What To Do With CO_2?

Additional teacher and student resources provided to accompany the GeoBus CCS Workshop.

GeoBus

THE CROWN ESTATE

The Crown Estates manages the UK seabed out to the 12 nautical mile territorial sea limit and, under the 2008 Energy Act, hold the rights for carbon dioxide (CO_2) storage within the Gas Importation and Storage Zone (GISZ), which extends out to the continental shelf. The Crown Estate is an independent commercial real estate business, created by an Act of Parliament, and returns all its profit to the Treasury for the benefit of the nation's finances. It is an active asset manager of the UK seabed, including awarding leases for offshore energy, cables, pipelines and marine aggregates. It has supported GeoBus under its stewardship programme as part of its commitment to good management and creating sustainable added value over the long term. www.thecrownestate.co.uk

Special thanks go to Katy Relph and Megan O'Donnell for the design of this workshop.

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Carbon Capture and Storage Workshop Support Materials

Introduction
This resource has been designed to provide teachers with an introduction to carbon capture and storage (CCS), a carbon emissions reduction technology.

It provides experiments, activities, lessons and homework ideas as well as links to a number of other useful CCS education resources.

Each module in this booklet has been organised so that it can be run as a stand-alone lesson, or can be combined to create a mini CCS project over a few weeks, ideally linked to a GeoBus visit.

Contents Overview
Chapter 1 contains a number of introductory modules designed to expose the students to new vocabulary, concepts and to get them thinking about CCS and why we might need it. Ideally these sessions would be taught before a GeoBus visit.

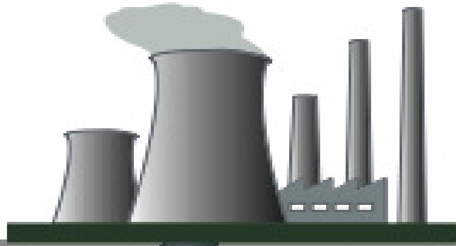
Chapter 2 consists of follow up materials that may be more technically complex and are intended to recap and summarise a topic taught during the GeoBus workshop.

Chapter 3 provides a number of additional, fun CCS education resources that can be utilised as extension tasks for faster students, or as shorter filler modules for use during another lesson.

Chapter 4 contains information about how to find and request further CCS teaching resources, useful links and publications and any other relevant information.

CCS: The Main Idea
Carbon dioxide (CO_2) is a waste gas produced by power plants and industrial processes that compounds climate change by increasing the greenhouse effect. As we use energy and industrial products we have a responsibility to take control of the levels of this gas released into our atmosphere. CCS could help us reduce carbon emissions into the atmosphere by removing CO_2 at source, compressing it and storing it underground in suitable geological formations.

Chapter 1



Getting Started with Carbon Capture and Storage

1.1 Calculating Your Carbon Footprint

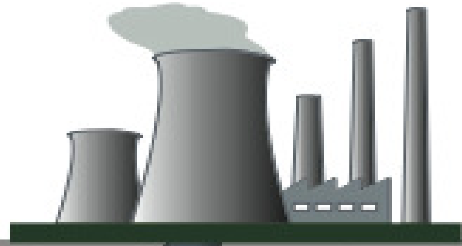
1.2 Energy, Fossil Fuels and Climate Change

1.3 The Carbon Cycle

1.4 How Much CO_2 Can Be Stored in a Tree?

1.5 The CCS Cinema

Chapter 1



1. Calculating Your Carbon Footprint

Calculating Your Carbon Footprint

Teacher Notes

Activity Description	Students learn about CO_2 emissions, what a carbon footprint is and calculate their individual carbon footprint. They consider how behavioural changes could reduce their carbon footprint.
Time	20mins / 40mins
Learning Outcomes	• To understand where carbon emissions come from • To define a carbon footprint • To ascertain ways in which lifestyle changes can affect your carbon footprint
Student Organisation	Individual (calculation) and Groups (discussion)
Materials Needed	Calculating Your Carbon Footprint; Student Worksheet and My Energy Diary

Talking Points
How much electricity do you think you use? How often do you travel by car? Do you travel by aeroplane? Do you eat lots of red meat or imported fruits?

Homework Task
Ask the students to take home the Student Worksheet and My Energy Diary and fill them in over a period of a week.

What is a Carbon Footprint?
A measure of CO_2 emissions attributed to an individual/family/business based on their lifestyle and behavioural choices.

Classroom Activity
In a following lesson use the worksheet answers to complete the carbon footprint calculator online at:
http://mothersagainstclimatechange.com/kidscarboncalculator.php

Ask the children in turn to read out their total carbon footprint values and create a scatter graph to show the class results (either using Excel or by hand).

Talking Points
What kind of behaviour affects your carbon footprint? What could you be doing to reduce yours? What could the school be doing to reduce theirs?

Tip!
Ask the students to leave the first question on the worksheet blank. To determine the distance from the school to each student's house they can measure the distance on Google Maps during the classroom activity. This activity, the graphing exercise plus further discussion will extend the 20 minute session to 40 minutes.

Calculating Your Carbon Footprint

Student Worksheet

What is a carbon footprint?

____

____

____

You are going to calculate your carbon footprint using an online calculator.

In order to complete the calculator next lesson you need to find out the following:

(Use estimates if necessary)

1. How far is your house from the school? [km]
2. How many hours a day do you spend watching TV? [hours]
3. How many hours a day do you spend on the computer? [hours]
4. How many light bulbs are there in your bedroom? [bulbs]
5. What is the wattage of the bulbs in your house? [watts]
6. How many hours do you leave your lights on in summer? [hours]
7. How many hours do you leave your lights on in winter? [hours]

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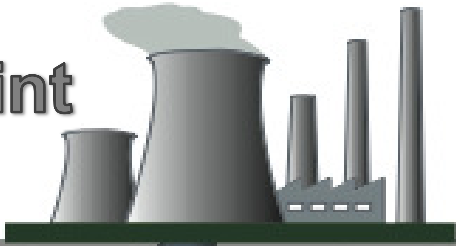
Calculating Your Carbon Footprint

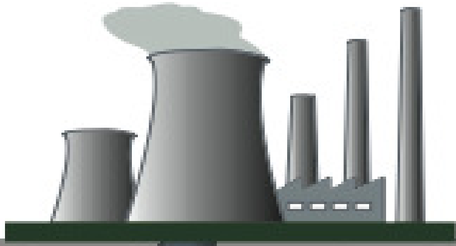
My Energy Diary



Make a note of the following activities for a week to give you an idea of how much energy you are using. Base this on your individual usage.

Day/Energy	Mon	Tues	Wed	Thu	Fri	Sat	Sun
TV (hours)							
Computer (hours)							
Mobile Phone (# of charges)							
Microwave (# of uses)							
Lights (hours)							
Car Journeys (hours and minutes)							
Showers (minutes)							
Hairdryer / Straighteners (minutes)							
Games Console e.g. Playstation / Xbox (hours)							
Other (hours)							

Chapter 1



2. Energy, Fuel and Climate Change

Energy, Fuel and Climate Change

Teacher Notes

Activity Description	The students will learn about energy, where it comes from and consider the consequences of our current energy consumption. They will understand the implications of using fossil fuels for the environment and they will be introduced to CCS in this context.
Time	1 hour
Learning Outcomes	• To understand what energy is • To know where electrical energy comes from • To understand the implications of fossil fuels for the environment • To consider carbon CCS as a CO_2 remediation solution
Student Organisation	Individual
Materials Needed	Energy, Fuel and Climate Change Student Worksheet Make Your Own Power Station Experiment resources (see below)

Talking Point
What do you think energy is?
Is the energy you use to swim, run, and dance the same as the energy used by the TV and the microwave?

Energy Facts:
Energy has lots of different forms.
Energy cannot be created or destroyed, it can only be transferred from one type to another. For example, energy eaten as food is transferred to kinetic energy and energy stored in coal is transferred to heat energy.

Fuel Facts
The energy we use to generate electricity can be created in many ways; most commonly in the UK we burn fossil fuels. Fossil fuels include coal, oil or gas. They form when organic matter such as plants, trees, and animals die and are rapidly buried under many layers of rocks.

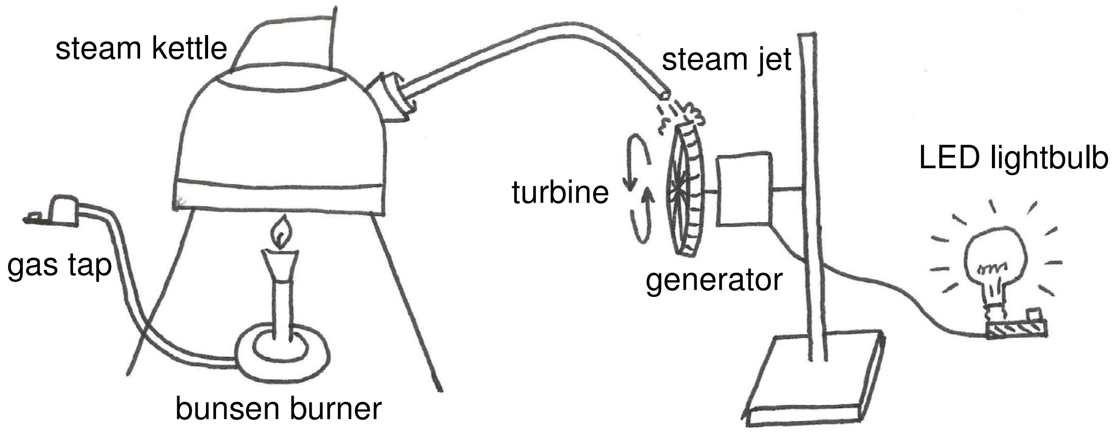
Fossil fuels take millions of years to form. When we take them out of the ground and burn them we rapidly release energy they have been storing for that time. Fossil fuels are an **unsustainable** energy source – we use them faster than they can replenish themselves. **Sustainable** energy sources cannot be exhausted and readily replenish themselves.

Talking Point
Can you think of any problems we might have if we only use sustainable sources of energy?

Hint: Energy companies choose to burn fossil fuels at times when electricity is in high demand. What happens on a wind farm when it is windy, but our demand for energy is not as high?

Classroom Activity
Make Your Own Power Station Experiment
You will need:

- Bunsen burner
- Steam kettle on a stand
- Cork stop for kettle
- Pipe to direct steam
- Turbine
- Generator
- LED lightbulb and connector cable



This experiment illustrates how power is generated in power stations. It also requires the students to think about scale. LEDs require a very small amount of energy to run. Ask the students to imagine the scale at which a power station supplying 500,000 homes must operate.

Talking point:
A by-product of burning fuels is waste CO_2 gas. CO_2 contributes to the greenhouse effect and prevents the sun's rays escaping from our atmosphere, consequently warming the planet. If we want to continue to use fossil fuels we must find a way of dealing with CO_2.

Energy, Fuel and Climate Change

Student Worksheet

Draw three things that use different types of energy. Write down the type of energy in the system and if the energy has changed from one state to another. *eg. heat to light, electrical to heat, etc.*

Energy, Fuel and Climate Change

Student Worksheet

Where does electrical energy come from?

Draw and name three sustainable energy sources.

What problems might we have if we only used sustainable forms of energy?

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Energy, Fuel and Climate Change

Student Worksheet

Draw a sketch of your power station in the box below and label each component.
With a coloured pencil, label each energy change in the experiment.
e.g. potential energy (*fuel*) -> light + heat energy (*flame*)

In the boxes below, brainstorm the advantages and disadvantages of renewable and non-renewable energy types.

Advantages of Renewable Energy	Advantages of Fossil Fuels
Disadvantages of Renewable Energy	**Disadvantages of Fossil Fuels**

Chapter 1

3. The Carbon Cycle

The Carbon Cycle

Teacher Notes

Activity Description	The students will learn about carbon, the carbon cycle, CO_2 emissions, their environmental significance and the role of CCS in this system.
Time	1–2 hour(s)
Learning Outcomes	• To understand the basic chemistry of carbon • To understand the carbon cycle and its components • To understand the imbalance within the carbon cycle due to CO_2 emissions
Student Organisation	Individual / Groups / Class
Materials Needed	Carbon Cycle Student Worksheet, Enhanced Oil Recovery Experiment resources (see below), Carbon Cycle Printable Resources

Key Facts

Carbon is a chemical element with the symbol **C**. Carbon can come in the form of **graphite**, the material in your pencils; **diamonds**, very old and compressed carbon from the ground; or **coal/soot**, the precursor/product of organic combustion.
Carbon is the fourth most abundant element in the universe. It is present in all living things and, second to oxygen, you are made of mostly carbon!

The amount of carbon on earth remains relatively constant, cycling from one reservoir to another from atmosphere to biosphere or ocean and back again. This is called the carbon cycle.

Carbon Cycle Puzzle

You will need:

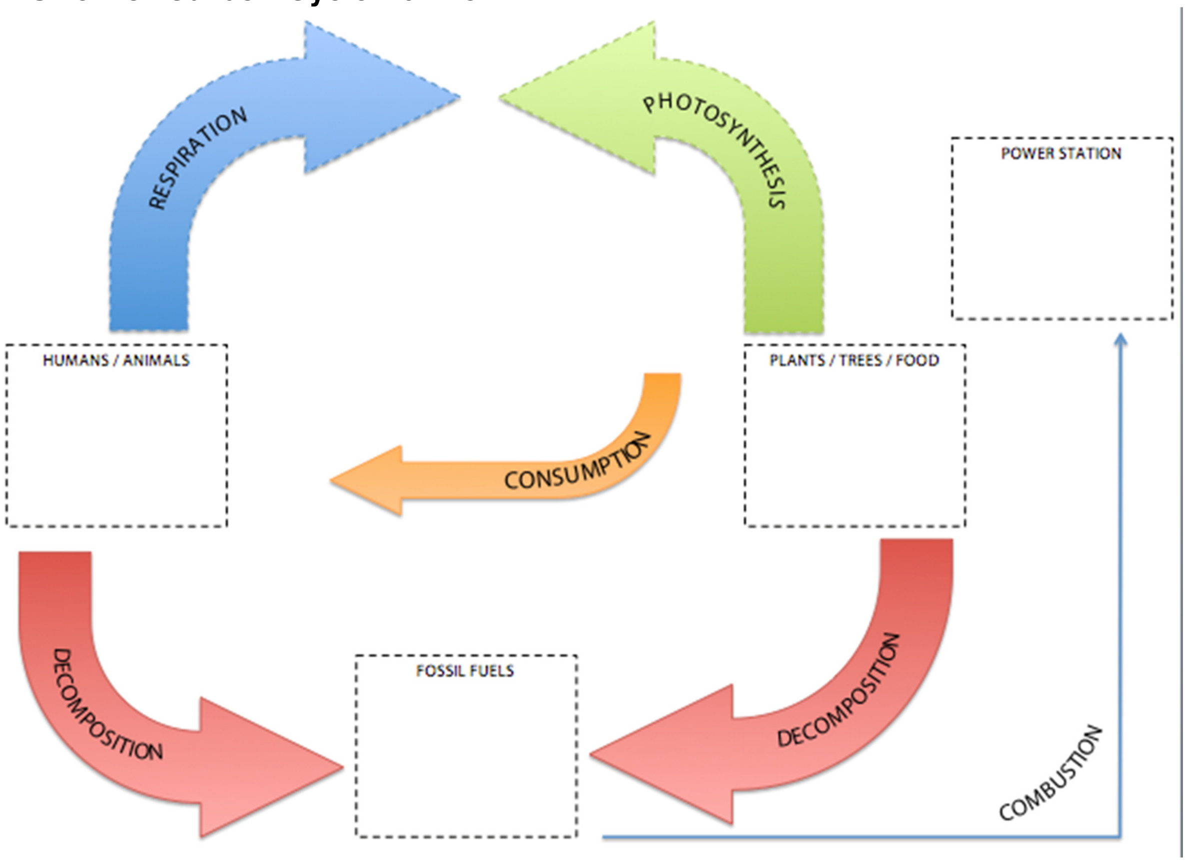
- 2x A4 sheets of blank paper
- pencils and pens
- scissors
- Carbon Cycle Puzzle printouts

Instructions:

1. Draw the carbon exchangers (dashed boxes).
2. Cut out the carbon processes (arrows).
3. Arrange all the pieces in a circle to illustrate the order of the carbon cycle.

The Carbon Cycle
Teacher Notes

Answer for Carbon Cycle Puzzle



Carbon Processes

Photosynthesis – plants and trees take in CO_2 and turn it into carbohydrates to live off
Respiration – humans and animals give out CO_2 when they exhale
Consumption – most foods consumed by humans and animals contain carbon
Combustion – when fossil fuels (hydrocarbons) are burned CO_2 gas is given off

! Modern Problems with the Carbon Cycle

As we take more and more fossil fuels out of the ground and burn them to generate electricity, our contribution of carbon to the atmospheric reserve, in the form of CO_2, increases.

CO_2 is a greenhouse gas. Greenhouse gases help regulate the temperature on earth by providing insulation to the atmosphere – just like thermal underwear does to your body.

The Carbon Cycle
Teacher Notes

Answers to the Carbon Reserves Task (Student Worksheet)

Reserves:	*Carbon Stored* (*gigatonnes*):
Atmosphere	810
Biosphere	1,900
Oceanic	39,000
Mineralogical (rocks)	4000

! Increased atmospheric CO_2 causes the oceans to absorb more carbon. This disrupts the chemistry of seawater, inhibiting the growth of corals and other sensitive marine organisms.

When CO_2 dissolves in raindrops it produces acid rain. Acid rain increases the weathering rates of certain rock types and causes damage to plants and buildings.

CO_2 is a greenhouse gas associated with climate change. It increases the frequency and severity of extreme weather events and makes global temperature rises.

Q: Can you name three consequences of increased atmospheric CO_2?
A: Acid rain, ocean acidification, increased weathering rates, global warming.

Talking Point
How can we reduce or prevent our CO_2 contribution to the atmosphere?

- Use more renewables
- Be more energy conscious
- CCS!

! **What is CCS?**
Scientists have developed a technology that allows the CO_2 emissions from a power plant or industrial source to be captured, transported deep underground and stored in a safe and secure geological location.
This technology has been adapted from a process called enhanced oil recovery (EOR) where CO_2 is pumped underground to increase the pressure in a reservoir to allow the last remaining bits of fuel to be extracted.

✎ **Extension Experiment**
Juice Carton Enhanced Oil Recovery Experiment

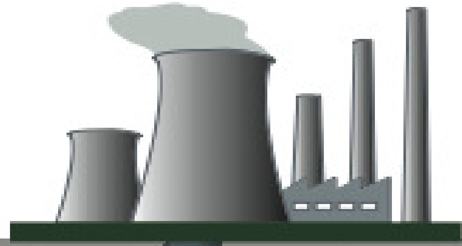
You will need:
1x juice carton per student with straw

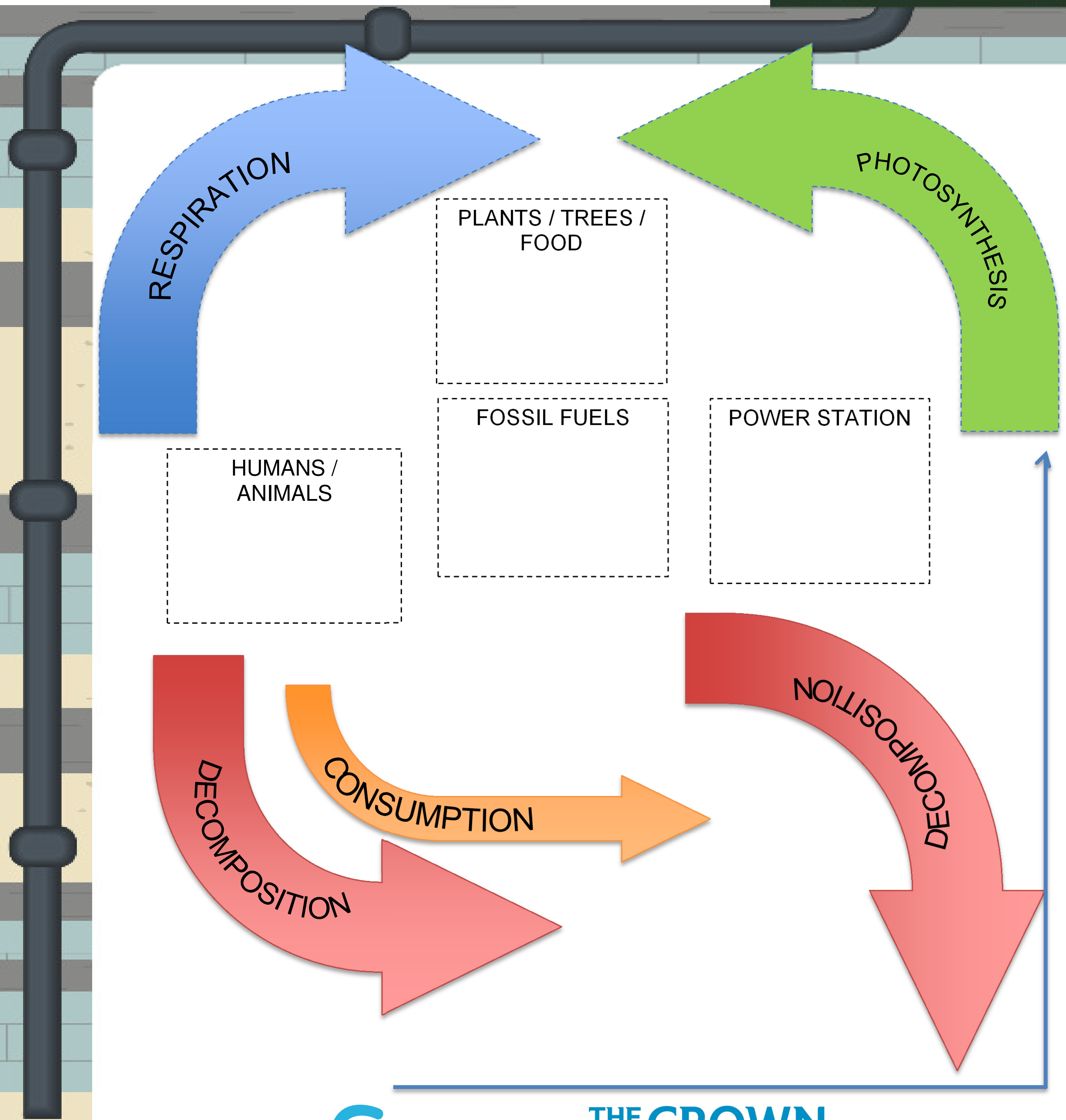
Instructions

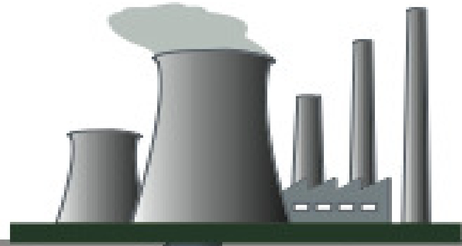
1. The student drinks all but 1cm of the juice in the carton.
2. They then blow gently into the straw to increase the pressure inside the carton.
3. The pressure difference between the inside of the carton and the outside encourages the last of the liquid to travel up the straw and into their mouth.
4. This is the exact principle used in EOR.

The Carbon Cycle

Printable Resources







The Carbon Cycle
Student Worksheet

The chemical symbol for carbon is ____________________

Name three forms of carbon 1____________________

2____________________

3____________________

The process of carbon circulating around the biosphere, atmosphere and oceans is called the ____.

Carbon Cycle Puzzle
You will need:

- 2x A4 sheets of blank paper
- pencils and pens
- scissors
- Carbon Cycle Puzzle printouts

Instructions:

1. Cut each piece of paper into four equal sheets.
2. On each sheet draw one of the following carbon exchangers:
    a. Atmosphere
    b. Plants/Trees
    c. Humans/Animals
    d. Fossil Fuels
    e. Power Station
3. Write the name of the exchanger below the picture.
4. Use the cards you have just made and the printouts of arrows and processes to arrange the components of the carbon cycle so that they make a complete circle.

The Carbon Cycle
Student Worksheet

When it is not part of the exchange cycle, carbon is stored in reserves. Match each of the four reserves with the amount of carbon stored in them on average at any one time.

Reserves	*Carbon Stored (gigatonnes)*
Atmosphere	39,000
Biosphere	810
Ocean	1,900
Minerals	4,000

The natural carbon cycle is balanced; each component exchanges with another so the reserves remain mostly constant. What man-made activity is disturbing the natural cycle?

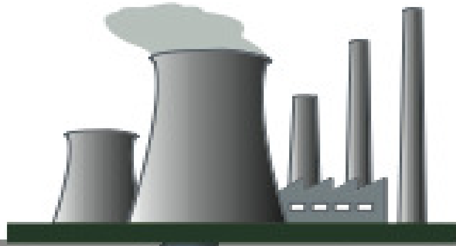
____

When we take ______________ __________ out of the ground, and burn them to create electricity and heat, we emit _________________ __________ gas. ___________gas contributes to global warming by preventing the ________________rays from escaping into ___________________.

WORD BANK: carbon dioxide, CO_2, fossil fuels, space, sun's

The Carbon Cycle

Student Worksheet



Write down three consequences of more CO_2 in the atmospheric reserves.

If we want to keep using fossil fuels we need to come up with a solution to reduce the amount of CO_2 in our atmospheric reserve.

Carbon Capture and Storage

Scientists have come up with a technology that ________________ CO_2 gas as it is emitted and ____________________ it to suitable geological storage sites where it is pumped _________to be stored.

WORD BANK: transports, underground, captures

Extension Experiment
Juice Carton Enhanced Oil Recovery
You will need:
1x carton of juice
1x A4 sheet to write up the experiment results

Listen carefully to your teacher for instruction before conducting this experiment.

Chapter 1

4. How Much CO_2 Can You Store in a Tree?

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How Much CO_2 Can You Store in a Tree?

Teacher Notes

Activity Description	The students find a tree within the school grounds to measure. The students measure the tree and record their results on scrap paper. Back in the classroom, they transfer these results onto the worksheet provided to help them make the calculations.
Time	1 hour
Learning Outcomes	• To understand that trees are a natural carbon sink • To calculate the amount of carbon stored in a real tree • To understand the implications of carbon sinks and sources
Student Organisation	Individual (calculation) and Groups (discussion)
Materials Needed	How Much CO_2 Can You Store in a Tree Student Worksheet, a tape measure **or** a metre stick and some string

Task

This task allows us to quantify the amount of carbon, and equivalent CO_2 gas, stored in a tree.

Talking Points

Trees are a natural carbon sink. Get the students to think about other CO_2 sources and sinks.

Sources:

Fossil fuels, leaks, biological sources

Sinks:

Oceans, atmosphere, plants, land, precipitation of carbonate minerals in rocks

Outdoor Instructions

1. Get the students to work in pairs. One student measures from the ground 1.3m (or chest height) up the trunk of the tree, the other marks their place. Then the second student measures the circumference of the tree at this height. The height ensures a fair representation of the tree circumference is recorded.
2. The students record each measurement, both times on scrap paper.

Talking Points

Get the students to think about what might affect the amount of carbon stored; do older trees store more carbon; does the type of tree make a difference; does the environment that the tree is in contribute to amount of carbon stored?

Classroom Instructions

Get the students to follow the instructions on the handout to complete the worksheet – there is a worked example at the end of this pack to help.

How Much CO_2 Can You Store in a Tree?

Teacher Notes

Discussion

Talk to the students about the link between trees and carbon: that carbon is locked up within trees but when trees are burnt for firewood, that carbon is released. Furthermore if the tree is buried and subject to heat and pressure over millions of years, the tree will become coal. Coal is a fossil fuel and burning fossil fuels releases CO_2 to the atmosphere. An increase in CO_2 in the atmosphere will lead to global warming.

Summary

Ask the students to think about how effective planting trees is, as a means to reduce carbon concentrations in the atmosphere. Consider: the rate at which trees grow, their environmental surroundings, the amount of carbon taken in from tree to tree and the lifetime of a tree. We may need a more immediate solution.

Worked Example

Tree circumference 1		Tree circumference 2	
132	cm	*144*	cm

A) Calculate the average of your two measured circumferences.

Why? This removes human bias from the measurements. Human bias is when the measurement is affected by the person who took it.

Tree circumference 1		Tree circumference 2		Number of measurements
132	+	*144*	÷	*2*

= *138* cm

How much CO_2 can be stored in a tree?

Teacher Notes

Average tree circumference		Estimated dry weight	
138	cm	*1964*	kg

The estimated dry weight of the tree is a) the closest value to the average tree circumferences in the references figures or b) read off the graph, whichever you prefer your students to do.

B) Calculate the weight of carbon stored in the tree.

How? Most living things are half carbon. Therefore we can estimate the carbon content by dividing the dry weight of the tree by 2. See reference figures for dry weight estimates.

Estimated dry weight		Weight of carbon in tree	
1964	÷ 2 =	*982*	kg

Weight of carbon in tree		Equivalent weight of CO_2	
982	kg	*3603.9*	kg

C) Calculate the equivalent weight of CO_2 gas stored as carbon in the tree.

How? We can calculate the equivalent weight of CO_2 stored as carbon in the tree by multiplying the estimated weight by the constant 3.67, as given by www.forestsforthefuture.co.uk.

Weight of carbon in tree		Equivalent weight of CO_2	
982	x 3.67 =	*3603.9*	kg

How much CO_2 can be stored in a tree?

Teacher Notes

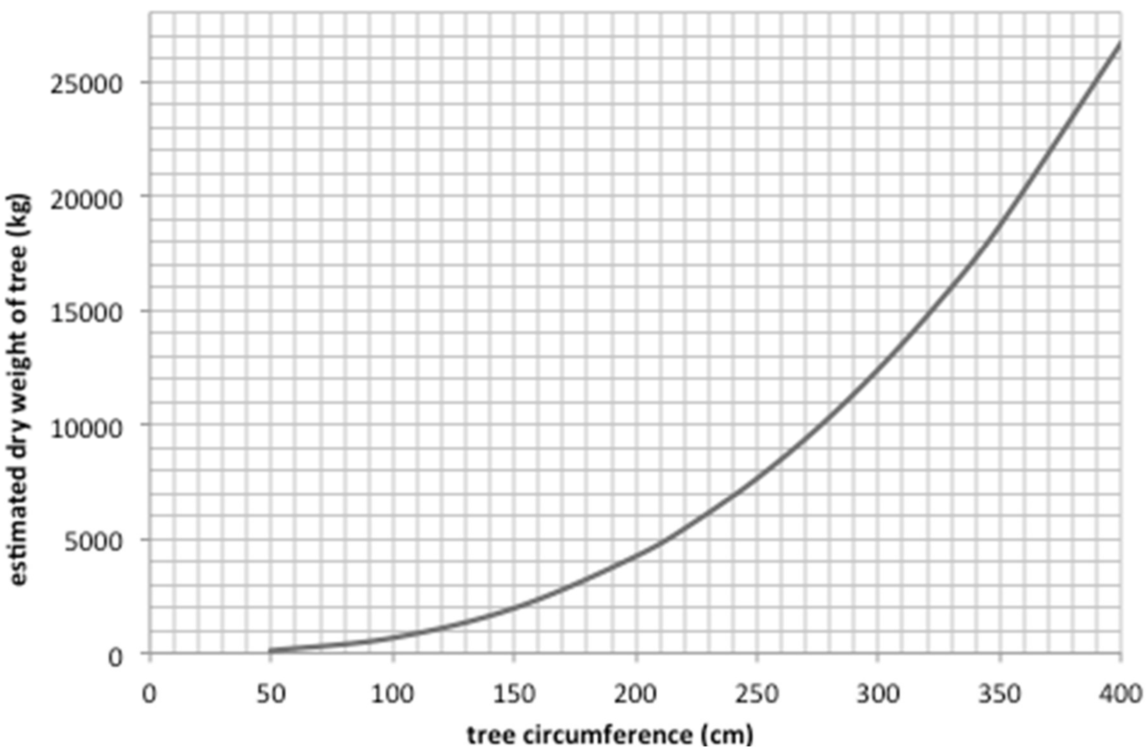
Reference Table: Dry Weight of a Tree

Circumference (cm)	Tree dry weight (kg)
50	106
100	668
150	1964
200	4221
225	5771
250	7641
275	9842
300	12410
325	15350
350	18700
400	26674

These values, provided by ***Forest Research****, are for an individual hardwood tree in Westonbirt Arboretum. They should be used as an* ***example****.*

Trees will grow at different rates across the UK depending on, for example, the species, soil, drainage, slope aspect and climate conditions.

Reference Graph: Dry Weight of a Tree



How much CO_2 can be stored in a tree?

Teacher Notes

! Plants, flowers and trees absorb CO_2 from the atmosphere. They use this CO_2 gas during photosynthesis to create carbohydrates, which help them grow. This process locks away CO_2 in the plant structure and helps regulate the levels of CO_2 in our atmosphere. The size of the tree directly relates to the amount of CO_2 locked inside. Older trees store more CO_2.

This activity consists of a field experiment. You and a partner measure a nearby tree before using some simple calculations to estimate the amount of CO_2 gas secured by the tree.

How Much CO_2 Can Be Stored in a Tree Experiment
You will need:

- A soft tape measure or/ string and a metre rule
- This worksheet
- A research partner
- A nearby tree

✎ **Field Instructions:**

1. Take turns in pairs.
2. Measure 1.3m from the ground up the trunk of the tree and hold your finger on that point.
3. Ask your partner to measure around the trunk of the tree at the height you are holding your finger. Record your results on scrap paper and transfer these into your worksheet in class. (You should have two measurements, yours and your partner's).

✎ **Classroom Instructions:**

1. Copy your tree measurements over from your scrap paper to the worksheet.
2. Calculate the average tree circumference.
3. Use this to estimate and record the dry weight of the tree using the table or the graph provided.
4. Calculate and record the weight of carbon stored by the tree.
5. Calculate the equivalent weight of CO_2 stored in the tree as carbon, over the tree's lifetime of growth.

How Much CO_2 Can Be Stored in a Tree?

Student Worksheet

Tree circumference 1		Tree circumference 2	
	cm		cm

A) Calculate the average of your two measured circumferences.
Why? This removes human bias from the measurements. Human bias is when the measurement is affected by the person who took it.

Tree circumference 1		Tree circumference 2		Number of measurements
	+		÷	

= ______ cm

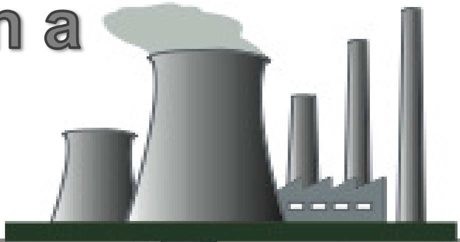
Average tree circumference		Estimated dry weight	
	cm		kg

B) Calculate the weight of carbon stored in the tree.
How? Most living things are half carbon. Therefore we can estimate the carbon content by dividing the dry weight of the tree by 2. See reference figures for dry weight estimates.

Estimated dry weight			Weight of carbon in tree	
	÷ 2	=		kg

How Much CO_2 Can Be Stored in a Tree?

Student Worksheet



Weight of carbon in tree

[ ] **kg**

C) Calculate the equivalent weight of carbon dioxide gas stored as carbon in the tree.

How? We can calculate the equivalent weight of CO_2 stored as carbon in the tree by multiplying the estimated weight by the constant 3.67, as given by www.forestsforthefuture.co.uk.

Weight of carbon in tree		**Equivalent weight of CO_2**	
[ ]	x 3.67 =	[ ]	**kg**

Equivalent weight of CO_2

[ ] **kg**

Reference Table: Dry Weight of a Tree

Circumference (cm)	Tree dry weight (kg)
50	106
100	668
150	1964
200	4221
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300	12410
325	15350
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400	26674

*These values, provided by **Forest Research**, are for an individual hardwood tree in Westonbirt Arboretum. They should be used as an **example**.*

Trees will grow at different rates across the UK depending on, for example, the species, soil, drainage, slope aspect and climate conditions.

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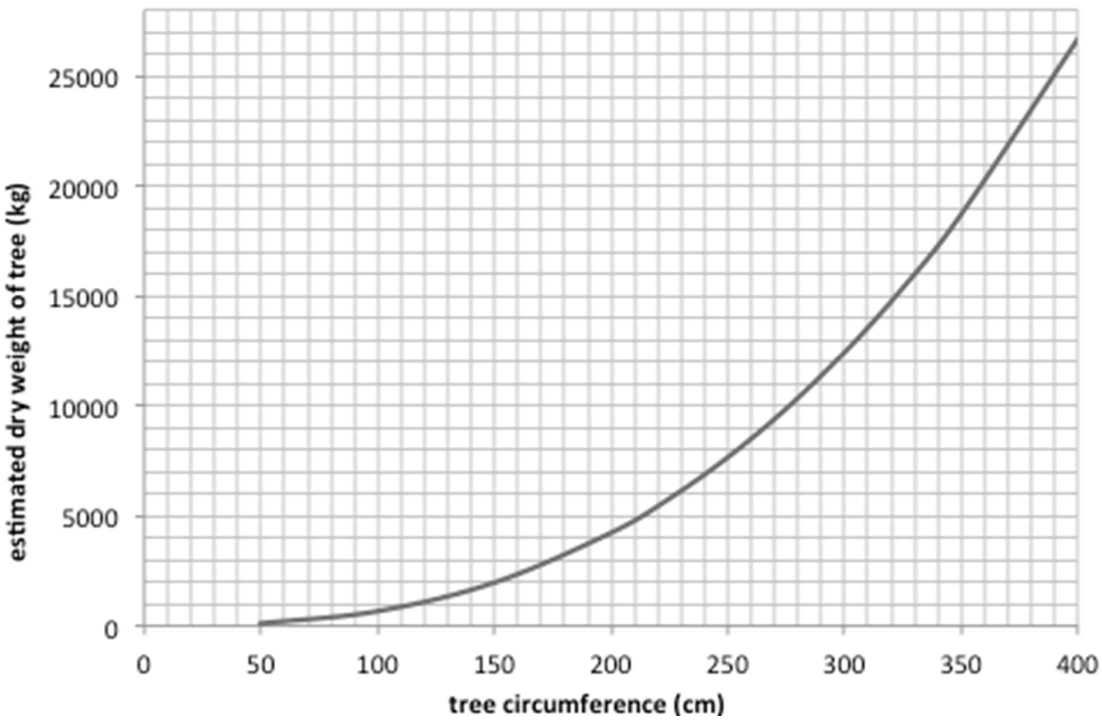
How much CO_2 can be stored in a tree?

Student Worksheet

Reference Graph: Dry Weight of a Tree



✎ So, you have just calculated that the tree you measured contains [ ] kg carbon, and [ ] kg equivalent weight of CO_2 gas.

! For scale

The average UK coal-fired power station emits 1kg of CO_2 per kWh generated.
1kWh of electricity will power:

- ONE **dishwasher** for 1 hour
- ONE **TV** for 3 hours
- ONE **games console** for 5 hours
- ONE **laptop** for 22 hours
- ONE **hoover** for 2 hours
- ONE **freezer** for 4 hours
- ONE pair of **straighteners** for 11 hours
- ONE **aquarium** for 33 hours

! Note

A molecule of CO_2 gas contains two (relatively heavy) oxygen atoms for every single carbon atom, so a single CO_2 molecule weighs more than a single carbon atom.

Chapter 1

5. The CCS Cinema

The CCS Cinema

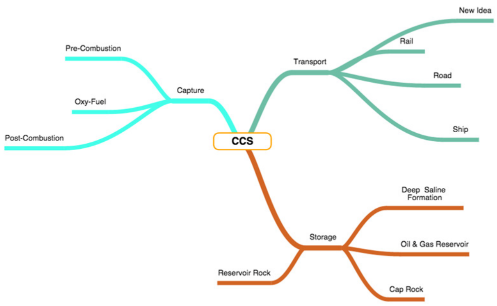
Teacher Notes

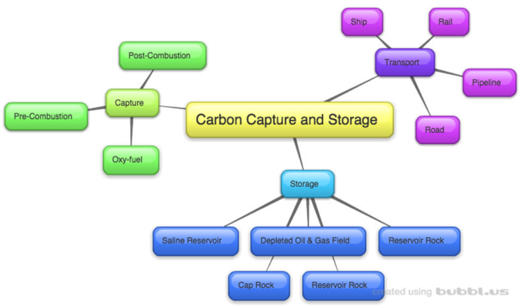
Activity Description	The students learn about the basic principles and terminology of the carbon cycle, CO_2 emissions, and carbon capture and storage technology through a series of videos. They learn to create mind maps to retain information from these videos.
Time	1 hour
Learning Outcomes	• To understand what CO_2 is, where it comes from and why it is a problem • To create a Mind Map • To understand the basics of the carbon cycle • To understand basic carbon capture and storage terminology
Student Organisation	Individual or groups
Materials Needed	A4 paper and coloured pencils ***or*** computer and internet access CCS Cinema Student Worksheet

✎ Classroom Task

The students use computers to access and watch the four videos listed below. They then generate mind maps to summarise the important information from each video. The students can watch each video as many times as is required.

Mind maps can be drawn by hand or using an online mind mapping tool such as *bubbl.us* ***or/*** *drichard.org/mindmaps/#* illustrated in the examples below.





The students should complete the questions on the CCS Cinema Student Worksheet once they are happy their mind maps contain all the relevant information.

Video Links:

- More Energy, Less CO2. Shell.
  https://www.youtube.com/watch?v=mQ8yfVV9i0U
- Climate 101, with Bill Nye.
  https://www.youtube.com/watch?v=3v-w8Cyfoq8
- Capturing Carbon to Store it Underground, Shell.
  https://www.youtube.com/watch?v=f3T9B83rZss
- What to do with CO2?
  http://www.wonderville.ca/asset/whattodowithCO2

The CCS Cinema
Student Worksheet

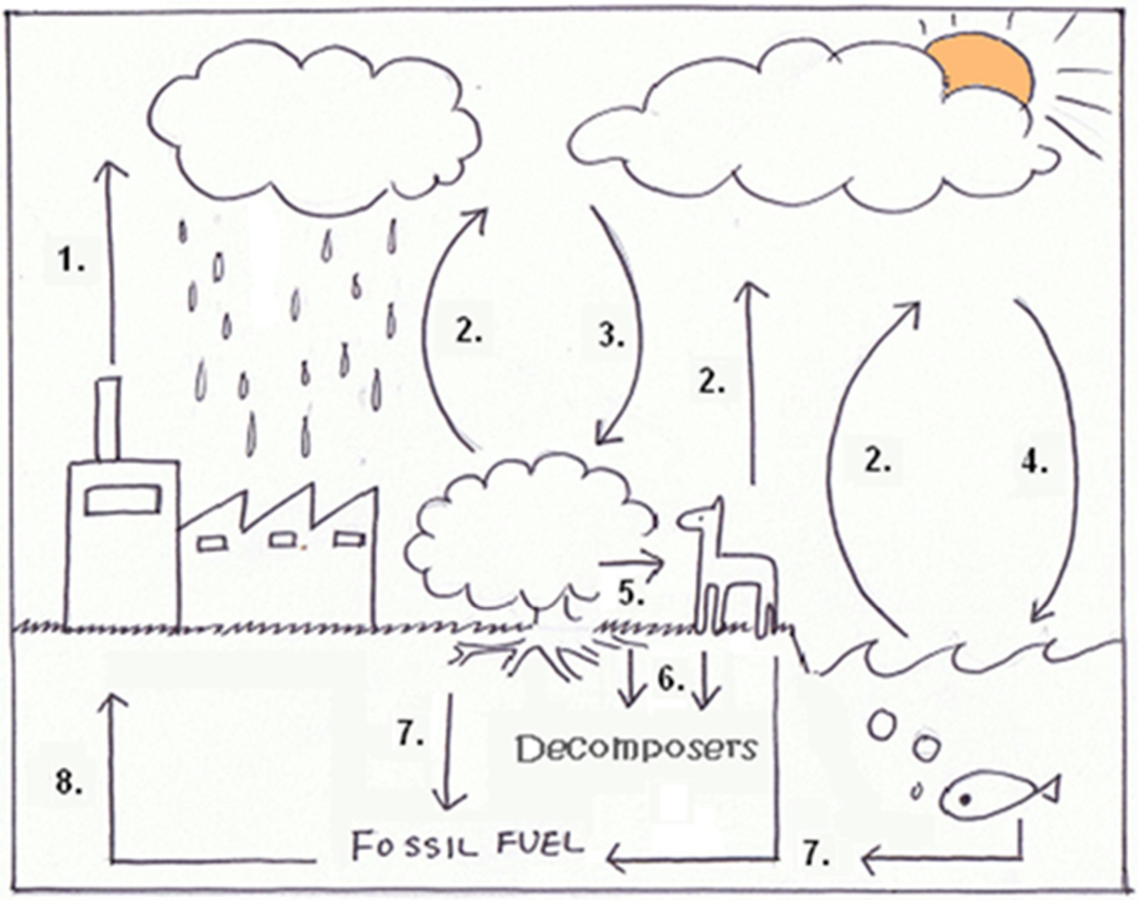
Mind maps are a good way of presenting information you need to remember. They use colours and connected lines to help your brain to link and recall tricky concepts.

Watch the following videos and make an A4 mind map for each one.

- More Energy, Less CO_2. Shell.
- Climate 101, with Bill Nye.
- Capturing Carbon to Store it Underground, Shell.
- What to do with CO_2?

Use your mind maps to help you answer the following questions:

1. Where can you find carbon?



Artwork by Julie Han

The CCS Cinema

Student Worksheet

2. Can you match the numbers to the processes of the carbon cycle illustrated on the previous page?

1	decomposition
2	respiration
3	extraction
4	fossilisation
5	oceanic exchange
6	photosynthesis
7	consumption
8	combustion

3. What is the problem with CO_2 ?

4. Can you draw a molecule of CO_2?

5. Can you name three types of fossil fuel?

6. Can you describe carbon capture and storage in three sentences?

Chapter 2

Following on with Carbon Capture and Storage

2.1 Saying YES to CCS?

2.2 Paper Pipelines

2.3 What Happens to CO_2 Stored Underground?

2.4 Investigating CCS: Past, Present and Future

2.5 Writing a Scientific Report

2.6 CCS Communication Activity

Chapter 2

1. Saying YES to CCS?

Saying YES to CCS?

Teacher Notes

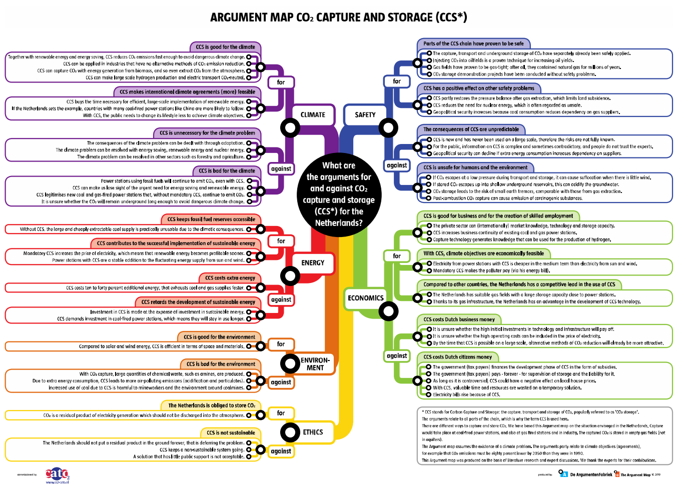
Activity Description	Students consider the advantages and disadvantages of carbon capture and storage. They have to discuss and agree as a group how to divide the factors into advantages and disadvantages.
Time	1 hour
Learning Outcomes	• To consider the advantages and disadvantages of carbon capture 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.



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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:

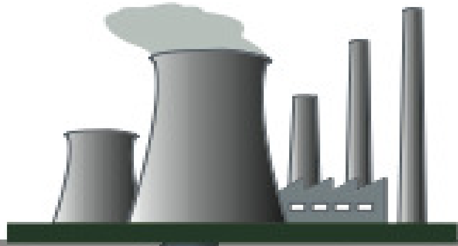
- 4x A4 sheets of paper
- 1x sheet of A3 paper
- 1x scissors
- pencils and pens
- 2x baskets/buckets/bins/boxes

✎ **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

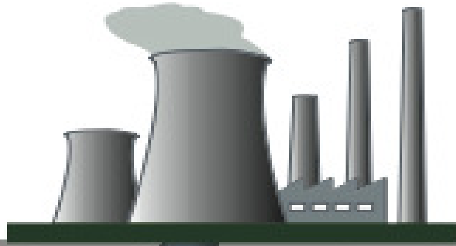
Encourage the students to experiment with angles, height differences and a variety of materials to see what effect these have on the speed and stability of the transport of the ball.

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.

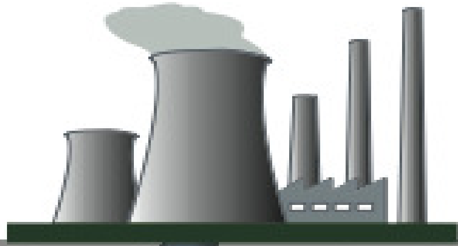
What have you learned?

- 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

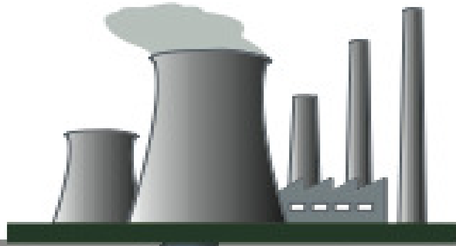


Chapter 2

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

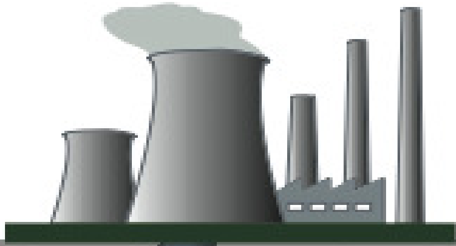
BEWARE: MAKE SURE THE PUPILS DO NOT SUCK – CALCIUM HYDROXIDE IS DANGEROUS TO INGEST – WARN THEM APPROPRIATELY

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 $CaCO_3$.

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What Happens to CO_2 Stored Underground?

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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Chapter 2

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?

____

Investigating CCS Projects: Past, Present & Future

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:*____

____

____

____

____

____

____

____

____

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.

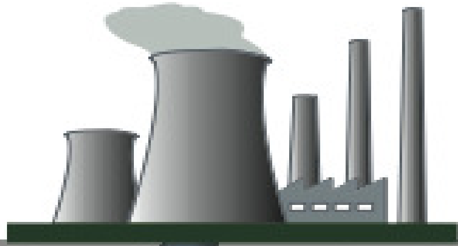
Introduction
What is the experiment?
Why did you do it?

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

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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?**

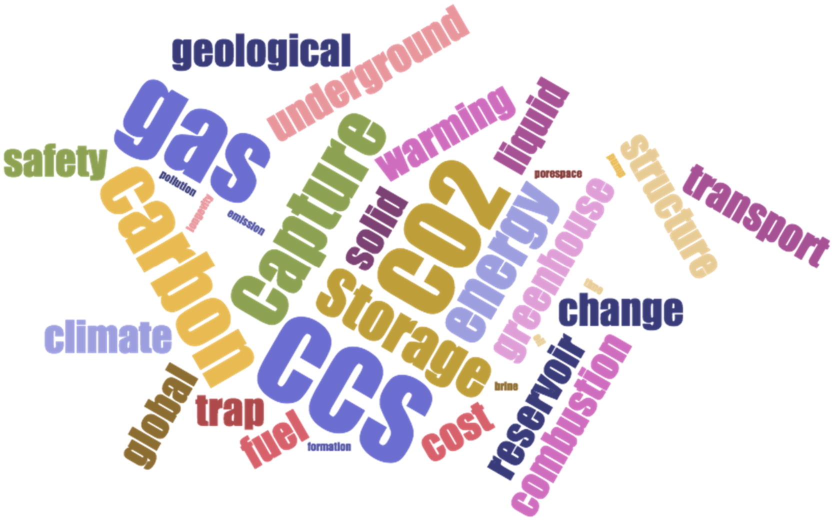
There is a draft story board sheet in this pack which you can distribute to the students to help their planning. Multiple sheets per group may be necessary.

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: ________________________________

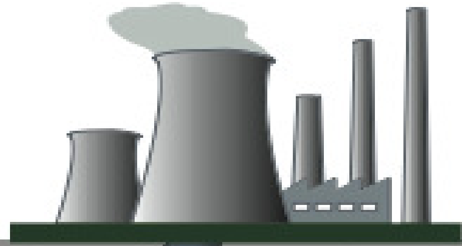
Chapter 3

Additional Resources

3.1 Climate Change Snakes and Ladders

3.2 CCS Happy Families

3.3 CCS Careers Top Trumps



Chapter 3

1. Climate Change Snakes & Ladders

Climate Change Snakes & Ladders

CCS Extension Tasks

Activity Description	Students design their own snakes and ladders board with positive and negative actions contributing to CO_2 emissions.
Time	45–60minutes
Learning Outcomes	• To understand actions that contribute to reducing or increasing CO_2 emissions.
Student Organisation	Groups of 2–6
Materials Needed	Board printout, dice, and a counter for each child.

Climate Change Snakes & Ladders
Taken from CO_2degrees Challenge, 'Host your own CCS Education Workshop'.
http://co2degrees.com/learn-more/educators

✎ **Instructions**
This game is for 2–6 players.

1. You will need an A3 colour printout of the board, dice and a counter for each player (you can cut-out counters below or you could recycle some old buttons).

2. To start, each player must roll the dice. The player with the highest score goes first.

3. To play, each player rolls the dice and moves to the corresponding square on the board. If a player lands on a square describing an action that is good for the environment, they move up the ladder to a higher square. If a player lands on a square describing an action that is bad for the environment, they slide down the snake's body to a lower square.

4. The winner is the first player to reach square 100!

Cut out the counters provided on the printout and fold and glue the dice.
If you have an ipod/pad, you can use the dice app from:
https://itunes.apple.com/en/app/dice/id429412843?mt=8#

Chapter 3

2. CCS Happy Families

CCS Happy Families

CCS Extension Tasks

Activity Description	Students play Happy Families after drawing pictures of the words on the vocabulary cards. This game can be played before or after the GeoBus workshop.
Time	45–60minutes
Learning Outcomes	• To become aware of or consolidate CCS vocabulary.
Student Organisation	Groups of 3–4
Materials Needed	Card printouts, scissors, colouring pencils

Carbon Capture and Storage Happy Families

Adapted from CO_2degrees Challenge, ‘Host your own CCS Education Workshop’.

Task

This game is played to the rules of Happy Families, for 3–4 players.
The game requires a pack of 56 cards, grouped into 14 sets of four.
The students are given a number of sets of families and asked to draw a picture of the term on the card before starting the game.

Instructions

The aim of the game is to collect all four cards in a group, for example to complete the Greenhouse Gases group you will need to collect the following four cards: water vapour, carbon dioxide, methane and nitrous oxide.

1. You will need A4 colour printouts of the card sheets and scissors (optional: backing card and glue).
2. To start, carefully cut-out all 56 cards (you can stick them onto cardboard to make them last longer) and shuffle them well. Deal the cards out to each player. Players can look at their cards but must not show them to others.
3. To play anybody who has been lucky enough to be dealt a complete set of four cards should put these cards face down in the centre before the game begins.
4. The player on the dealer’s left goes first. This player (Player 1) can ask any other player for a card so long as they already hold at least one card in the set. If Player 2 does not have the card asked for by Player 1, then it is Player 2’s turn to ask any player for a card that they are looking for. If Player 2 does have the card asked for by Player 1, they have to pass it to Player 1 and Player 1 can then ask another player for a different card. Once a player forms a complete set of four cards, they place the set face down in the centre of the group.
5. The winner is the first player to get rid of all their cards.

Chapter 3

3. CCS Careers Top Trumps

GeoBus THE CROWN ESTATE

CCS Careers Top Trumps

CCS Extension Tasks

Activity Description	Students play careers tops trumps. Careers are based around geological careers.
Time	15–30minutes
Learning Outcomes	• To become aware of the different types of jobs in the geological and CCS sector. • To understand the different aspects about jobs in the geological sector.
Student Organisation	Groups of 2–6
Materials Needed	Card printouts, scissors.

Carbon Capture and Storage Careers Top Trumps

Instructions adapted from *www.toptrumps.com.*

Instructions

This game is for 2-6 players.

1. To start the game, shuffle and deal all the cards face down. Each player holds their cards so that they can see the top card only.

2. The player to the dealer's left starts by reading out a category from the top card (e.g. Teamwork Factor, value 5) The other players then read out the same category from their cards. The one with the best or highest value wins, and that player collects all the top cards, including their own, and moves them to the bottom of their pile. It is then their turn again to choose a category from the next card.

3. If two or more cards share the top value or data is not available for that particular subject then all the cards are placed in the middle and the same player chooses again from the next card. The winner of the hand takes the cards in the middle as well.

4. The person with all the cards at the end is the winner.

Chapter 4

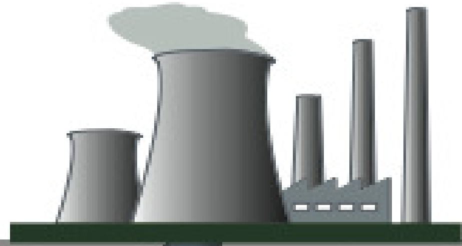
Links to other materials

4.1 Resources

4.2 Websites and Games

4.3 Videos

Chapter 4



1. Resources

Resources

Carbon Capture and Storage in a Box
http://www.yecscotland.co.uk/secondary_school_resources.html

Shell, the Scottish Earth Science Education Forum and the University of Edinburgh have developed the Carbon Capture and Storage in a Box resource. Aimed at S1/S2, the project involves students in hands-on experiments as chemists, geologists, engineers and environmental managers. Activities cover a range of disciplines including science, technology, numeracy and maths, literacy and social sciences. Schools can request a free kit along with a half-day training workshop for teachers. For further information contact yesc@scdi.org.uk.

Host Your Own CCS Education Workshop
http://co2degrees.com/learn-more/educators

CO_2degrees Challenge offer:

- hands-on experiments
- energy in a low-carbon future resources
- materials to host your own CO_2degrees education workshop

This workshop is designed for educators looking to introduce CCS and the wider energy/climate change context into lessons/curriculum, and for those wanting to hold a CO_2degrees education workshop at a school or community group. CO_2degrees can also connect you with other science, climate and energy educators from around the world.

Chapter 4

2. Websites and Games

Websites & Games

Websites

CO_2degrees Challenge: http://co2degrees.com/

Global CCS Institute: http://www.globalccsinstitute.com/

International Energy Agency: http://www.iea.org/topics/ccs/

Commonwealth Scientific and Industrial Research Organisation (CSIRO): http://www.csiro.au/Outcomes/Energy/Energy-from-coal/Carbon-Capture-Storage.aspx

United States Environmental Protection Agency: http://www.epa.gov/climatechange/ccs/

Carbon Capture and Storage Association (UK): http://www.ccsassociation.org/

CO_2 Cooperative Research Centres: http://www.co2crc.com.au/

Zero Emissions Platform: http://www.zeroemissionsplatform.eu/

NASA Climate Kids: http://climatekids.nasa.gov/carbon/

CO_2 Capture Project: http://www.co2captureproject.org/a/digital_in_depth_tool.html

CCS Browser: http://www.ccsbrowser.com/#

Zero CO_2 : http://www.zeroco2.no/

Global CCS Institute Map: http://www.globalccsinstitute.com/projects/large-scale-ccs-projects#map

Games

The Carbon Cycle Game: http://www.windows2universe.org/earth/climate/carbon_cycle.html

3. Videos

Videos

Videos

Zero Emissions Platform
The Hard Facts Behind Carbon Capture and Storage
https://youtu.be/aHtbDmzjYgg

Zero Emissions Platform
Safe Storage: Closing the Carbon Loop - CO_2 Capture and Storage
https://www.youtube.com/watch?v=GglSLuWP5cM

New Gen Coal
Carbon Capture and Storage
https://vimeo.com/16307994

CCS Education
Carbon Capture and Storage
https://www.youtube.com/watch?v=Cm4dHLflK08

Crash Course
The Hydrologic and Carbon Cycle
https://www.youtube.com/watch?v=2D7hZpIYlCA

Shell
Take a journey more than 2000 metres underground with Shell's Carbon Capture and Storage project
https://www.youtube.com/watch?v=sqkXYKRFkFc

Earth Institute
Carbon Capture Sequestration and Reuse, Webisode 1: The Basics
https://www.youtube.com/watch?v=3dm1esCpzR0

Appendix A

Curriculum Links

Curriculum for Excellence (Scotland)

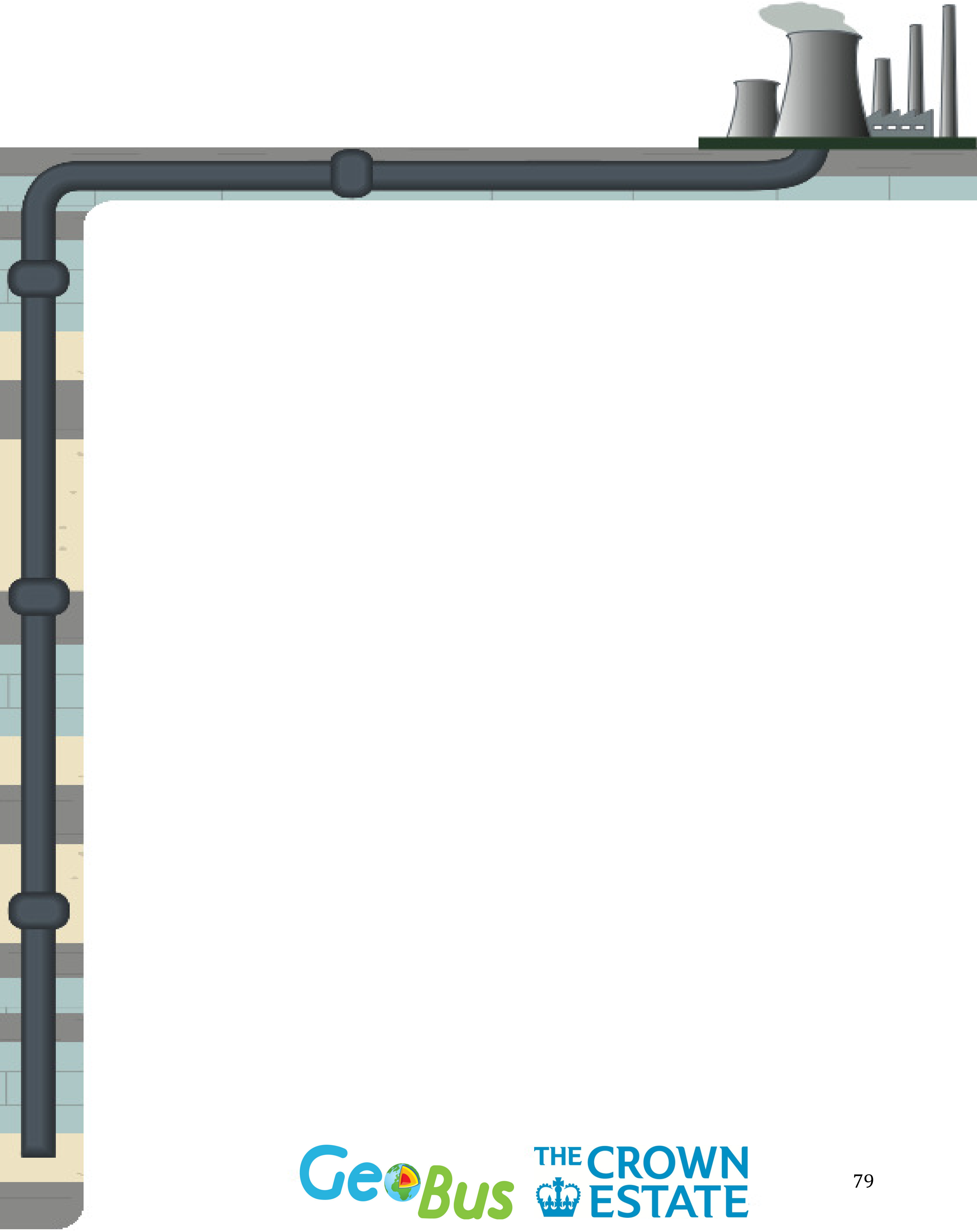
Key Stage 3 (England)

Curriculum for Excellence Experiences and Outcomes

Activity	Page	CfE E's and O's
Chapter 1		Social Science, Science, Maths & Numeracy, Literacy
Energy Fossil Fuels and Climate Change		SOC 4-12b, SCN 2-04b, SCN 4-04a, SCN 4-04a, SCN 3-05b
The Carbon Cycle		SCN 2-04b, SCN 4-04a, SCN 4-04a, SCN 3-05a, SCN 4-05b,
Calculating Your Carbon Footprint		SOC 2-08a, SCN 4-04a, SCN 3-05a, SCN 3-05b, MNU 3-01a, MNU 1-03a, LIT 3-02a
How Much CO_2 Can Be Stored in a Tree?		SOC 2-08a, SCN 3-05a, SCN 3-15b, MNU 3-01a, MNU 1-03a, MNU 3-07a, MNU 3-11a, LIT 3-09a
The CCS Cinema		SCN 2-04b, SCN 4-05a, SCN 4-16a, LIT 3-06a / LIT 4-06a, LIT 3-09a, LIT 3-14a / LIT 4-14a, LIT 3-15a / LIT 4-15a
Chapter 2		Social Science, Science, Maths & Numeracy, Literacy
Saying Yes to CCS?		SOC 2-08a, SOC 2-08b, SOC 3-08a, SOC 4-12b, SCN 4-04a, MNU 3-20a, LIT 3-02a, LIT 3-06a / LIT 4-06a, LIT 3-09a, LIT 3-24a
Paper Pipelines		SCN 4-05a, LIT 3-02a, LIT 3-09a
Writing a Scientific Report		SCN 4-16a, MNU 3-20a, LIT 3-06a / LIT 4-06a, LIT 3-14a / LIT 4-14a, LIT 3-15a / LIT 4-15a, LIT 3-22a / LIT 4-22a, LIT 3-24a, LIT 3-26a / LIT 4-26a
CCS Communication Activity		LIT 3-02a, LIT 3-06a / LIT 4-06a, LIT 3-09a, LIT 3-14a / LIT 4-14a, LIT 3-15a / LIT 4-15a, LIT 3-22a / LIT 4-22a, LIT 3-24a, LIT 3-26a / LIT 4-26a
What Happens to CO_2 Stored Underground?		SCN 3-05a
Investigating CCS: Past, Present and Future		SOC 3-14a, MNU 3-20a, LIT 3-06a / LIT 4-06a, LIT 3-14a / LIT 4-14a, LIT 3-24a
CCS Happy Families		
CCS Careers Top Trumps		
Climate Change Snakes & Ladders		SOC 2-08a, SOC 4-12b, SCN 3-05b

Key Stage 3
Topics and Outcomes

Topic	Outcome
Relationships in an ecosystem	How organisms affect, and are affected by, their environment, including the accumulation of toxic materials.
The particulate nature of matter	The properties of the different states of matter (solid, liquid and gas) in terms of the particle model, including gas pressure.
	Changes of state in terms of the particle model.
Energetics	Energy changes on changes of state (qualitative).
Earth and atmosphere	Earth as a source of limited resources and the efficacy of recycling.
	The carbon cycle.
	The composition of the atmosphere.
	The production of carbon dioxide by human activity and the impact on climate.
Energy	Comparing power ratings of appliances in watts (W, kW).
	Comparing amounts of energy transferred (J, kJ, kW hour).
	Domestic fuel bills, fuel use and costs.
	Fuels and energy resources.
	Other processes that involve energy transfer: changing motion, dropping an object, completing an electrical circuit, stretching a spring, metabolism of food, burning fuels.
	Energy as a quantity that can be quantified and calculated; the total energy has the same value before and after a change.
Motion and Forces	Pressure in liquids, increasing with depth; upthrust effects, floating and sinking.
Matter	Conservation of material and of mass, and reversibility, in melting, freezing, evaporation, sublimation, condensation, dissolving.
	Similarities and differences, including density differences, between solids, liquids and gases.
	Brownian motion in gases.



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