Carbon Capture & Storage - Resouces

Thank you for donwloading this Carbon Capture & Storage resource from the *GeoBus* website.

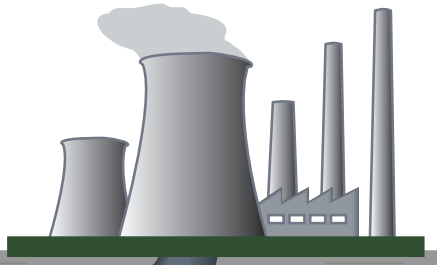
This resource pack was developed in partnership with The Crown Estate, with support from The Global CCS Institute, Royal Dutch Shell and SCCS. Special thanks are due to Megan O'Donnell and Katy Relph for their involvement. These resources, and further carbon capture and storage education materials can be found on the CO2 degrees challenge website.

The development of this resource would not have been possible without the generous support of the *GeoBus* sponsors, which we gratefully acknowledge.

University of St Andrews

Earth & Environmental Sciences

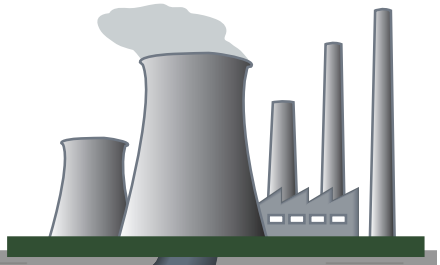
Chapter 2



1. Saying YES to CCS?

Saying YES to CCS?

Teacher Notes



Activity Description	Students consider the advantages and disadvantages of carbon capture and storage. They have to discuss and agree as a group how to divide the factors into advantages and disadvantages.
Time	1 hour
Learning Outcomes	• To consider the advantages and disadvantages of carbon capture and storage • To evaluate the risk/reward ratio of carbon capture and storage • To create a mind map
Student Organisation	Pairs / Groups
Materials Needed	List of CCS Factors, Saying Yes to CCS Student Worksheet

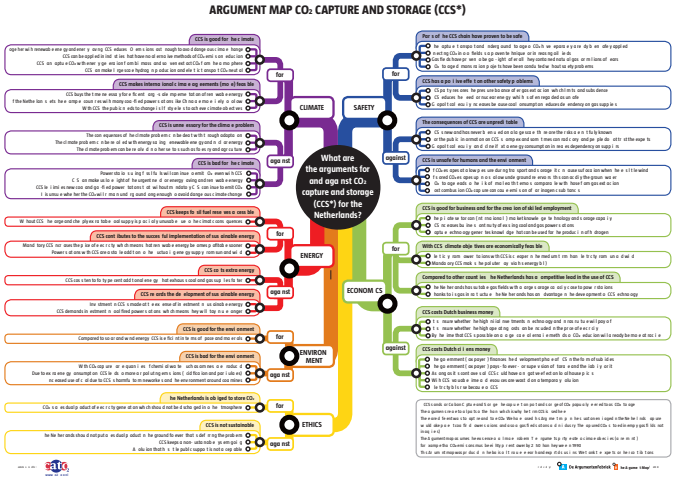
Saying Yes to CCS?
You will need:

- 4x A4 sheets of paper
- 1x sheet of A3 paper
- 1x scissors
- pencils and pens
- 2x baskets/buckets/bins/boxes

Task

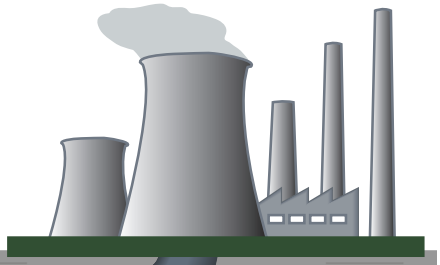
The students make cards representing each factor of CCS from the list provided. They are also given the chance to make up their own factors as they think of them in groups. They have to discuss and agree whether each factor is an advantage or a disadvantage before summarising their results in a table or on a mind map

See attached PDF of the 'argument map' for CCS in the Netherlands for use as an example.



Saying YES to CCS?

Student Worksheet



Saying Yes to CCS?
In this activity we consider the advantages and disadvantages of CCS.
Work in groups of 2 – 4.

You will need:

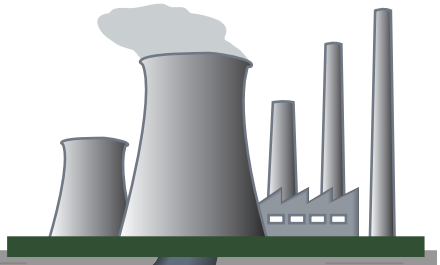
- 4x A4 sheets of paper
- 1x sheet of A3 paper
- 1x scissors
- pencils and pens
- 2x baskets/buckets/bins/boxes

Instructions

1. Cut each A4 sheets into four equal pieces, so you end up with 16 x A6 sheets.
2. Write the name of each CCS factor on the front of each sheet, draw a picture if you like, and copy the definition onto the back.
3. Use the two baskets for advantages and disadvantages.
4. Discuss in your groups and decide where the factor belongs.
5. Some factors may not fit in either basket (as they can be both) and they can be placed in the centre.
6. Once you have all agreed draw a mind map or table of the advantages on one side of the paper and a mind map or table of the disadvantages on the other.

Saying YES to CCS?

List of CCS Factors



The following list describes some factors to be considered in the Saying Yes to CCS task. Feel free to make some extra blank cards and add your own as you come up with them.

RETROFIT
CCS can be added to existing CO_2 sources, reducing the cost of implementation and the need for materials.

EOR (ENHANCED OIL RECOVERY)
CO_2 injection can increase the lifetime of fossil fuel reservoirs that are running low by increasing the pressure enough to drive out extra reserves.

LESS FREE CO_2
CO_2 in the atmosphere will be reduced.

KEEPS FOSSIL FUELS IN THE PICTURE
CCS allows fossil fuel reserves to continue to be exploited.

SPACE and MATERIALS
In comparison to solar or wind energy technologies, the space and materials required to implement CCS are minimal.

ASSOCIATED EMISSIONS
The CO_2 emissions associated with separation of CO_2 from combustion waste, transportation and compression at the site, should be considered.

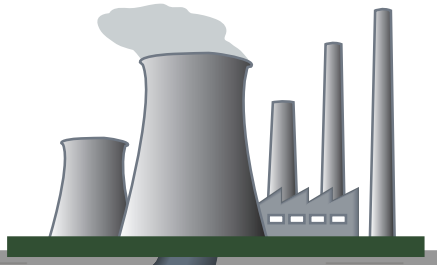
PROVEN CASE STUDIES
There are numerous long-term case studies proving the success and safety of CCS on a variety of scales and in a variety of locations. As each site is unique proven case studies do not guarantee safety for every project. However it is an indication that if best practice is used CCS can be successful and safe.

STABLISING RESEVOIRS
When oil or gas is removed from a formation it creates a pressure imbalance due to removal of supporting material. CO_2 injection can help to stabilise this imbalance.

JOBS
CCS implementation creates jobs requiring many different levels and types of skills.

Saying YES to CCS?

List of CCS Factors



COST
CCS is currently an expensive practice. Improvements in efficiency of capture and transport technology could reduce this cost.

RESEARCH
A drive to implement CCS will fund academic research in this field. This will aid the progression of science in this field.

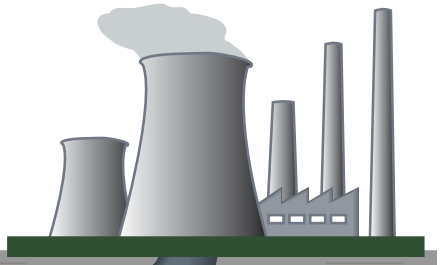
PUBLIC VIEWS
The public have a poor veiws of CCS, which is likely to hinder planning applications and funding. This is because of the likely social impact of transportation by tankers and uncertainty surrounding changing underground pressure.

WASTE
CCS creates chemical waste that must be dealt with responsibly and economically.

SCALE
CCS is always going to be a risk if implemented on an untested scale or formation.

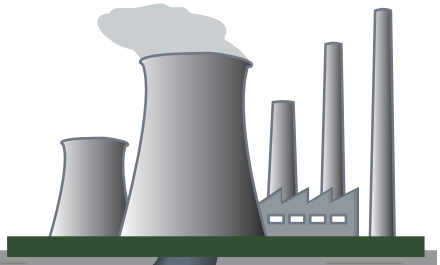
ENVIRONMENTAL CONCERNS
There are many concerns with how CCS will impact on the environment. Most are based on leakage scenarios that are unlikely if CCS is implemented using best practices.

Chapter 2



2. Paper Pipelines

Paper Pipelines Teacher Notes



Activity Description	This is a whole class activity involving teamwork, communication and group discussions. The aim is to highlight the importance of pipeline engineering and management within the context of carbon capture and storage.
Time	1 hour
Learning Outcomes	• To consider the advantages and disadvantages of carbon capture and storage • To evaluate the risk/reward ratio of carbon capture and storage • To create a mind map
Student Organisation	Whole Class
Materials Needed	Paper Pipelines Student Worksheet, ball, cups/buckets, a variety of papers and cards, a large open space

Talking Point

Discuss the advantages and disadvantages of pipeline transport.
Where is the CO_2 being transported from/to?
What is the most important thing to beware of when you design a pipeline? *Cost, security, impact on landscape, noise, materials?*

You will need:

- One sheet of A4 paper or card for each student (plus spares)

Use different types and thicknesses of paper/card/plastic to vary the level of difficulty

- A marble, table tennis ball, or golf ball
- A cup, mug or bucket
- A large classroom with space for the students to stand and move

Task

Explain to the students that they are going to make their own pipeline. Give them a choice of materials with which to construct their pipe. Show them where to start and finish their pipeline, i.e. back corner of the room to the front corner, and place the bucket/box/cup in the finishing zone. Remind them that they are to work together.

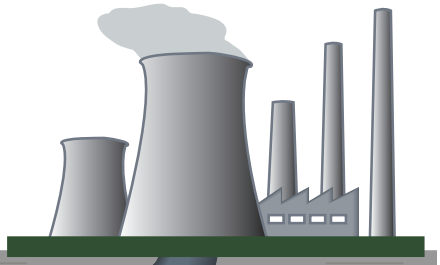
Extension Task

Encourage the students to experiment with angles, height differences and a variety of materials to see what effect these have on the speed and stability of the transport of the ball.

Talking Point

What if the pipeline had to transport liquids, gases or dangerous or hazardous materials instead of just one ball? What might need to be considered?
What happens when pipelines have to travel uphill?

Paper Pipelines
Student Worksheet



Pipelines can be used to transport pressurised fluids (liquids or gases) from where they are produced to where they are needed. Water, oil, natural gas, and waste gas such as CO_2 can be transported by pipeline.

CCS uses pipelines to transport CO_2 from emissions source to suitable reservoirs for storage, reducing the need to use rail or roads. Engineering these pipelines is key to the successful transport of CO_2.

This activity involves working as a team to create a pipeline that can transport a table tennis ball around the classroom.

You will need:

- One sheet of A4 paper each
- A marble, table tennis ball, or golf ball
- A cup or mug

Instructions:

1. Place the cup at the front of the classroom – this is the targer destination for the ball.
2. Think of different ways you can use your sheet of paper to create a pipeline for the ball e.g. a rolled tube, a curved sheet, a flat angled sheet.
3. Using every piece of pipe, create a continuous pipeline to transport the ball from the furthest corner of the classroom to the cup at the front.
4. Experiment with angles, styles of pipe and positioning, aiming to lengthen *and* strengthen your pipeline.

What have you learned?

- Pipelines are only as successful as their component parts.
- There is no room for error in pipeline construction.
- Pipeline construction requires teamwork and communication.

Extension:

- Could you create a pipeline that would enable something to travel uphill?
- What would you have to be sure of if you were transporting a gas or liquid, not a solid ball?

Activity adapted from Wonderville.ca

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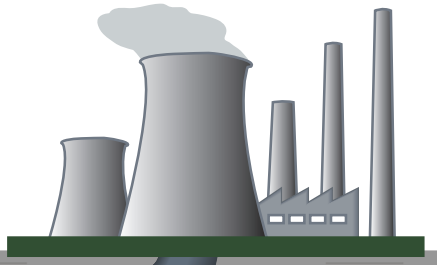
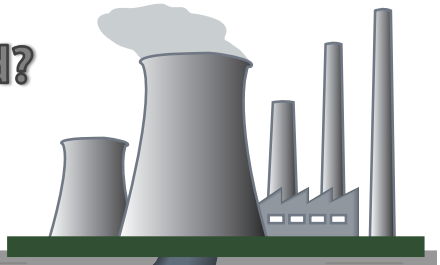


3. What Happens to CO_2 Stored Underground?

What Happens to CO_2 Stored Underground?

Teacher Notes



Activity Description	The students consider and test what happens to CO_2 when it is stored underground for long periods of time.
Time	1 hour
Learning Outcomes	• To understand the basic chemistry of CO_2-rock-water interactions • To understand that over time mineral precipitation secures injected CO_2
Student Organisation	Groups
Materials Needed	What Happens to CO_2 Stored Underground Student Worksheet

Talking Point

What does the CO_2 do underground?
Does it stay in a gaseous state?
Does it move?
Does it react with its surroundings?

What Happens to CO_2 Stored Underground Experiment

You will need:

- A 400–500ml beaker
- 200ml calcium hydroxide solution (limewater)
- A straw per student

Instructions:

1. Fill up the small beaker with 100–200ml of calcium hydroxide solution
2. Make a note of the state of the liquid at the start of the experiment
3. Begin to blow bubbles gently through the straw into the solution – take turns to try this

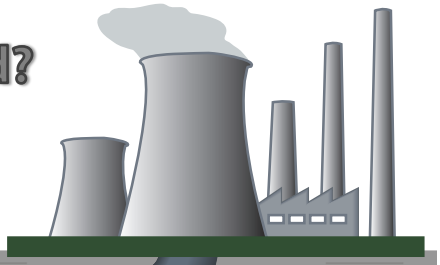
BEWARE: MAKE SURE THE PUPILS DO NOT SUCK – CALCIUM HYDROXIDE IS DANGEROUS TO INGEST – WARN THEM APPROPRIATELY

Extension

If you have somewhere safe to store the beaker for a week then encourage the students to do so. They can come back to the beaker and see that the calcium carbonate will have precipitated out – leaving a 'limestone' layer on the base of the beaker.

What Happens to CO_2 Stored Underground?

Student Worksheet



This experiment will show you one of the things that can happen to CO_2 when it is stored in formations containing salty, undrinkable water.

You will need:

- A 400–500ml beaker
- 200ml calcium hydroxide solution (limewater)
- A straw per student

Instructions:

1. Fill up the small beaker with 100–200ml of calcium hydroxide solution.
2. Make a note of the colour of the liquid at the start of the experiment .
3. Begin to blow bubbles gently through the straw into the solution – take turns to try this.

DO NOT SUCK – CALCIUM HYDROXIDE IS DANGEROUS TO INGEST

4. Make a note of any observed changes in the liquid.

Colour of the liquid before experiment:

Colour of the liquid after the experiment:

When you blow CO_2 into the calcium hydroxide solution, it causes a chemical reaction to occur and calcium carbonate, or limestone, precipitates.

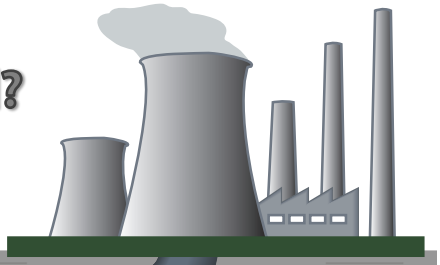
The chemical equation for this reaction is:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

calcium hydroxide + carbon dioxide -> calcium carbonate + water

Follow the path of the CARBON atoms (highlighted in red). They are initially present as a gas, and are then locked into the solid structure of the $CaCO_3$.

Student Worksheet



! When this reaction occurs in the reservoir, CO_2 gas becomes stable calcium carbonate minerals. Scientists predict this process will become more dominant as storage time increases, so the longer the CO_2 is stored the more likely this will occur.

✎ **Extension Experiment**
Will Calcium Carbonate Precipitate Out?

Leave the cloudy solution for a week, and return to observe what has happened.

Write down your observations and draw a diagram of the beaker, explaining the processes that have occurred.

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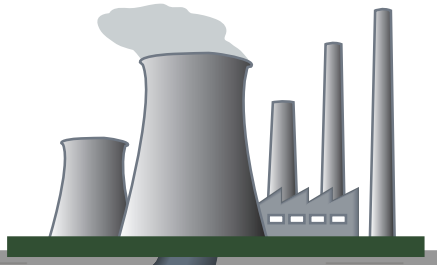
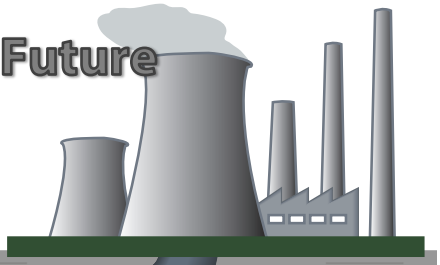


4. Investigating CCS Projects: Past, Present and Future

Investigating CCS Projects: Past, Present & Future

Teacher Notes



Activity Description	The students investigate CCS projects in planning, completed and in action all over the world.
Time	1 hour
Learning Outcomes	• To understand the scale of global CCS • To increase their awareness of the circumstances of past, present, and future CCS projects
Student Organisation	Individual / Pairs
Materials Needed	Computer and internet access, State of CCS: Student Worksheet

The students should visit the Scottish Carbon Capture and Storage Global CCS Map [*http://www.sccs.org.uk/expertise/global-ccs-map*] and work through the questions on the worksheet in this booklet.

The answers to the questions are below (correct at July 2015). Work through the sheet with the students discussing their answers.

Answers

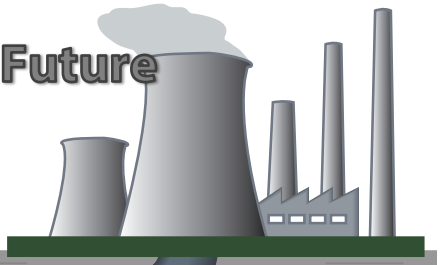
1. North America.
2. Longyearbyen, Svalbard. $110million.
3. Not enough money. Poor public reception to project.
4. Sleipner, offshore Norwegian North Sea, Norway: Saline formation.
   K12-B, offshore Netherlands North Sea, Netherlands: Depleted oil and gas reservoir.
5. Power stations.
6. Saline formations.
7. Because the company can offset the cost of CCS by selling the recovered fuel.

Extension Task:

The final question on the sheet can be extended for fast-working students. The questions asks the students to choose a site and write a report as if they were prospecting their chosen site for CCS. To extend the task, request that the report is presented in a formal style as if it were for a real energy company.

Investigating CCS Projects: Past, Present & Future

Student Worksheet



As of July 2015 there are 55 CCS projects in planning, preparation and in action worldwide
This exercise aims to familiarise you with the locations, types of site and size of storage available.

To complete this activity you will need to access to the Scottish Carbon Capture and Storage Global CCS Map, found online here:
http://www.sccs.org.uk/expertise/global-ccs-map

Spend some time familiarising yourself with the map and what it can tell you, before moving on to answer the following questions:

1. Which continent which boasts the most CCS sites in operation?

_____

2. Name the most northerly CCS site on the map. What is the project estimated to cost overall?

_____

3. On the very east of the map find New Zealand, and the cancelled Southland Coal to Fertiliser Project. What are the two main reasons why this project was cancelled?

_____

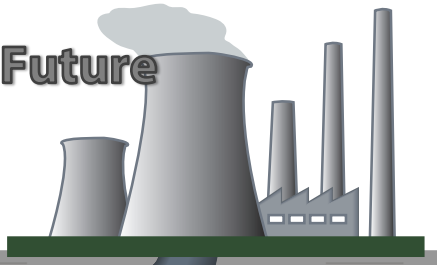
4. Locate the two operational CCS projects closest to the UK. What kind of rock formations do these use for storage?

_____

5. *Select the 'Source' button on the map to only show the emissions source.* In the UK, what is the major source of CO_2 that is stored?

_____

Student Worksheet



6. *Select the 'Storage' button on the map to only show the type of geological storage available.* What type of formation is the most common for storing CO_2 in Europe?

_____

7. EOR stands for enhanced oil recovery. In the USA many CCS sites inject CO_2 to force remaining oil reserves out of low-running reservoirs. Why might this be an advantage to a site?

_____

_____

8. Choose a project from anywhere in the world that is either operational or in planning. Write a summary of its features as if you were reporting back to your company about a prospective site with your findings.

*Project name:*_____

*Summary:*_____

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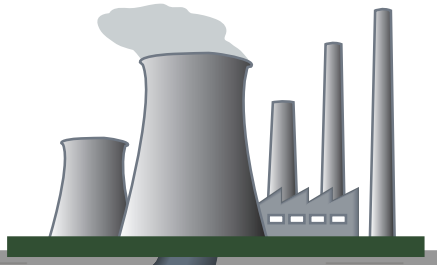
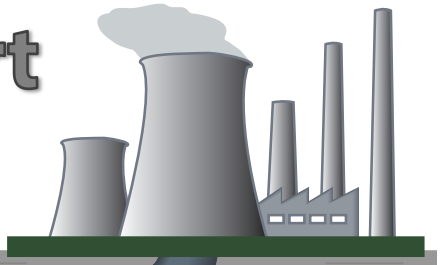
Chapter 2



5. Writing a Scientific Report

Writing a Scientific Report Teacher Notes



Activity Description	The students learn how to write a scientific report.
Time	1 hour
Learning Outcomes	• To write a scientific report • To understand the aims of a scientific report
Student Organisation	Individual
Materials Needed	Writing a Scientific Report Student Worksheet

The students will use the reservoir design experiment they conducted on the day of the Geobus CCS Workshop to structure and form the content of their report.

These reports should be written individually.

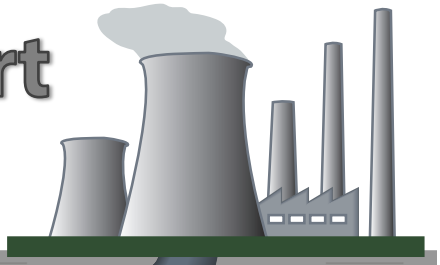
They can use the experiment instructions to help them write the 'Methods' section. Their summary from the day can be used to help write the 'Conclusions' section.

Each student should draft the report before finally writing it up or word processing it to a presentation standard.

Encourage the students to use diagrams and subheadings when they write their report to ensure it is clear and easy to read.

Key Points:
What is the experiment?
Why do we care?
What did they do?
How did they do it?
What did they expect to happen?
What actually happened?
Why this happened? Or why they think this happened?
What other tests could be performed to tell us more?

Writing a Scientific Report Student Worksheet



When we conduct scientific experiments we need to report the results in a clear and consistent format so that the work can be evaluated, compared to other studies, and reproduced in the future.

This exercise will lead you through how to write a scientific report using the carbon capture experiment you conducted as part of the GeoBus Carbon Capture Workshop.

You will need:
Lined paper or computer.

Instructions:
Write one or two sentences for each subheading. Make sure you use clear language and include every detail so that someone could use your report to conduct their own CCS Experiment.

Introduction
What is the experiment?
Why did you do it?

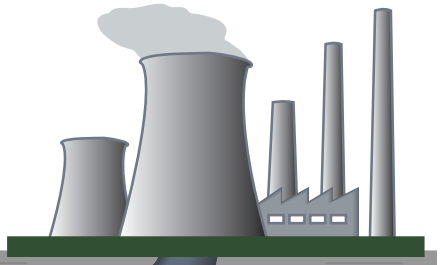
Hypotheses
What did you think the outcome of the experiment would be before you did it?

Methods
What equipment and materials did you use?
How did you conduct the experiment?
Use the experiment instructions to help you write this section.
Include at least one technical drawing of the experiment set-up.

Results
What happened?
If there were numerical results, present them in a table or graph.

Discussion
Were the results what you expected?
What can you conclude?
What are the implications of the results?

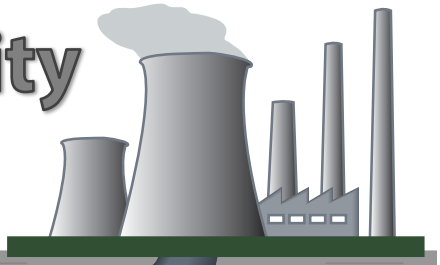
Chapter 2



6. CCS Communication Activity

CCS Communication Activity

Teacher Notes



Activity Description	The students write, produce and perform an informative piece of media about CCS to help educate the public about the things they have learnt.
Time	2 hours minimum – max time flexible
Learning Outcomes	• To recap everything they have learnt about CCS • To think about how to present this information to others • To work as a team to develop an idea • To use media skills to execute the production of this idea
Student Organisation	Groups
Materials Needed	CCS Communication Activity Student Worksheet

This activity requires a minimum of two periods, if a poster or leaflet is chosen as the format of presentation but will require longer if the students are creating a video, podcast, play, etc.

Students who participated in the CO_2degrees CCS Workshop's have created videos of their efforts that can be viewed at http://co2degrees.com/media.
Here are some particularly good examples:
https://www.youtube.com/watch?v=SQDK5Q5G3r0 and
https://www.youtube.com/watch?t=32&v=IF-6-CDv0Fo.
For a chance to get your pupils' work displayed alongside other international examples on the CO_2degrees website, submit your videos, podcasts or posters to *kirsty.anderson@globalccsinstitute.com*

Task

First, the students should spend some time making a note of everything they remember about CCS. They should also record anything they think they need to know more about.

Allow them to spend some time researching using a computer session, or as a homework task so that they have all the information they require to start planning.

Then they will complete a plan as a group, submitting one plan draft for review before continuing to the production. At this stage you can make sure they will answer the two key questions:

1. What is CCS?
2. Why should we care?

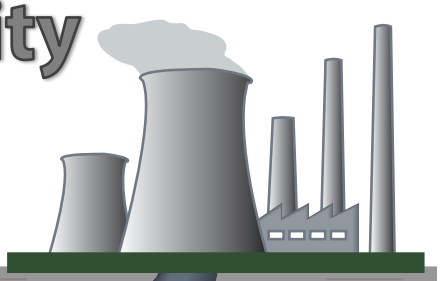
There is a draft story board sheet in this pack which you can distribute to the students to help their planning. Multiple sheets per group may be necessary.

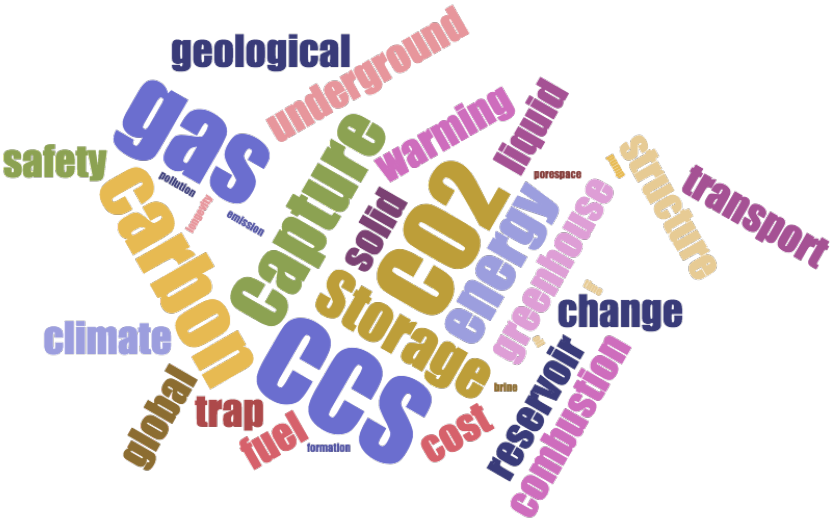
If time allows, each group should write, record and produce their educational media. The final products can be watched, or listened to, as a class.

The process of collating and organising the CCS information to write the piece will strengthen their CCS knowledge base. The additional research session will allow them to identify and then review anything that wasn't clear before.

CCS Communication Activity

Student Worksheet





! Ensuring that people understand CCS is one of the most important jobs of the companies trying to implement it. They need to know the public understand the risks and the benefits associated with each project.

✎ We want you to use what you have leant from the GeoBus CCS workshop to create a video/podcast/song/play/advert to educate others about CCS. Make sure you include:

1. What is CCS?
2. Why should we care?

You should work in groups of 4 – 6.

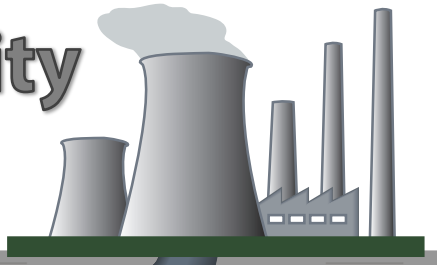
Start by writing down on a large sheet of paper everything your group knows and remembers about CCS.

Make a note of anything you might need to do some more research on – your teacher may give you some time to do this.

Once you understand the main CCS features, make a plan. You can use the story board template on the next page or design your own.

CCS Communication Activity

Student Storyboard



My name is: _____