coded. These links to the Australian Curriculum are also relevant to the Western Australian Syllabus. – Please see the colour key below:

Covered in Scaffolded, Guided and Open Student Booklet
Covered in Guided and Open Student Booklet
Covered in Open Student Booklet
Italics – WA syllabus for DT and D and T

List of activities

Background Research
Enhanced Oil Recovery
Investigating the Effect of Carbon Dioxide on the pH of Water
Investigating the Effects of Acid on Materials
Investigating the Effect of Temperature on Solubility of Carbon Dioxide
Investigating the Effect of Pressure on the Solubility of Carbon Dioxide
Investigating the Effect of Salinity on the Solubility of Carbon Dioxide
Selecting Rocks
Mineral Trapping
3D Models for Structural Trapping

**Please note that any reference websites provided were accessed in May 2019 therefore these addresses may have changed slightly. We would be grateful if you could let us know if these sites are no longer accessible.*

CCUS – Teacher Resource

Background Research

Objective

Students will gain a general understanding of what carbon capture utilisation and storage (CCUS) is and how it could be beneficial, as well as gain some understanding of the difficulties involved with CCUS.

The background questions should lead them to start thinking about further investigations they could do to find out more about CCUS. They are "teaser" questions about which students will be able to find out more through the other activities. Therefore, if you do not have time to complete all the activities you may wish to add to the background questions.

Students will find that currently there is very little CCUS actually occurring as the cost of carbon capture and storage is very high and it is also very energy intensive. This is a major reason for research into utilisation. If carbon dioxide can be used in industry, for example in fizzy drinks or enhanced oil recovery, then it will make it more economically viable for companies. Unfortunately, both uses require very little carbon dioxide. Until it becomes cheaper to store carbon, or more economic uses of carbon dioxide are found the only way that companies can be encouraged to employ carbon storage techniques is through carbon taxes or environmental legislation.

	Australian Syllabus Links
Science	ACSSU189 Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. ACSHE230 Values and the needs of contemporary society can influence the focus of scientific research.
Design and Technology	ACTDEK040 Social, ethical and sustainability considerations that impact on designed solutions, complexity of design, and production processes involved ACTDEK041 Impact of emerging technologies on design decisions, and/ or economic, environmental and social sustainability.

Useful resources and websites:

- Very detailed, yet not too high level, explanation the need for CCUS as well as the difficulties with it from the Society of Petroleum Engineers: http://www.spe.org/industry/carbon-capture-sequestration.php
- Carbon research, with factsheets and videos explaining carbon capture theory and a case study: http://www.co2crc.com.au/

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Enhanced Oil Recovery

Objective

Students will model the process of enhanced oil recovery (EOR) and relate this to its suitability for carbon utilisation and storage.
Other methods for creating carbon dioxide gas can be used, such as vinegar on baking soda.
If a dropper bottle is used to deliver the acid onto the powder, then we suggest that the students use a piece of card to put over the top of the delivery tube when the reaction is occurring to prevent carbon dioxide from escaping.
The carbon dioxide released will then travel up the delivery tube into a beaker with dyed water in it, and displace the water, which will then travel up the other delivery tube into the empty beaker.
This experiment could also be simplified by replacing the conical flask filled with water for a container with wet sand in it. Ensuring that the delivery tube is right at the bottom of the container, when the gas enters the wet sand it will make the water move out of the pore spaces and rise to the surface.
This experiment can also be linked to rates of reaction, where students look at using different concentrations/different sized chips/different volumes of reactants etc.

	Australian Syllabus Links
Science	ACSSU189 Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. ACSHE230 Values and the needs of contemporary society can influence the focus of scientific research. ACSSU187 Different types of chemical reactions are used to produce a range of products and can occur at different rates.
Design and Technology	ACTDEK041 Impact of emerging technologies on design decisions, and/ or economic, environmental and social sustainability. WATPPS64 Apply design thinking, creativity, enterprise skills and innovation to develop, modify and communicate design ideas of increasing sophistication.

Useful websites and resources:

- Explanation of enhanced oil recovery using carbon dioxide: https://www.energy.gov/fe/science-innovation/oil-gas-research/enhanced-oil-recovery
- Raising raisins experiment from the Year 7 WASP package gives further suggestions on how to show the influence of carbon dioxide on enhancing oil recovery: http://www.wasp.edu.au/course/view.php?id=4&section=4
- Enhanced Oil recovery video: https://www.youtube.com/watch?v=azLVjYij5U4

Investigating the Effect of Carbon Dioxide on the pH of Water

Objective

Students will determine the relationship between the amount of dissolved carbon dioxide in water and the pH of the water. Then use this information to highlight any challenges in designing carbon capture utilisation and storage (CCUS) systems.

This experiment is also useful if you wish to look into ocean acidification caused by increased dissolution of carbon dioxide. The use of carbon capture will hopefully reduce the amount of carbon dioxide which enters the oceans.

It is also an interesting investigation to look into the health problems associated with consumption of lots of fizzy drinks, as not only is the sugar bad for your teeth but they are also acidic.

A fun way to do this experiment as a demonstration, would be to use a soda stream with water and universal indicator in it and watch the colour change each time you press the button. Please note that this will probably not give any quantitative results as each press will likely not release the same amount of carbon dioxide.

Carbon dioxide could also be created using vinegar and bicarbonate of soda in this experiment. Students could also investigate if having an open system (the water in a beaker instead of a sealed conical flask) makes a difference to the pH and the amount of carbon dioxide dissolved.

This experiment can also be linked to rates of reaction, where students look at using different concentrations/different sized chips/different volumes of reactants etc.

	Australian Syllabus links
Science	ACSSU189 Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. ACSIS198 Formulate questions or hypotheses that can be investigated scientifically ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately ACSIS203 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data.

	Australian Syllabus links
Design and Technology	WATPPS64 Apply design thinking, creativity, enterprise skills and innovation to develop, modify and communicate design ideas of increasing sophistication. WATPPS66 Select, justify and safely implement and test appropriate technologies and processes, to make solutions WATPP68 Work independently, and collaboratively to manage projects, using digital technology and an iterative and collaborative approach. Consider time, cost, risk, safety, production processes, sustainability and legal responsibilities.

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Investigating the Effects of Acid on Materials

Objective

Students will investigate how different metals and rocks react to acid. They then relate their findings to the design of suitable methods for transporting and storing carbon dioxide.
For an extended project, students can do further research looking into the cost of materials, to determine if it is more cost effective in the long run to replace a cheap material frequently or use a more expensive material that will last longer.
Some interesting rock types to use would be granite, marble, limestone, sandstone and basalt. The acid should react with the marble and limestone due to their high calcium carbonate content. The marble is particularly interesting as it is usually quite impermeable, but it would not be effective at trapping dilute acid. The rocks which have reacted should demonstrate a change in mass. It may be best to allow the rocks to dry overnight, as highly porous rocks could still contain water after washing and drying and will therefore bias the results. This could provide the basis for a good discussion point.

	Australian Syllabus links
Science	ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data. ACSIS208 Communicate scientific ideas and information for a particular purpose, including construction evidence based arguments and using appropriate scientific language, conventions and representations.
Design and Technology	WATPPS64 Apply design thinking, creativity, enterprise skills and innovation to develop, modify and communicate design ideas of increasing sophistication. WATPPS66 Select, justify and safely implement and test appropriate technologies and processes, to make solutions WATPP68 Work independently, and collaboratively to manage projects, using digital technology and an iterative and collaborative approach. Consider time, cost, risk, safety, production processes, sustainability and legal responsibilities. ACTDEK046 The combination of a range of characteristics and properties of materials, systems, components, tools and equipment to create designed solutions

Investigating the Effect of Temperature on Solubility of Carbon Dioxide

Objective

Students will investigate the relationship between the temperature of a liquid and solubility of carbon dioxide gas. This can then be related to storing carbon dioxide at depth in saline aquifers.

You may wish students to do some investigations and calculations to determine the geothermal gradient. They can relate this to their learning in Year 9 Science and look at geothermal gradient at different tectonic settings, to gain understanding that some places in the world have a lower increase in temperature with depth than others. Places where the geothermal gradient is low are generally more favourable for carbon capture and storage.

Students should find that as the temperature increases less carbon dioxide can be dissolved in the water. This can also be demonstrated in a few fun ways, such as placing one bottle of soda water in an ice bath, another in a hot water bath and the third left at room temperature. When the bottles are opened the cold one will hardly fizz at all, the bottle at room temperature will fizz a bit and the one that has been heated should spurt quite violently. This will not give numerical data but is a nice visual.

Another method is to place upturned measuring cylinders into water of differing temperatures and then to add Alka-Seltzer or another effervescent tablet to the cylinder. Students would measure how much water the gas displaces from the cylinder. The more water displaced the less gas was absorbed.

This experiment can also be linked to rates of reaction, where students look at using different concentrations/different sized chips/different volumes of reactants etc.

	Australian Syllabus links
Science	ACSSU187 Different types of chemical reactions are used to produce a range of products and can occur at different rates. ACSSU189 Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. ACSIS198 Formulate questions or hypotheses that can be investigated scientifically ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately ACSIS203 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies

	Australian Syllabus links
Science	ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data.
Design and Technology	WATPPS64 Apply design thinking, creativity, enterprise skills and innovation to develop, modify and communicate design ideas of increasing sophistication. WATPPS66 Select, justify and safely implement and test appropriate technologies and processes, to make solutions WATPP68 Work independently, and collaboratively to manage projects, using digital technology and an iterative and collaborative approach. Consider time, cost, risk, safety, production processes, sustainability and legal responsibilities.
Mathematics	ACMSP251 Use scatter plots to investigate and comment on relationships between two numerical variables

Useful websites and resources

- WASP Year 10 carbon cycle solution experiment: http://www.wasp.edu.au/course/view.php?id=19
- Video of class demonstration showing solubility of carbon dioxide in water of differing temperatures (in this case the teacher relates it to warming oceans): https://www.youtube.com/watch?v=C1HgycVC8e4

Investigating the Effect of Pressure on the Solubility of Carbon Dioxide

Objective

Students will investigate the relationship between pressure and the solubility of carbon dioxide and then relate this to carbon storage at depth.
Good qualitative data can be gathered however it can be challenging depending on how clearly students can see the colour change of the indicator used (this can be near impossible for students with certain types of colour blindness). You can use a pH meter that will fit into the end of the syringe, ensuring that you have a tight seal with plasticine or Blu tack. A larger syringe will make it easier to see change and to take accurate readings.
Students could use coloured pencils to show the change in colour as the pressure changes, then from this try to match to the colour chart to determine the pH.
Students should find that as the pressure decreases then the pH also decreases as carbon dioxide is released. This shows that more carbon dioxide can be absorbed under higher pressures, so a deeper burial (where pressure is higher) should be more favourable.

	Australian Syllabus links
Science	ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately ACSIS203 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data. ACSIS208 Communicate scientific ideas and information for a particular purpose, including construction evidence based arguments and using appropriate scientific language, conventions and representations.
Design and Technology	WATPPS64 Apply design thinking, creativity, enterprise skills and innovation to develop, modify and communicate design ideas of increasing sophistication. WATPPS66 Select, justify and safely implement and test appropriate technologies and processes, to make solutions
Design and	WATPP68

Technology	Work independently, and collaboratively to manage projects, using digital technology and an iterative and collaborative approach. Consider time, cost, risk, safety, production processes, sustainability and legal responsibilities.
Mathematics	ACMSP251 Use scatter plots to investigate and comment on relationships between two numerical variables

Useful websites and resources

- Video showing the set-up of experiment and changes you should expect to observe: https://www.youtube.com/watch?v=QtCRxvCxa6M&t=104s

Investigating the Effect of Salinity on the Solubility of Carbon Dioxide

Objective

Students will determine the relationship between the salinity of a solution and the amount of carbon dioxide it can dissolve. Then relate this to proposed carbon capture utilisation and storage (CCUS) methods.
Students should find that with higher salinity there will be less carbon dioxide dissolved. This may seem like a strange reason to use a saline aquifer however, carbon dioxide cannot be injected into freshwater as it will make it acidic and therefore unable to be used for drinking, as well as impacting the natural ecosystem. When injected into a saline solution carbon dioxide will start to react with the salt and form precipitates. This will form a mineral, trapping the carbon dioxide. This occurs over long periods of time, with estimates being hundreds to thousands of years.

	Australian Syllabus links
Science	ACSSU187 Different types of chemical reactions are used to produce a range of products and can occur at different rates. ACSIS198 Formulate questions or hypotheses that can be investigated scientifically ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately ACSIS203 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data.
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	Australian Syllabus links
Design and Technology	WATPPS68 Work independently, and collaboratively to manage projects, using digital technology and an iterative and collaborative approach. Consider time, cost, risk, safety, production processes, sustainability and legal responsibilities.
Mathematics	ACMSP251 Use scatter plots to investigate and comment on relationships between two numerical variables

Selecting Rocks

Objective

Students will investigate the properties of different rocks to determine their suitability for carbon storage.

Porous and permeable rocks, such as sandstone, are ideal for storing carbon dioxide. These rocks, should also not react with the acidic water (carbon dioxide makes water acidic), as opposed to limestone which is porous and permeable but reacts with weak acid. Some rocks are porous but not permeable, such as pumice, however they would not be good at storing carbon dioxide as the upward pressure of injected carbon dioxide could easily cause cracks and fissures in the rock allowing it to leak out.

Metamorphic and igneous rocks are generally very impermeable and good at trapping fluids, provided the rocks do not have lots of cracks and fissures. Marble is metamorphosed limestone, so although it is quite impermeable it will react with the carbon dioxide and will not be able to trap it. Rocks with interlocking, platy minerals, such as shale, are generally very good at trapping fluids also.

	Australian Syllabus links
Science	ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data. ACSIS208 Communicate scientific ideas and information for a particular purpose, including construction evidence based arguments and using appropriate scientific language, conventions and representations.
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	Australian Syllabus links
Design and Technology	ACTDEK046 The combination of a range of characteristics and properties of materials, systems, components, tools and equipment to create designed solutions

Useful websites and resources

- Demonstrating permeability vs porosity with chocolate: https://blog.csiro.au/carbon-capture-and-storage-explained-with-chocolate/
- WASP Year 8 package Rocks and Minerals – Poster, App and animation: http://www.wasp.edu.au/mod/page/view.php?id=87
- WASP Year 7 Oil and Gas poster: http://www.wasp.edu.au/pluginfile.php?file=/120/mod_page/content/20/Oil%20and%20Gas%20Formation%20Poster.pdf

Mineral Trapping

Objective

Students will research how minerals might play a role in the storage of carbon and discuss the difficulties of the processes involved. They will also, investigate the formation of calcium carbonate through experimentation.

This experiment can be done very simply by students blowing into limewater, however, the suggested method may show a clearer link for carbon capture and storage than blowing into limewater, which students often associate with respiration. This could also be extended to look at rates of reaction as well as investigating precipitates and ionic reactions further.

Mineralisation of calcium carbonate naturally takes hundreds to thousands of years. Recent research in Iceland (Carbfix project) demonstrated that mineralisation of carbon dioxide can be completed in a few years. However, the method uses lots of water and further research will need to be done to determine if they can get the same results using less water.

	Australian Syllabus links
Science	ACSSU187 Different types of chemical reactions are used to produce a range of products and can occur at different rates. ACSSU189 Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
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Mathematics	ACMSP251 Use scatter plots to investigate and comment on relationships between two numerical variables

Useful websites and resources

- WASP Year 10 Carbon cycle poster and activities package: http://www.wasp.edu.au/mod/page/view.php?id=89
- Carbfix project –injecting hot water and pressurised carbon dioxide into basalts to increase the rate of mineralisation: https://www.or.is/carbfix

3D Models for Structural Trapping

Objective

Students interpret seismic data to determine the best geological location to store carbon dioxide and create a 3D model of an appropriate site.

To complete this activity students may need to recap some of the Year 9 Earth Science course on fault types. They can use knowledge from previous activities if they have completed them to give good reasons for choosing a particular geological structure to attempt carbon capture and storage. For example, if they have completed the investigation on the effect of hydrochloric acid on materials, they will know that limestone reacts with acid and therefore site one might not be very sensible. If they have completed the mineralisation activity they will also know that recent research has shown that carbon dioxide can react quickly with basalt to create calcium carbonate, and therefore trap the carbon dioxide in the rock, making site two and three quite promising. However, as the basalt is porous it might be fractured by the high pressures. High pressures around faults can also cause fault movement and allow gas to escape.

Making the models in clear plastic food containers will mean that they can see the model in from all sides. However, students will realise that only two dimensions have been given, and hopefully will report this as an issue that would cause difficulty and something that would need to be further investigated.

They should use permeable materials, such as sand, to represent permeable rocks, and impermeable materials, such a plasticine, to represent impermeable rocks. Advanced students should be making models to scale and considering angles.

As they will not be able to see what happens to the carbon dioxide as they inject it they may want to use coloured water instead.

	Australian Syllabus links
Science	ACSSU187 Different types of chemical reactions are used to produce a range of products and can occur at different rates. ACSIS198 Formulate questions or hypotheses that can be investigated scientifically ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data.
Design and Technology	ACTDEK040 Social, ethical and sustainability considerations that impact on designed solutions, complexity of design, and production processes involved ACTDEK041 Impact of emerging technologies on design decisions, and/ or economic, environmental and social sustainability. WATPPS64 Apply design thinking, creativity, enterprise skills and innovation to develop, modify and communicate design ideas of increasing sophistication.

	Australian Syllabus links
Design and Technology	WATPPS66 Select, justify and safely implement and test appropriate technologies and processes, to make solutions WATPP68 Work independently, and collaboratively to manage projects, using digital technology and an iterative and collaborative approach. Consider time, cost, risk, safety, production processes, sustainability and legal responsibilities.
Mathematics	ACMMG242 Solve problems involving surface area and volume for a range of prisms, cylinders and composite solids. ACMMG245 Solve right-angled triangle problems including those involving direction and angles of elevation and depression.

Useful websites and resources

- Interpreting seismic data activity –this gives students a good idea of how seismic data is used:
  http://www.sub-surfrocks.co.uk/?page_id=197

Bibliography

(Figure numbers from scaffolded booklet)

Figure 1: Changes in the Carbon Cycle, NASA Earth Observatory, accessed at https://earthobservatory.nasa.gov/features/CarbonCycle/page4.php, on 2/5/19.

Figure 2: The Basics of Climate Change, The Royal Society, accessed at https://royalsociety.org/topics-policy/projects/climate-change-evidence-causes/basics-of-climate-change/, on 2/5/19.

Figure 3: Global Systems & Cycles, Woodside Australian Science Project, accessed at www.wasp.edu.au, on 3/4/18.

Figure 10: Oil Traps, Wikimedia Commons, accessed at https://upload.wikimedia.org/wikipedia/commons/thumb/a/af/Oil_traps.svg/2000px-Oil_traps.svg.png, accessed on 3/5/19.

Figure 11: Find the Oil: A Seismic Interpretation Exercise, accessed at http://www.sub-surfrocks.co.uk/?page_id=197, accessed on 3/5/19.