TEACHER RESOURCE

CLIMATE CHANGE

WITH COMPLIMENTS FROM • CSIRO EDUCATION AND OUTREACH • CSIRO

Introduction to the guide

This Student Learning Resource is designed to assist high school teachers engage students in Years 7 to 10 in the study of climate change and related issues. It is supported by the use of the CSIRO text *Climate Change* and links to the Australian Curriculum: Science, with a flexible matrix of activities based on the Five Es model.

The resource explores elements of Years 7 to 10 science and geography curriculums, covering the cross-curriculum priorities of Sustainability and Aboriginal and Torres Strait Islander Histories and Cultures. For science, it more specifically covers the areas of: science understanding; science as a human endeavour and science enquiry skills. For geography, it covers the area of geographical knowledge and understanding, and geographical inquiry and skills.

How to use the guide

The notes in this study guide offer both variety and flexibility of use for the differentiated classroom. You and your students can choose to use all or any of the five sections – although it is recommended to use them in sequence, along with all or a few of the activities within each section.

The ‘Five Es’ model

This guide employs the ‘Five Es’ instructional model designed by Biological Sciences Curriculum Study, an educational research group in Colorado. It has been found to be extremely effective in engaging students in learning science and technology. It follows a constructivist or inquiry-based approach to learning, in which students build new ideas on top of the information they have acquired through previous experience.

ABOUT

Its components are:

Engage

Students are asked to make connections between past and present learning experiences and become fully engaged in the topic to be learned.

Explore

Students actively explore the concept or topic being taught. It is an informal process where the students should have fun manipulating ideas or equipment and discovering things about the topic.

Explain

This is a more formal phase where the theory behind the concept is taught. Terms are defined and explanations are given about the models and theories.

Elaborate

Students have the opportunity to develop a deeper understanding of sections of the topic.

Evaluate

Both the teacher and the students evaluate what they have learned in each section.

WARNING: Aboriginal and Torres Strait Islander people are warned that this document may contain images of deceased persons.

CREATED BY Sally Parker
WRITERS Karen McGhee, Ben Skuse
EDITOR Karen McGhee
DESIGNER Alison Eaton
PROOFREADER Selma Nadarajah
PUBLISHER Karen Taylor
HEAD OF CONTENT Heather Catchpole
PRODUCTION MANAGER Heather Curry

This CSIRO Learning Resource is produced by Refraction Media for CSIRO.

INTRODUCTION

This resource is based on content from the CSIRO book *Climate: Science and Solutions for Australia*. The main concepts it covers include:

- Climate change and variability
- Evidence for climate change
- Collecting data about climate change
- Climate change impacts
- Future climate scenarios
- Adaptation to climate change events
- Mitigation strategies

See Chapter 1: Observations of global and Australian climate for background information.

To help you prepare your lessons, the table below shows which pages of the CSIRO book *Climate: Science and Solutions for Australia* have been used as reference material for student activities.

Section and Activity	Page
Engage	
Starting questions about climate change	V
Explore	
Making greenhouse gases	15
Adapting to extreme weather conditions	49
Graph analysis	24
Small steps, big impact: self inventory	131
Explain	
Article 1 – Introduction	ix–xii
Article 2 – Summary of evidence for and impact of climate change (Chapters 1–4)	1–57
Article 3 – Summary of Adaptation to climate change and Mitigation strategies (Chapters 5–11)	59–138
Elaborate	
First hand investigation: Ocean acidification	9
Maker space: Sea level and tidal surges + Collecting data	10
Ethical thinking: Using scientific evidence for climate change	1–34
ICT: Weather report podcast	39–43
Personal capabilities: Communicating mitigation and	97–134
Strategies for adaptation	59–96
Creative and critical thinking: Design of book cover	Front page of book
Time travel: Future scenario	35–44

PROFILE

Understanding climate patterns

Dr Penelope Whetton makes sense of all the what-ifs, buts and maybes that complex computer modelling tells us about climate change.

Before we can hope to reduce the impacts of climate change, we have to, of course, know what we're dealing with. We need to understand all the complex interactions underway in Earth's atmosphere, driving weather and changing it. The best way to do that is with mathematical models constructed by computers with extraordinary memory, operating at phenomenal speeds, using complex laws of physics, chemistry and fluid motion.

Then we need to understand all that and make sense of what it's telling us. And that's what scientists such as Dr Penelope Whetton do. Dr Whetton, an honorary Research Fellow with CSIRO's Oceans and Atmosphere Business Unit, works in climate protection information. Put simply, she's an interface between climate change modelling and how we use it to assess the potential impacts on our world, from ecosystems and biodiversity to hydrology and agriculture.

“People who work in my area, climate protection, make use of the output of global climate models, but we’re not climate modellers,” Dr Whetton explains. “We are people that interpret those results and cast them in a form so that they can be used in impact assessment.”

There are two parts to the work. Firstly, the numerical information produced by climate models needs to be translated so that it can be used in impact assessment. To do this Dr Whetton and other scientists in this field look at data from all of the many and varied models from centres around the world.

They also use multiple models to help reduce the uncertainty around climate change projection. For example, there is inconsistency for the projected rainfall changes for northern Australia. Some models suggest it will increase while others indicate it will decrease. To determine which outcome is more likely, Dr Whetton says, we need to better understand the processes in the models, such as different representations of atmospheric physics, that are driving some of those inconsistencies.

The other part of this work involves assessing the different climate models and the data they produce, and determining which information should be used in impact assessments. Scientists in this area take the observed real climate data of today, which in Australia is collected by the Bureau of Meteorology, and compare this to what the model is indicating should be happening. This is done for multiple models.

“By working at that interface, we’re not just translating the results of the CSIRO climate model to use in impact assessment; we’re working out how we can draw conclusions about future climate change,” Dr Whetton says.

Climate Change

2015 was the hottest year on record globally.

The global average temperature for 2015 was 0.9°C above the 20th century average.

Part of a long-term trend, 2015 was the 39th consecutive year with above-average global temperatures.

In 2015, Australia had its hottest October. Global warming makes these record-breaking temperatures around six times more likely, research has found.

Climate change is a major factor in extreme heat and fire in Australia.

No one aged under 40 has experienced a year in which global temperatures were at or below the global 20th century average.

Severe bushfires in Australia over summer 2015-2016 were worsened by extreme heat.

Averaged across Australia, temperatures for nine out of 12 months of 2015 were above average.

July 2015 was the hottest month on Earth since climate records were begun in 1850.

Countries must drastically reduce their emissions from coal, oil and gas to slow and then halt the escalating impacts of extreme heat.

The Great Barrier Reef and other marine ecosystems are under threat from rising ocean temperatures and increasing ocean acidity.

ENGAGE

Look at the image on the previous page and read the statements it contains about climate change, which were all Key Findings contained in the 2015 Climate Council of Australia report *The Hottest Year on Record (Again)* and read the Foreward on page v of CSIRO book *Climate Change: Science and Solutions for Australia*.

1. Use the jigsaw image, your reaction to the Foreward, and any previous ideas you have about climate change to put at least one question in each box below. One question has been added already to get you started.

Questions about the text What do you want to know about anything you have read or seen in the text on the previous page?	**Personal questions** Questions about you, your family and your friends that relate to climate change.	**Big picture or global questions** These questions refer to issues that might affect everyone or the world itself and might be hard to answer because there might be multiple responses or no correct response at all.
e.g. How does climate change make bushfires worse?	e.g. Should I be doing anything about climate change?	e.g. Who will be the most affected when it comes to living with a changing climate?

2. Choose a question or group of questions to discuss in a 'yarning' circle. Share and listen to the concerns and knowledge of your class mates. (For information about participating in yarning circles see: harlaxtonss.eq.edu.au/Supportandresources/Formsanddocuments/Documents/yarning-circles.pdf)

3. To summarise this experience, write down what you most want to learn about climate change.

4. Why do you think pieces of a jigsaw puzzle were used to represent these statements about climate change?

Teacher information

The aim of the Explore section is for students to begin investigating some concepts within the broad topic of climate.

Some or all of the workstations can be set up, depending on the size and interests of the class. It is intended that students work independently as they move around the different workstations.

The table below lists the equipment and preparation required for each of the workstations.

Station	**Materials list**
1. Making greenhouse gases	Molymod kits or other form of ball-and-stick models to represent carbon, hydrogen and oxygen (Ref: Chapter 2, p15, *CSIRO book Climate Change: Science and Solutions for Australia*)
2. Adapting to extreme weather conditions	Images of extreme weather events, provided (Ref: Chapter 4, p49, *CSIRO book Climate Change: Science and Solutions for Australia*)
3. Carbon emissions	Small (birthday cake) candle, beaker larger than the candle, tissue, heat-proof glove
4. Fossil fuels	Samples of one of these types of coal – peat, lignite, bituminous coal or anthracite; sample of product made from crude oil, such as petroleum (only needs to be a small sample in a sealed vial or jar)
5. Greenhouse gas game	Computer to access the NASA website spaceplace.nasa.gov/greenhouse-gas-attack/en/#
6. Graph analysis	Graph (provided) (Ref: Chapter 2, p24, Fig 2.4, *CSIRO book Climate Change: Science and Solutions for Australia*)
7. Small steps, big impact: self inventory	Carbon footprint table (provided) (Ref: Chapter 10, p131, *CSIRO book Climate Change: Science and Solutions for Australia*)
8. Energy ratings on household appliances	Energy-rating stickers (provided)
9. Making water currents with ice	Kettle, ice, tea leaves, beaker
10. Measuring the weather	Thin piece of paper to act as a wind vane; thermometer; light meter and any other relevant equipment such as an anemometer, hygrometer
11. Making convection currents with warm water	Two small recycled plastic drinking bottles per set, large plastic tray or sink to conduct activity over, blue food dye, yellow food dye, kettle, playing card
12. Solar energy	Samples of solar panels, wires and small globes

Climate change activities

Work around each station in any order. As you go, write any questions that you have here. Include questions about the science behind the activities in the stations, how the ideas are related to climate change and how they relate to your life.

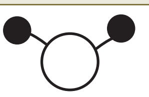
Questions:

Station One

Making greenhouse gases

1. Refer to page 15 and identify the 4 main GHGs (greenhouse gases) other than water vapour. Write the name and chemical formula in Table 1 below. Water vapour has been done for you as an example.

Table 1

Name of GHG	Chemical formula of GHG	Drawing of the structure of the molecule
Water vapour	H2O	

2. Using the key provided, build a model of each of the 5 greenhouse gases, and draw them in right hand column of Table 1 above.

Table 2

Type of greenhouse gas	A source of this gas (How it is produced)	A way to mitigate this gas so there is not so much in the atmosphere

Station Two

Adapting to extreme weather conditions

1. Look at the image on page 49 of the CSIRO book *Climate Change: Science and Solutions for Australia*. What extreme weather event does this image depict?

2. What other types of extreme weather events are there? List at least two more.

____

____

____

____

3. Choose one extreme weather event and describe what actions a community might have to take if this type of event began to happen more often.

____

____

____

____

Station Three

Carbon emissions

1. Light the candle and use a bit of melted wax to stand it upright on its own.
2. Using a heat-proof glove, place a beaker over the candle until all the oxygen is used up and the flame goes out.
3. Once the beaker has cooled, use a tissue to wipe the inside of the beaker. Observe what is on the tissue and describe it.

____

____

____

____

____

____

4. Use your findings to say what you think the consequence on the environment might be of burning things? Give examples.

____

____

____

____

____

____

Station Four

Fossil fuels

1. Have a look at the samples of coal and oil.
2. Write down some observations about their colour, texture and anything interesting you observe.

Coal	Oil

3. Suggest how you think they may have been formed in nature.

4. What do you think coal is used for?

5. What do you think oil is used for?

6. What are some issues or problems related to fossil fuel use that you have heard about?

Station Five

Greenhouse gas game

1. Go to spaceplace.nasa.gov/greenhouse-gas-attack/en/# and read the instructions for the game.
2. Play one or two levels of the game.
3. What happens to the temperature of the land close to the Earth's surface when you manage to knock a red ball (greenhouse gas) into space?

Station Six

Graph analysis

1. Look at the graph (Fig 2.4) on p24 of the CSIRO book *Climate Change: Science and Solutions for Australia*.

2. Describe the shape of the graph.

3. Why do you think there was such a sudden increase in CO_2 levels in the 1850s?

4. What do you think the graph will look like in another 100 years, 200 years?

Station Seven

Small steps, big impact: self inventory

1. Use the list from the CSIRO Home Energy Saving Handbook, reproduced on p131 of the CSIRO book *Climate Change: Science and Solutions for Australia*, to do a self inventory of the number of bags of CO_2 that you and your family currently produce per year. Write the number of bags you use in the middle column in the table below.

Possible impacts **Do you…**	**Current impact (based on CO_2 bags currently used)**	**Possible improved impact (based on CO_2 bags you could save)**
Wash your clothes in cold water?		
Have a spare fridge that is always on?		
Dry your clothes on a clothes line?		
Eat foods with a low carbon content?		
Reduce purchases by 10%?		
Grow your own vegetables and have a compost?		
Ride your bike or share lifts in the car?		
Refuse to use plastic bags?		
Use passive heating?		
Use natural gas instead of electrical heaters?		
Use solar, gas or heat pumps for hot water?		
Have energy efficient fridges and washing machines?		
Have mostly low wattage lighting?		
Make 75% of your journeys by bike or public transport?		

2. Estimate the total number of bags of CO_2 you and your family currently use each year:

____

3. Create a plan to reduce your carbon footprint. How would you and your family cut down on the emissions you produce? Where would your biggest savings be? With this new plan in mind, re-do the inventory. How many bags of CO_2 did you save compared to your previous estimate?

Station Eight

Energy ratings on household appliances

The appliances you purchase for your home have energy rating stickers on them that look like the ones in the image below. These stickers are for two different television sets:

1. Which TV uses the most energy?

2. What information on the sticker allows you to answer question 1 above?

3. Which TV would cost the most money to leave switched on and why?

Station Nine

Making water currents with ice

1. Prepare a saturated solution of about 50ml of salty water by heating the water a little before placing it in a beaker and stirring in salt until no more salt dissolves.
2. Sprinkle a few tea leaves over the top.
3. Place some ice in the salty water and observe what happens as it dissolves.
4. Describe what you see. Why do you think this is happening?

Station Ten

Measuring the weather

1. Use the equipment provided and your general observations to gather as much data as you can about the weather conditions outside your school laboratory. Record the data in the space provided here.

2. Use the data you have collected to write a current weather report that could be read over the radio at the end of the next news bulletin.

____

____

____

____

____

____

____

____

____

Station Eleven

Making water currents with ice

Making convection currents with hot water

Here are a few rules for this fun station:

- Conduct this activity over the top of a plastic tray or sink so that any water spillage will be contained and not end up over the bench and floor.
- Do not pour boiling water from the kettle directly into the bottle. Instead, mix some warm water in a large beaker and use that.
- Use a lab coat and other protective clothing to avoid stains from the food colouring.

1. Place five drops of blue food colouring in two of the bottles.
2. Place five drops of yellow food colouring in the other two bottles.
3. Fill the bottles with the blue food colouring with cold water. The water should reach right up to the rim of the bottle.
4. Fill the bottles with the yellow food colouring with hot water. The water should reach right up to the rim of the bottle.
5. Place the playing card over the top of one of the yellow bottles.
6. Carefully turn the yellow bottle over, with the card in place, and place it on top of one blue bottle.
7. Slowly remove the card and observe what happens to the water.
8. Place the card on top of the other blue bottle.
9. Carefully turn the blue bottle over, with the card in place, and place it on top of the second yellow bottle.
10. Slowly remove the card and observe what happens.

1. Record your observations.

2. What might the effect of large bodies of water of different temperature moving in the ocean have on the air temperature nearby?

Station Twelve

Solar panels

1. Have a look at the solar panel supplied. Make some observations about its appearance. What is it made from? Is it heavy or light? What colour is it?

2. What are solar panels used for in homes?

3. How do you think the panel is able to make energy?

4. Use the equipment provided to use the solar panel to light the globe. You may need to use more than one panel. In the space below, describe how you did this.

5. List all the ways the energy produced by a solar panel could be maximised.

6. Identify as many other forms of renewable energy as you can that can be used to generate electricity.

Student literacy activities

Teacher instructions

In this section, we delve deeper into some of the issues associated with climate change and explain some of the science involved. Students read a series of articles and complete a number of linked literacy activities. These include:

- Brainstorming
- Glossary
- Comprehension and summarising questions
- Questioning Toolkit

Articles

1. **An introduction to climate change: The past, the present and the future**
   Climate change is one of the greatest ecological, economic, and social challenges facing us today. Here we examine what climate change is and how it will affect our future. See the CSIRO book *Climate Change: Science and Solutions for Australia* introduction, page ix.
2. **Evidence for and impacts of climate change**
   Without rapid action to reduce CO_2 emissions, it is very likely that climate change will continue to accelerate. Here we look at the scientific evidence and what it means for us. See the CSIRO book *Climate Change: Science and Solutions for Australia* chapters 1–4. Watch Dr Karl Braganza talk about the *CSIRO-Bureau of Meteorology State of the Climate Analsysis* at www.scienceimage.csiro.au/mediarelease/images/mr12-State_of_Climate2012/VNR_Karl_Braganza.mov
3. **Responding to climate change: adaptation and mitigation**
   The less we mitigate, the more we will be forced to adapt to the inevitable changes in the climate. Here we look at the decisions we face in response to climate change. See the CSIRO book *Climate Change: Science and Solutions for Australia* chapters 5–11. Watch the video *Adaptation: reducing risk, gaining opportunity* at www.youtube.com/watch?v=k7V_wQz6TcM

Brainstorming: Climate change thinking hats

Before reading any of the articles, students can think about what you already know about climate change and what you imagine your future to be. The six thinking hats is a great way to explore a range of issues related to climate change.

Either break up into groups and take one thinking hat each, or think about climate change from the perspective of each hat. Whichever method you choose, share your ideas with the rest of the class.

Use the following table to record your ideas:

Hat	Meaning	Comment
White	**The facts:** What points do we need to consider when we think about climate change?	
Red	**Emotions:** How does it make you feel? Could you write your feelings in a song or poem?	

EXPLAIN

Yellow	**The strengths:** Positive points. What are some of the positive outcomes for climate change?	
Black	**The weaknesses:** Negative points. What are some of the negative issues we need to face?	
Green	**New creative ideas:** Can you think of some solutions to avoid the impacts and consequences of climate change.	
Blue	**Thinking about the issue as a whole:** What are your summarising ideas about climate change? What are the most urgent issues we need to act on?	

An introduction to climate change: the past, the present and the future

What is climate change?

Read the Introduction on xi–xii of the CSIRO book *Climate Change: Science and Solutions for Australia*.

Activity 1 – Glossary

Using the table provided, define some of the terms used in the article.

Term	**Definition**
Weather	
Climate	
Climate variability	
Climate change	
Glacial conditions	
Interglacial	
Earth's orbit	

EXPLAIN (ARTICLE ONE)

Axial tilt	
Surface reflection	
Atmosphere	
Atmospheric composition	
Greenhouse gas	
Greenhouse effect	
Natural greenhouse effect	
Enhanced greenhouse effect	
Frozen tundra	
Hydrocarbons	
Feedback processes	
Fossil fuels	
Radiation	
Computer modeling	
Climate change adaptation	
Terrestrial store	
Natural ‘sinks’	

Activity 2 – Summarising

Answer the following questions relating to the article.

1. Write three or four statements that summarise the most important information in the Introduction on xi–xii of the CSIRO book *Climate Change: Science and Solutions for Australia.*

____

____

____

____

____

2. Place each of the following examples in the appropriate column in the table below.

- The temperature today is a fine 24°C.
- Summer heatwaves have increased in many countries leaving them with a decade or more of drought.
- This winter was warmer and wetter than it was last year.
- Temperatures have increased more in the past 100 years than they have in all of recorded history.

Climate change	Weather	Climate variability

3. Write in three more examples of your own to the table.

Climate change	Weather	Climate variability

4. Identify three human activities that release greenhouse gases into the atmosphere.

5. Identify at least two 'sinks' where CO_2 can be stored and explain why the release of CO_2 from sinks is a problem.

Activity 3 – Questioning Toolkit

Complete the Questioning Toolkit below.

Write your ideas and opinions relating to each of the different types of questions. Add some of your own questions.

[Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits: McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html]

Type of question	Your ideas, opinions and questions
Essential questions *These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer.* Questions What causes global warming? How does global warming influence climate change? Is it too late to reduce the rapid increase in climate change? What types of data do scientists collect from the environment when they study climate and climate change?	
Subsidiary questions *These questions help us to manage our information by finding the most relevant details.* Questions How can models best be used to predict and manage the changing climate? What can we do to reduce the impact climate change has on our everyday lives? What can the government do to reduce the impact of climate change? Whose responsibility is climate change?	

Type of question	Your ideas, opinions and questions
Hypothetical questions Questions designed to explore the possibilities, the 'what ifs?' They are useful when we want to test our hunches. Questions What if our computer modeling is underestimating climate change in the future? What if computer modeling is overestimating climate change in the future?	
Provocative questions *Questions to challenge convention.* Questions Why does a climate change debate exist? Will you change your behavior due to climate change? Do you agree with this statement by Dame Barbara Stocking, the former CEO of aid agency Oxfam: "Climate change is a gross injustice – poor people in developing countries bear over 90% of the burden – through death, disease, destitution and financial loss – yet they are least responsible for creating the problem."	

Evidence for and impacts of climate change

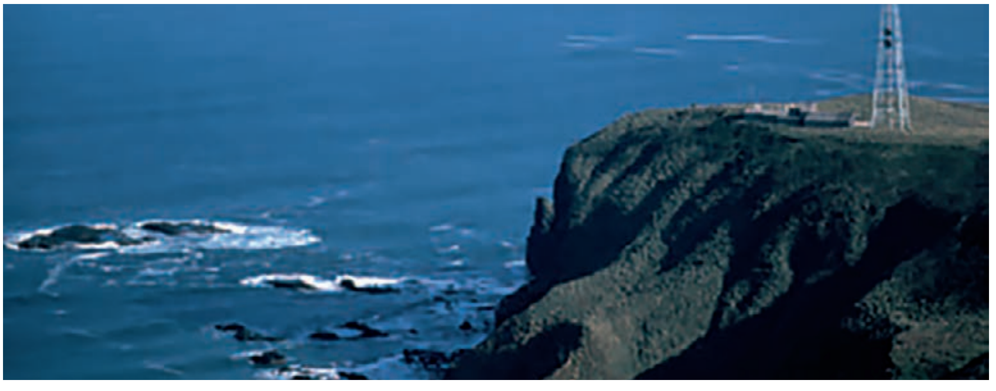
The following information is a summary of Chapters 1–4 in the CSIRO book *Climate Change: Science and Solutions for Australia*, describing the data-based observations that tell us what we know about climate change, and the major impacts it will have on our future and the future of Australia.

It is now likely that within the lifetime of the current generation, the world will see 2ºC global warming on top of changes already experienced. Without rapid action to reduce CO_2 emissions, there is a serious risk that global warming could be as much as 4ºC by late this century.

What does the scientific data tell us about climate change in Australia?

For Australia, heatwaves, fires, floods and droughts in the continent's south are all expected to become more frequent and intense in coming decades. Snow and frost are likely to become more rare or less intense events. Locally and regionally, the greatest impacts will be felt through changes in water availability and sea level, and in extreme weather events.

Observations of temperature (on land and in the oceans), rainfall, sea level, ocean acidity and salinity, and other aspects of the climate system, combine to give us a picture of our climate over time, and enable us to identify trends and changes in key climate features. The following table on the next page summarises the data that provides scientists with evidence for climate change.



Climate change data that provides evidence for a changing climate	
Climate factor	**Scientific observations**
Terrestrial temperature	Records show that surface temperatures in Australia rose by slightly less than 1ºC between 1910 and 2009. Global average temperatures have risen by about 0.7ºC during the past century. Warming was modest in Australia in the early part of the 20th century, followed by a slight decline between about 1935 to 1950, and then a rapid increase between then and 2010. Australia's average temperature has increased by about 0.7ºC since the middle of the 20th century. This trend is continuing: the second half of 2009 was the warmest on record for Australia and 2010 was one of the hottest years in the instrumental climate record. The past decade (2000 to 2009) was Australia's warmest decade on record.
Rainfall	While much of southern Queensland and northern New South Wales have experienced (on average) severe and prolonged dry periods in recent decades, the longer term trend is not sufficiently clear to be able to distinguish whether these recent dry periods are different from the large decade-to-decade variability that is a natural feature of climate in these regions. Indeed, record- and drought-breaking rain during 2010 across Queensland and NSW is consistent with long-term natural variability.
Sea surface temperature	Measurement taken at the surface of the oceans show that temperatures have warmed considerably in the past 120 years. Globally, averaged sea surface temperatures have increased by about 0.7ºC. Temperatures of the surface waters surrounding Australia have warmed by about 0.9ºC since 1900, with about 0.4ºC of that warming having taken place in the past 50 years.
Ocean temperature	The oceans are the Earth's true thermometer. Observations between 1961 and 2008 indicate that the upper few hundred metres of the oceans absorbed well over 100 billion trillion joules of energy.
Ocean salinity	Parts of the sea that are naturally quite saline have become measurably saltier owing to either increased evaporation or less rainfall, or both, while other parts have become fresher as they have been diluted by increased rainfall or decreased evaporation, or both.

Ocean acidification	As well as storing heat, the oceans absorb vast amounts of CO_2. They presently remove about 25% of the CO_2 emissions produced by human activities. A direct result of this CO_2 uptake is the gradual acidification of the oceans. Ocean absorption of CO_2 in the last 250 years has decreased the near-surface ocean pH level by about 0.1 and is expected to decrease it a further 0.2–0.3 by 2100. This could have profound effects on corals, plankton and other marine organisms with carbonate skeletons. These organisms span the entire marine food chain.
Sea levels	The main contributions to sea-level rise in the past half-century have been expansion of the upper layers of the oceans as they warm and increased discharge from glaciers. The vast amounts of heat that the oceans have absorbed in recent decades are causing them to expand and therefore rise – just as heat makes the mercury in a thermometer rise – and to change in profound ways. Global sea levels are currently rising at around 3.2mm a year, nearly twice the average rate (1.7mm per year) experienced during the entire 20th century. Rising sea levels have already significantly increased the frequency of high coastal sea-level events in Australia and overseas. These occur when storms and strong onshore winds coincide with high tides. Current climate models project that by 2100, sea level could be about 20 to 60cm above 1990 values. However, current models do not adequately represent the recently observed contribution of the ice sheets in response to warming. If this contribution was to grow linearly with temperature, then sea level could rise a further 10 to 20cm, resulting in a total range during 2100 of 20 to 80cm.

High-quality climate observational data sets will continue to play a significant role in our quest to understand our changing climate. This is particularly the case as we try to determine the full extent of the impact of greenhouse gases.

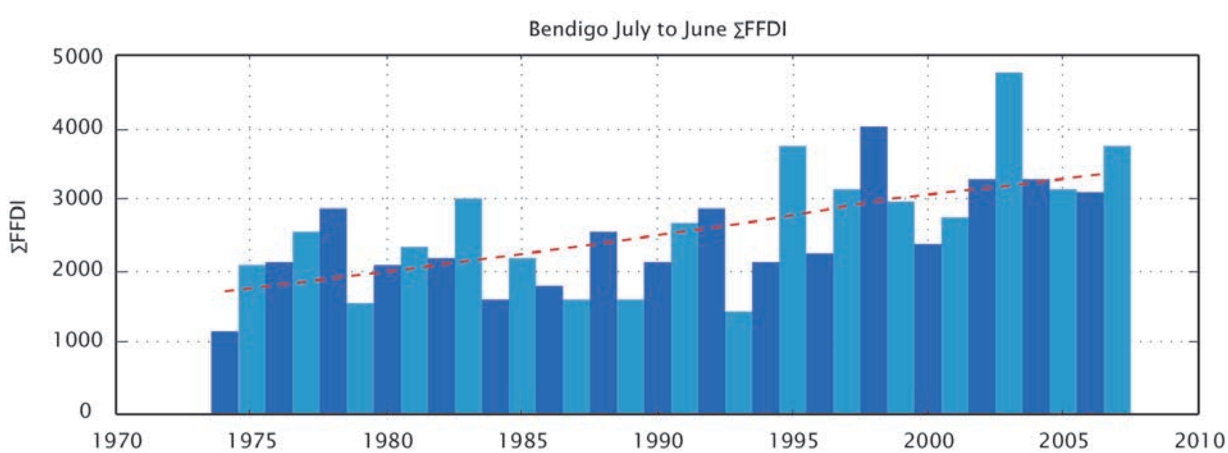
What are the impacts of climate change?

The impact of climate change, which is due to a combination of natural variability and changes in greenhouse gas concentrations from human activities, can now be clearly seen in stresses on our water supplies and farming, changed natural ecosystems, coastal impacts, and reduced seasonal snow cover.

Climate change impacts will increasingly be experienced first through extreme events rather than gradual changes in mean temperature or rainfall.

A good case study of how we can look at the impacts of current extreme events and assess their importance in the future is the Victorian bushfire event of early February 2009. This catastrophe killed 173 people and more than 1 million animals, destroyed more than 2000 homes, burnt about 430,000 hectares and cost about $4.4 billion. Conditions leading into that fire were extreme. Temperatures were high, humidity was low and there were strong winds and a lot of very dry fuel as a result of years of drought – all of which combined to produce an extreme forest fire danger index (FFDI). When the daily FFDI is greater than 50, the risk rating is ‘extreme’ and a ‘total fire ban’ is usually declared. The bushfires of February 2009 had a FFDI that greatly exceeded 100 in many locations and, as a consequence, an additional fire rating of ‘catastrophic’ has since been added to the rating system.

An analysis of the annual total FFDI (i.e. the sum of daily FFDI indices) for the past 30 years shows that in southern Australia, the index has been trending upwards, primarily in response to increasing temperatures and worsening drought since the mid-1990s.



Climate change impacts will be experienced across all sectors of the economy and in all ecosystems. There are six areas in particular where the impacts will be significant: water security; coastal development; natural ecosystems; infrastructure; agriculture and forestry; and health. The following table summarises the possible impacts of global warming in these six areas.

Possible impacts of global warming

Climate factor	Scientific observations
Water security	There is likely to be less water available for irrigation, and domestic and industry use, as well as reduced environmental flows. The decline in water supply is likely to be accompanied by a growth in water demand as our population expands, which makes water potentially one of Australia's most critical national issues.
Coastal development	Continued development and population growth in Australia's coastal regions – where about 85% of the population now resides – will exacerbate risks from sea-level rise and increase the likely severity and frequency of coastal flooding caused by climate change. There is likely to be an increased risk of coastal flooding, especially in low-lying areas exposed to cyclones and storm surges.
Natural ecosystems	Among the most significant impacts of climate change may be the loss of unique Australian animal and plant species, and the gradual changing of quintessentially Australian landscapes. Significant losses of biodiversity are projected to occur in iconic sites such as the Great Barrier Reef, Queensland Wet Tropics, Kakadu wetlands, south-west Australia, our sub-Antarctic islands, and eastern alpine areas. Marine ecosystems are likely to experience some of the most severe impacts. For example, a 0.5ºC warming of the tropical oceans may cause bleaching of 30% of the Great Barrier Reef and a 1ºC warming may bleach 65%. Such changes could directly affect a tourism industry worth $5 billion a year and supporting around 70,000 employees.

Infrastructure	Typical risks include the failure of floodplain protection and urban drainage and sewerage systems, more heatwaves causing blackouts or buildings failing under excessive wind loads. In addition to these acute impacts, there are a whole range of chronic impacts such as accelerated degradation of materials and infrastructure (such as water pipes, road surfaces, transmission lines, foundations, and building materials) associated with higher temperatures, altered groundwater and soil conditions, sea-level rise, and changed rainfall regimes.
Agriculture and forestry	Higher levels of CO_2 increase the rate of photosynthesis and improve the efficiency of water use in plants, hence stimulating plant growth (known as CO_2 fertilisation). However, the positive effects of CO_2 can be more than offset by accompanying changes in temperature, precipitation, pests and the availability of nutrients. As a consequence, production from cropping and livestock is projected to decline by 2030 over much of southern Australia due to increased drought and the fact that the availability of nutrients will limit productivity in most Australian landscapes. Heat and drought are likely to reduce the quality of grain, grape, vegetable, fruit and other crops.
Health	Direct impacts are via heatwaves, fires, storms and floods. For Australia, heatwaves are likely to have a major impact on human health. Heat-related deaths for people aged over 65 in six of Australia's largest cities are likely to increase from around 1100 per year at present to around 2300 to 2500 by the year 2020 and 4300 to 6300 by the year 2050. During a two-week heatwave in early 2009, 374 heat-related deaths were recorded in Victoria. Health is also affected by climate change indirectly, principally through biological processes such as vector-borne and other infectious diseases and physical processes such as air pollution.

Greg Rinder/CSIRO

John Coppi/CSIRO

Climate models indicate that it is very likely that warming and other climate changes will continue to accelerate through the coming century if emissions of greenhouse gases continue to increase. The impacts of climate change on Australia's economy, society and environment during the coming decades will be significant. Some impacts will be unavoidable in the short-term due to past and current greenhouse emissions already producing effects. Adaptation on a scale far more extensive than is currently occurring will be essential in all walks of life to limit these impacts.

Bruce Miller/CSIRO

Activity 1 – Glossary

Using the table provided, define some of the terms used in the article.

Term	**Definition**
Extreme weather event	
Acidity	
pH	
Salinity	
Terrestrial	
Joules	
Evaporation	
Coral	
Plankton	
Carbonate skeleton	
Marine food chain	
FFDI	
Infrastructure	
Bleaching (of coral)	
CO_2 fertilisation	
Vector-borne disease	
Infectious disease	

Activity 2 – Summarising

Answer the following questions relating to the article.

1. List the different types of environmental data that scientists collect to monitor climate change and suggest the units of each type of measurement.

Type of data collected	Instrument data collected with	Units of measurement

2. Outline all the ways a bushfire might impact a community.

____

____

____

____

____

3. Looking at the Bendigo FFDI graph in the article:

a) What year did the FFDI peak?

____

b) What is the general trend of the FFDI over time from 1975 to 2005?

____

____

____

c) Use the internet to identify the five categories of the FFDI between low-moderate and catastrophic.

____

____

____

____

____

____

____

____

____

____

____

____

4. How will the increase in heat and drought affect:

a) The health of the community?

____

____

____

____

b) Water security?

____

____

____

____

c) Agriculture?

____

____

____

____

d) Infrastructure?

____

____

____

____

Activity 3 – Questioning Toolkit

Complete the Questioning Toolkit below.

Write your ideas and opinions relating to each of the different types of questions. Add some of your own questions.

[Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits: McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html]

Type of question	Your ideas, opinions and questions
Essential questions *These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer.* Questions What makes the data that scientists collect reliable? Why are scientists worried about the data they are collecting on climate?	
Subsidiary questions *These questions help us to manage our information by finding the most relevant details.* Questions Of the six major impacts of climate change, which do you think will have the greatest and least impact? Why do you think this?	
Hypothetical questions *Questions designed to explore the possibilities, the 'what ifs?' They are useful when we want to test our hunches.* Questions What if the impacts of global warming cannot be slowed down? What if greenhouse gas emissions continue to rise?	
Provocative questions *Questions to challenge convention.* Questions What do you think the positive impacts of climate change will be? Do you think there is an over-representation of human-focused impacts of global warming (rather than on other species)? Give examples to support your thinking.	

Responding to climate change: adaptation and mitigation

The following information is a summary of Chapters 5–11 in the CSIRO book *Climate Change: Science and Solutions for Australia*, describing how we will need to respond to climate change through adaptation and mitigation.

Adaptation and mitigation are closely linked. The less we mitigate, the more we will be forced to adapt to inevitable changes in the climate and the bigger the adaptations will have to be. Conversely, success in mitigation through early and deep cuts to greenhouse emissions will necessitate fewer, less extreme adaptations in the long run.

Another important distinction

Mitigation = reducing the amount of climate change that occurs

Incremental adaptation= a gradual process of adjustment

Transformational adaptation = a major adjustment to the way people go about their work and their lives

Adaptation

Adaptation is about coping with the changes that are already happening or that appear unavoidable in the future. Just as early settlers progressively adapted European farming systems to Australian landscapes and conditions or built their homes with wide verandas to suit our long, hot summers, so we will now need to change many of our society's activities, systems and habits to make allowance for warmer, more variable and more extreme climatic conditions, as well as rising sea levels and other global environmental changes.

Incremental adaptation is what we tend to do throughout our normal lives as we cope with changed circumstances, gain new knowledge, acquire new technologies, or move to different places. In its early stages, climate change will mostly require incremental change, such as:

farmers deciding to plant crops that are more drought-tolerant to suit drier conditions; householders choosing to insulate their homes to reduce heat stress; or architects ensuring their building designs are suited for possible increased wind gust speeds.

Transformational adaptation, on the other hand, might involve the relocation of an entire industry, farm or community, to avoid increasingly unfavourable conditions such as rising sea levels, floods, bushfires or persistent drought. This demands careful planning with long lead times and usually a degree of support from all levels of government because of the disruption it can cause to people's lives and the psychological break with what they are used to. Such changes have been accomplished many times in our past. For example, when the Snowy Mountains Scheme was built, the townships of Jindabyne and Adaminaby had to be relocated.

However, not all of these adaptations need to happen at the same time or immediately. Many can be achieved progressively over time and many will also lead to fresh opportunities, new markets and more sustainable technologies. In other words, with good preparation, adaptation can be positive.

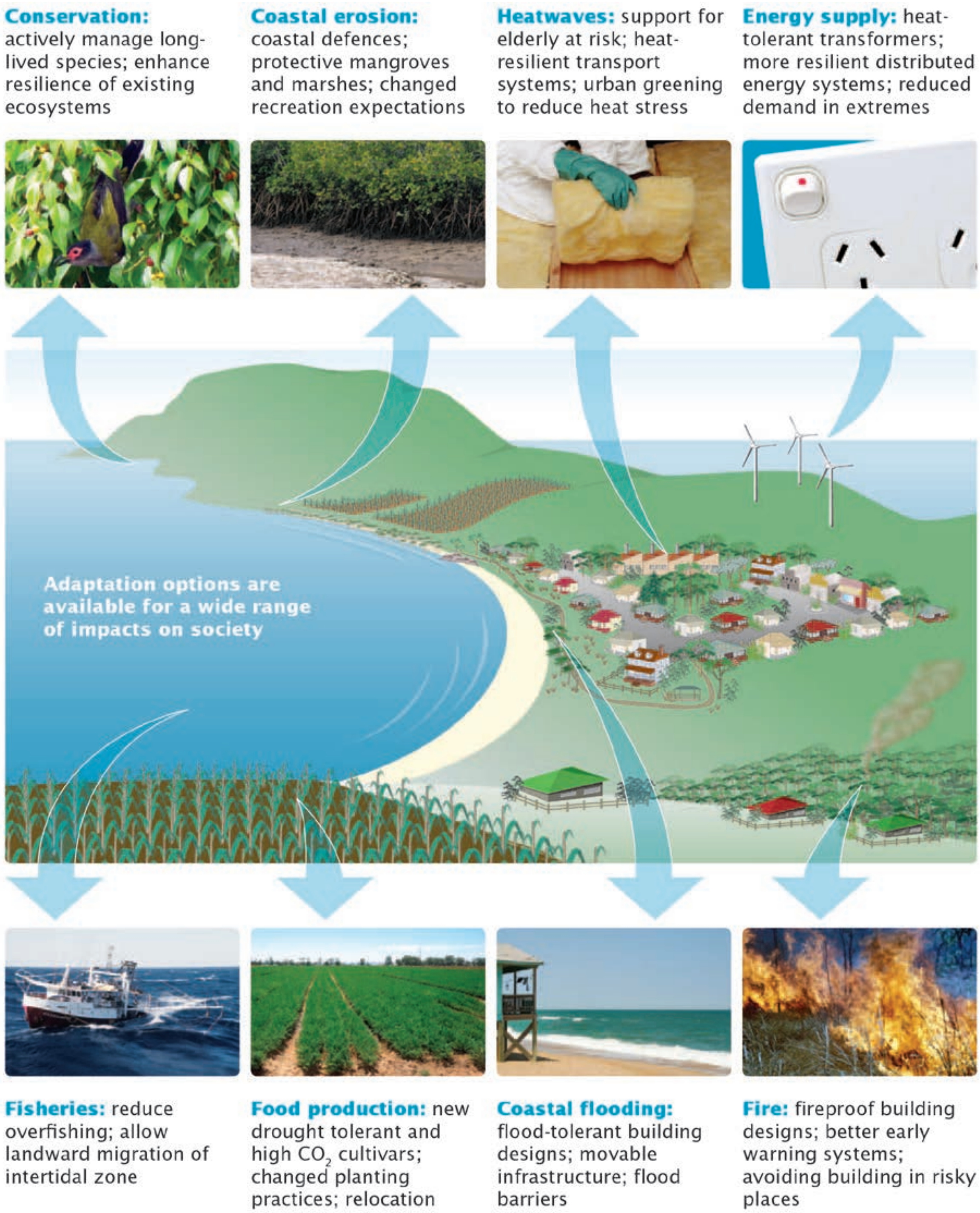
As incremental adaptations become less effective with changing weather conditions, larger transformational adaptations, may become desirable. These might include changes in land use, the re-location of significant industries or diversification into new activities, such as carbon sequestration or farming for energy provision. Inevitably, as we move from incremental to transformational change, the complexity, cost and risk of actions will also increase, and these must be planned well.

As climate change unfolds through the early decades of the 21st century, adaptation will become the pivotal response by Australia to maintain its own food security and self-sufficiency, retain vibrant rural communities and sustain globally important agricultural exports.

Mitigation

Australia has a high emissions intensity and has high energy use per capita.

An abundance of clean energy opportunities, such as hydro, wave, hot fractured rock, solar, and biomass must feature in our diverse energy future. Each of these technologies faces obstacles to its continued use and/or future deployment. These include cost, development, environmental issues, government policy, the need for storage technologies and public acceptability. The energy mix we achieve by the mid-century will depend on which technologies are best able to overcome the various barriers facing them and prove to be most adaptable to the Australian policy environment.



Adaptation is needed in many different areas of decision-making in Australia.

Energy and transport technologies

- **Energy efficiency** gains can come from all sectors.
- **Demand reduction** can be achieved in many ways, such as through the use of 'smart agents' and 'intelligent grids'. Here, sensors monitor and report information about energy use that can be used to manage supply and demand to a central controller. For example, systems that sense whether rooms are occupied – and that can regulate lighting, heating and cooling accordingly – can reduce overall demand for power. Many modern buildings are designed with considerations of reduced energy use in mind, such as natural lighting, thermal load management via the use of appropriate building materials, positioning of buildings, and the use of shading, breezes, and vegetation. Demand reduction can be stimulated by government incentives and regulation, and is very often another case of win–win: making sense for both the economy and climate.
- **Distributed power generation** seeks to achieve energy savings by generating electricity close to the point of use – even inside the actual building that uses the energy.

Renewable and nuclear power

- **Solar power** holds great promise as the energy source of the future. Two categories of solar power may play a role in future electricity generation: photovoltaic and solar thermal. Photovoltaic technologies convert sunlight directly to electricity through the properties of photoactive materials. Solar thermal technologies concentrate the Sun's rays to produce heat that can then be used to heat water, induce chemical reactions or drive other energy processes.
- **Wind power** is currently the most adoptable of the renewable energies and is being deployed on quite a large scale across Australia.
- **Biomass energy** – for electricity or fuels – is seen as having considerable potential if sustainable use can be established and costs reduced through new technologies.
- **Hydropower** has limited large-scale expansion opportunities in Australia due to public aversion to the large-scale impacts on river systems, limited accessible sites, and declining rainfall in the south.
- **Hot fractured rocks** are still being developed as a potential base-load energy source for the future.
- **Ocean energy** – Australia has access to vast ocean resources: some of the best in the world for wave, current, and tidal energy, especially along the WA, Victorian and Tasmanian coasts.
- **Nuclear energy** may become an economic option for power generation in Australia.

Gregory Heath/CSIRO

Nick Pitsas/CSIRO

Fossil fuel energy and carbon capture and storage

The world is heavily committed to the use of fossil fuels through its existing generation's infrastructure, which will continue to provide the bulk of electricity generated for some time. In addition, many developing economies see coal as the lowest-cost option to provide electricity for the growth of their economies and to increase the living standards of their people.

Carbon capture and storage (CCS)

This is the pathway for reducing greenhouse gas emissions from fossil fuels that are used for large-scale electricity generation. The aim is to capture the CO_2 that is released when coal is burned and then store it in stable geological formations, deep underground. It is worth noting that oil, natural gas and CO_2 have been stored naturally in such formations for many millions of years.

Transport

Realistically, only four additional transport fuel options are capable of being produced in large enough volumes to satisfy a significant part of the needs of the transport sector in the next two decades and supplement traditional fossil transport fuels. These are biofuels, liquefied natural gas (LNG), compressed natural gas (CNG) and electricity.

Managing the land

The way we choose to manage our rural lands will have a significant impact on Australia's future net greenhouse gas emissions. In Australia, we can make a major contribution to lowering our greenhouse gas emissions by reducing direct emissions and by increasing the amount of carbon stored in soils and landscapes.

Reducing emission from Australian land use

Our soils and forests store large quantities of carbon: between 100 and 200 times Australia's current annual emissions. We can potentially increase these stores in our rural lands and perhaps store or mitigate enough greenhouse gases to offset up to 20% or more of Australia's emissions during the next 40 years.

Afforestation

Forest plantings are the most straightforward way to sequester carbon in rural landscapes and, along with reduced land clearing, provide the most immediate, significant, and realisable carbon sequestration opportunity.

Native ecosystems

Native ecosystems are vital to Australia's greenhouse gas dynamics because they both store and emit large volumes of greenhouse gases, which fluctuate depending on disturbance and climate variability. Australia is the world's most fire-prone continent, and fire is a particularly influential factor on the carbon cycle in many native ecosystems.

Consequently, there is growing interest in curbing the extent and severity of these fires using Aboriginal burning techniques, which produce cooler, less-destructive fires. This could generate livelihoods in remote Aboriginal communities, reduce the risk of wildfires, encourage native species and – through reduced greenhouse gas emissions and increased carbon storage – help to lower Australia's emissions.

Livestock methane

Ruminant animals (such as sheep and cattle) emit methane as a by-product of digesting feed. Options to reduce this include dietary manipulation, modification of rumen fermentation, feedstock quality and selective breeding for reduced emissions. Dietary manipulation is an option available today. Others, such as the modification of rumen fermentation and animal breeding, will take longer to have an impact. In general, options that increase animal growth rates and reproductive performance can reduce emissions intensity and increase profitability.

Willem van Aken/CSIRO

Cropping emissions

High soil nitrogen levels, particularly under wet soil conditions, are a significant driver of greenhouse gas emissions associated with fertiliser use. In many cases, the actions required to reduce emissions through fertiliser use in agriculture are identical to best-practice strategies to maximise the efficiency of fertiliser use and minimise undesirable environmental impacts such as the contamination of waterways.

Through practical and sometimes beneficial or low-cost actions, we can make significant progress in tackling climate change.

Activity 1 – Glossary

Use the table to define any science words that are related to this article.

Term	Definition
Adaptation	
Mitigation	
Incremental adaptation	
Transformational adaptation	
Clean energy	
Photovoltaics	
Solar-thermal	
CCS	
Biofuels	
LNG	
CNG	
Afforestation	
Ruminant animals	
Methane	

Activity 2 – Summarising

Summarise the information in Article 3 by responding to the following questions:

1. Which of the following would be incremental and which would be transformational adaptation?

a) A small community living at sea level relocates to higher ground after their crops fail for a second year.

____

b) A family insulates their home to keep it cool in summer and warm in winter.

____

c) A farmer plants a more drought-resistant crop.

____

d) Farmers in a particular area of Australia decide to stop farming cattle and instead farm kangaroos.

____

e) An architect designs a house to withstand high wind speeds.

____

2. Explain how it is possible that some Australian species may have become extinct before we even knew they existed.

____

____

____

____

3. What are the two ways we can remove CO_2 from the atmosphere in order to mitigate its effects?

____

____

____

____

4. Choose an example of mitigation and describe how it reduces the effects of greenhouse gas(es)

____

____

____

____

Activity 3 – Questioning Toolkit

We have provided a series of discussion questions in the form of a questioning toolkit. Choose some or all of the questions to answer, or ask some of your own.

[Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits: McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html]

Type of question	**Your Ideas and Opinions**
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. Questions Which is more effective in the immediate future, adaptation or mitigation? How much of an effect can a community have on mitigating greenhouse gases? Is it people's attitudes or government policy that direct successful adaptation and/or mitigation?	
Subsidiary questions These questions help us to manage our information by finding the most relevant details. Questions How, as an individual, might you adapt to the increased risk of death from heatwaves in your community?	
Hypothetical questions Questions designed to explore the possibilities, the 'what ifs?' They are useful when we want to test our hunches. Questions What if fossil fuels run out before we have clean energy sources in place ready to take over our energy needs? What if we spend money developing technology to adapt to climate change and it is not successful?	
Provocative questions Questions to challenge convention. Questions Who should take the greater share of responsibility for adapting and mitigating climate change impacts: individuals or government? Should individuals bother about mitigating greenhouse gases in their homes when industry emits far more?	

Bringing it all together

1. Do you feel more confident in understanding what causes climate change?

____

____

2. Do you feel more confident in understanding how society can reduce the impacts of climate change?

____

____

3. How has your thinking changed from when you completed the six thinking hats activity, especially with regard to the red, green and blue hats?

____

____

____

____

____

____

____

____

____

____

____

About the Learning Matrix

What is the Climate Change Learning Matrix?

A Learning Matrix is a flexible classroom tool designed to meet the needs of a variety of different learning styles across different levels of capabilities. Students learn in many different ways; some are suited to hands-on activities, others are strong visual learners, some enjoy intellectually challenging independent hands-off activities, while others need more guidance. The matrix provides a smorgasbord of science learning activities from which teachers and/or students can choose.

Can I use the Matrix for one or two lessons, or a whole unit of study?

Either! The Matrix is designed to be time flexible as well educationally flexible. Choose to complete one activity, or as many as you like. The box below is meant to be attached to the rest if the boxes below.

Is there room for student negotiation?

Yes! Students can be given a copy of the Matrix and choose their own activities, or design their own activities in consultation with their classroom teacher.

What do the column headings mean?

Developing	**Extending**
Designed to enhance student comprehension of information by including research (other peoples' knowledge and ideas) into their activities.	Gives the student the opportunity to apply or transfer their learning into a new format where they have to create using their own design or evaluate using their own criteria.

What do the row headings mean?

First hand investigations	Hands-on activities that follow scientific method. Includes experiments and surveys. Great for kinaesthetic and logical learners, as well as budding scientists.
Maker space activities	Hands-on building, troubleshooting and reviewing a design of their own.
Ethical thinking	Students learn to recognise and explore ethical concepts. They examine reasons supporting ethical decisions, consider consequences of ethical decisions and reflect on ethical actions. Students examine values, rights, responsibilities and points of view.
ICT	Students use searches to locate, access and generate digital data and information. Students generate ideas, plans and processes, and communicate these via ICT. They select and use software, manage data, understand social and ethical protocols, and understand the impacts of ICT.
Personal and social capabilities	Students recognise emotions, personal qualities and achievements in themselves and diverse perspectives and relationships with and between others. They learn self management through working independently and learning how to express emotions appropriately. Students work collaboratively, make decisions, negotiate, resolve conflict and develop leadership skills.
Creative and critical thinking	Models the inquiry process. Students question, identify, clarify organise and process information. They generate ideas, possibilities and actions, connect ideas, consider alternatives and seek solutions. Students also reflect on thinking (metacognition) and processes, apply logic and reasoning, draw conclusions, and evaluate procedures. Knowledge is transferred into new contexts.
Time Travel	Here students consider scientific and technological development as a linear process by travelling back in time or creatively into the future.

Climate Change Learning Matrix		
	Developing	**Extending**
First hand investigations	Composting vegetable matter can help sequester carbon. Conduct an experiment to see which conditions are best for breaking down organic matter. See Linked Activity 1.	Extra CO_2 dissolved in large bodies of water can affect the pH of the water. A change in water pH can in turn affect the organisms that live in the water. Conduct an experiment to test the effect of dissolved CO_2 on water pH. See Linked Activity 2.
Maker space activities	Sea level rise and tidal surges are starting to play a major impact on coastal living. (Ref: p10 of the CSIRO book *Climate Change: Science and Solutions for Australia*) Make a model to demonstrate to your peers how sea level rise as ice melts and the impact it may have. How will you create an iceberg or glacier? How will you measure sea level rising and demonstrate its impact? OR The role of innovation (Ref: p113 of the CSIRO book *Climate Change: Science and Solutions for Australia*) Build a model of a house that has been designed for living with either a reduced carbon footprint, or a particular extreme weather event that is expected to occur more often in the future. List all the modifications you have made to the house to make it greener, or to withstand the extreme weather event.	Chapter 1 (Ref: pp1–14 of the CSIRO book *Climate Change: Science and Solutions for Australia*) describes a range of scientific data that is collected around the globe to measure evidence of climate change. Create your own model biodome that demonstrates how a natural ecosystem might work so that you can carry out a series of scientific measurements. For example, within the biodome you could measure temperature, amount of CO_2, pH, salinity, growth rate of plants, germination rate of seeds, and anything else you think is relevant. Once you have established the biodome and recorded some basic data, change one variable (e.g. temperature) and record any differences you observe.

Climate Change Learning Matrix		
	Developing	**Extending**
Ethical thinking	Karen and Heather read Chapter 1 and 2 of the CSIRO book *Climate Change: Science and Solutions for Australia*. Karen was speaking to Heather about climate change and how she believes human generated greenhouse gases are the cause. Heather disagreed, saying that this is just a natural cycle of the earth's climate. Do you believe Heather or Karen? How did you come to this belief? How would you try to help Heather and Karen to come to an agreement? Would it matter what they thought if they both had a low carbon foot print? Use information in Chapter 1 and Chapter 2 of the CSIRO book *Climate Change: Science and Solutions for Australia* to justify your response.	Are the effects of global warming and climate change in any way social justice issues? Will some communities have the opportunity to prepare and protect themselves physically and economically against the problems associated with global warming? Examine the communities that have contributed to global warming and those that are, and will in the future, suffer the consequences. Research and collect evidence to support your response to this question.
ICT	Look at snapshots of general weather projections for your state on pp39–42 of the CSIRO book *Climate Change: Science and Solutions for Australia*. Use the information and appropriate software to create an info-graphic to display the data for your state. OR Create a podcast of a regional weather report set in your local area in the future.	Search the internet to find organisations that use live data to monitor the environment, such as levels of CO_2, atmospheric or water temperature, ocean pH, or any other data you can think of. Can you help with the monitoring or analysis of the data in any way as a citizen scientist? How does this data compare to the corresponding data in the climate change book?
Personal and social capabilities	How would you communicate greenhouse gas mitigation strategies to people living in cities who don't think twice about the weather or their carbon footprint? What evidence would you provide to encourage them to change their actions and become more responsible? Use Chapters 8–10 of the CSIRO book *Climate Change: Science and Solutions for Australia* to help you choose the strategies.	Adaptation to climate change can come in many forms. See Chapters 5–7 of the CSIRO book *Climate Change: Science and Solutions for Australia*. Create a pamphlet, policy or advert to educate one group in society, e.g. farmers, coastal dwellers, the elderly living in the tropics of ways that they can adapt their lives to the predicted climate changes ahead.

Climate Change Learning Matrix		
	Developing	**Extending**
Creative and critical thinking	Write the terms below on separate pieces of paper and place them face down on the table. Randomly, and without looking, take two words and describe how they are similar and different. You can use the internet or a science textbook to research these terms if you need help. Alternatively you could play Pictionary or charades to describe each term to the class. Mitigation, solar panel, climate variability, greenhouse gas, carbon dioxide, adaptation, fossil fuel, flood, extreme weather, ocean temperature, terrestrial temperature, salinity, acidity, sea level, water security, coastal erosion, nuclear energy, wind power. OR Pretend you write interactive science games. Go to www.windows2universe.org/earth/climate/carbon_cycle.html and review the carbon cycle game. Visit the six carbon reservoirs and answer the questions along the way. When you have done this suggest how the game was helpful in learning about the carbon cycle and how it could be improved.	Review a film or book with extreme weather events as the main focus and use your scientific knowledge to analyse the story line for scientific accuracy. Could this event really take place? Why or why not? OR Design a new cover for the CSIRO book *Climate Change: Science and Solutions for Australia*. Justify why you have used the images, design and text to communicate climate change science.
Time Travel	Create a timeline of extreme weather information for your local area where you live from 1900 to present day. Include information such as the hottest day, wettest day, strongest winds, greatest amount of rainfall etc.	Read Chapter 3: Future Australian climate scenarios. Choose two Australian cities and write a diary entry for the climate for each city. Imagine it's 50 years in the future. How has the weather and climate changed in the cities? Has one changed more than the other? Use the data Chapter 3 to predict future trends. Will Australians still be using fossil fuel as their major source of energy? How much greenhouse polluting gas will there be? Will there be laws to help prevent greenhouse gas polluting? Will natural resources have run out, be rationed, or be 100% reused or recycled? Which clean energy sources will be used to generate electricity? What effect will the rise in sea level have on coastal cities? What advances in technology have been made to counteract global warming? What is it like living with extreme weather events? How is the lifestyle, home and food different?

Linked Activity 1

Under what conditions do organic materials compost the quickest?

Background Information

Do you have a compost at home or in your school garden? Composting is good for the environment because it reduces pollution.

- It makes use of organic household waste that would otherwise go to landfill where they would rot due to not breaking down properly.
- It avoids the use of harmful chemical fertilisers by producing a natural fertiliser.

In this investigation you will build two mini composts and then decide which variable to change to see which one composts the best. Conditions to test to see which compost breaks down the best could be: the amount of light, heat, moisture each receives; the amount of aeration (turning of the composted material) they are given; the type of materials used in the compost, or any other variable you think might make a difference to how the organic matter breaks down.

Write your independent variable here:

____

____

____

Aim

(Complete this once you have decided what to test.)

To build and test compost to see if…

____

____

____

____

Hypothesis

(Predict what is going to happen during your experiment and suggest why you think this.)

____

____

____

____

Materials:

- 4 x large plastic drink bottles of the same diameter
- Scissors
- Masking tape
- Stones
- Leftover kitchen waste such as bread, fruit and vegetables. Do not include protein produce such as meat, fish, eggs, cheese or milk.
- Leaves and/or grass – brown and fresh
- Newspaper or cardboard

Risk Assessment

Once you have written your method, read through the experiment and list any risks and precautions that can be taken to reduce these when conducting this experiment.

Risk	Precaution	Consequence

Procedure:

1. Cut the top off one plastic bottle and the bottom off another.
2. Stand the bottle with the top cut off on the bench. Remove the cap from the other bottle and insert it upside down into the standing bottle.
3. Use the masking tape to seal the two bottles together.
4. Place a few stones into the neck of the upturned bottle. Use stones that are too large to fall through the pouring end of the bottle.
5. Place some leaves and/or grass on top of the stones.
6. Place vegetable scraps on top of the leaves and/or grass.
7. Cut a circle out of cardboard or several layers of newspaper to lie on top of the vegetable scraps. Keep this paper lid moist at all times so that the compost material does not dry out.
8. Make a second compost, similar to the one you have just made, but think about the one variable that you are going to change (the independent variable) and build the compost according to that difference. Be sure to keep all other variables the same.
9. Label the mini composts and keep them in the classroom.
10. Observe how well the material breaks down in your two composts during several weeks. You will need to decide how you are going to describe or measure the breakdown of the compost.

Results:

1. Design a data table to collect your observations on the two composts you have made. You may also want to take photos as the experiment progresses to show what happens.

Discussion

1. What was the independent variable you were testing (the one you changed)?

____

____

2. Which other variables did you have to keep the same?

____

____

____

3. Were you able to keep all variables except the one you were testing the same? If not, do you think that any of the other variables might have affected the result of the experiment so that it was not a fair test?

____

____

____

4. What was your dependent variable (the one you were measuring)?

____

____

____

5. Were your results reliable? Why or why not? What could you do to make your results more reliable?.

____

____

____

6. What advice would you give to someone else to help them if they wanted to conduct this experiment?

____

____

____

____

7. How might the reduction of organic waste in landfill have a positive effect on global systems?

____

____

____

____

8. What did you learn that was useful while conducting this experiment?

____

____

____

____

Conclusion:

Write a conclusion to summarise your results and respond to your aim.

____

____

____

____

____

Linked Activity 2

What effect does excess CO_2 have on the pH of water?

Introduction

The ocean's waters are becoming more acidic due to absorbing some of the excess $C0_2$ in the atmosphere. This in turn is affecting the organisms that live in the oceans, such as coral, that cannot tolerate the increased acidity.

Aim

To find out how the pH of water changes when the amount of CO_2 dissolved in water increases.

Materials:

Part 1: Change in pH of water using exhaled breath

- Straw
- Small beaker
- Universal indicator paper and colour chart

Part 2: Change in pH of water using an acid carbonate reaction

- Test tube
- Test tube with side arm, delivery tube and cork
- Test tube rack
- Calcium carbonate
- Spatula
- Hydrochloric acid (dilute)
- Universal indicator paper and colour chart

Procedure

Part 1: Change in pH of water using exhaled breath

1. Before you begin, make sure the beaker is clean by rinsing it with tap water, and that you are wearing appropriate personal protective equipment, such as protective clothing and goggles.
2. Half fill the beaker with tap water.
3. Use the universal indicator to measure the pH of the tap water. Record pH in Results Table 1.
4. Using a clean straw, blow bubbles into the water for 30 seconds.
5. Use the universal indicator to measure the pH of the tap water. Record pH in Results Table 1.
6. Empty the water from your beaker and rinse it.
7. Repeat the experiment two more times and record all results in Results Table 1.
8. Calculate the average pH of water before and after blowing bubbles.
9. Calculate the change in pH for each of the three trials.

Part 2: Change in pH of water using an acid carbonate reaction

1. Half fill a clean test tube with water. Use the universal indicator to measure the pH of the tap water. Record pH in Results Table 2.
2. Place a spatula of calcium carbonate in the test tube with the side arm.
3. Add enough hydrochloric acid to cover the calcium carbonate in the test tube with the side arm and immediately replace the cork.
4. Place the end of the delivery tube into the test tube of water so that any gas will bubble through the water.
5. When any bubbling has subsided remove the delivery tube and use the universal indicator to measure the pH of the tap water. Record pH in Results Table 2.
6. Share your results with your peers and ask two groups to share their results with you
7. Clean all equipment and pack away.

Risk Analysis:

Consult your teacher to complete a risk analysis for this investigation.

Risk	Precaution	Consequence

Results:

Results Table 1: Change in pH of water using exhaled breath			
pH of water			
	A. Before bubbling CO_2 into water	B. After bubbling CO_2 into water	C. Change in pH (A-B)
Trial 1			
Trial 2			
Trial 3			
Average of Trials 1, 2, 3			

Results table 2: Change in pH of water using an acid carbonate reaction			
pH of water			
	A. Before bubbling CO_2 into water	B. After bubbling CO_2 into water	C. Change in pH (A-B)
Trial 1			
Trial 2			
Trial 3			
Average of Trials 1, 2, 3			

Discussion

1. What is pH?

____

____

____

2. Did the water become more acidic or basic when CO_2 was bubbled through it for either the exhaled breath or the acid carbonate reaction?

____

____

3. What might happen to seashells (calcium carbonate) or coral if they are exposed to an increase in acidity for a long period of time?

4. Why were three trials completed in both parts, and not just one?

5. Identify the independent variable in each part of the experiment.

6. Identify the dependent variable in each part of the experiment.

7. Identify the control in the experiment.

____

8. Why was a control necessary?

____

____

____

____

9. Use the space below to create a graph to show the average change in pH of normal tap water and water that has had CO_2 bubbled through it for both part 1 and part 2.

Conclusion:

Write a conclusion to summarise your results and respond to your aim.

____

____

____

____

____

____

Linked Activity 3

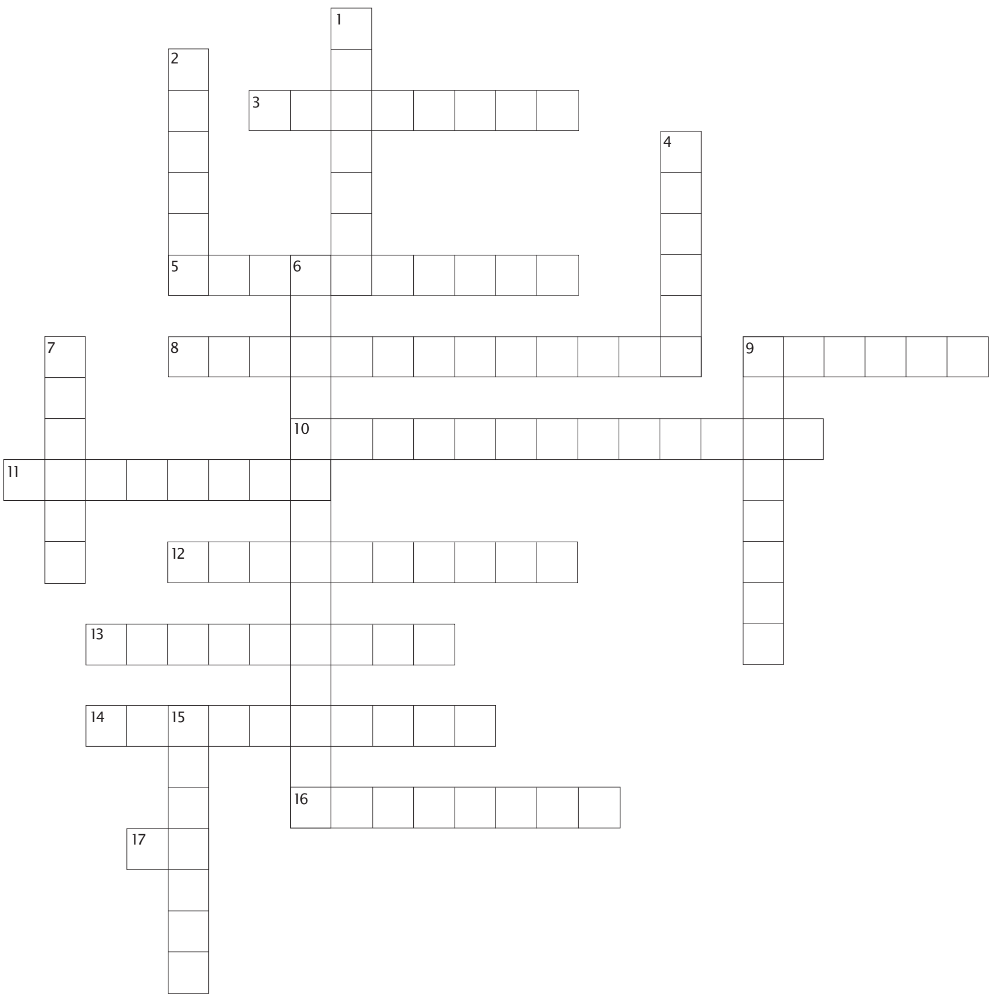
Why aren't we using more renewable energy sources?

1. Choose 3 different renewables (pages 118–121 of the CSIRO *Climate Change: Science and Solutions for Australia* book) and complete the following table.

Renewable energy source	Current disadvantages needing to be overcome	Future advantages

2. Choose a combination of two renewables you think will most likely be in use in the future when non-renewables such as coal run out. Using information gathered in the table, prepare a presentation to the class on why you support this idea.

Section 1 – Crossword



EVALUATE

Down

1. An example of an extreme weather event.

2. The opposite cycle to the El Niño events.

4. An example of matter that cycles through the different spheres of the Earth.

6. A process where plants use carbon dioxide to make sugar.

7. The unit used to measure energy.

9. To reduce the amount of carbon produced.

15. Greenhouse gas produced when livestock belch and fart.

Across

3. Coastal areas are prone to this.

5. Coping with changes that are already happening.

8. Planting forests.

9. Scientists use these mathematical ______ to predict possible future climate change events.

10. A marine phenomena that affects weather patterns.

11. There is evidence that these are slowly melting.

12. Is being destroyed by CFCs.

13. This happens to coral due to increased water temperatures or increased acidity.

14. A process in the carbon cycle.

16. How salty something is.

17. A measure of acidity.

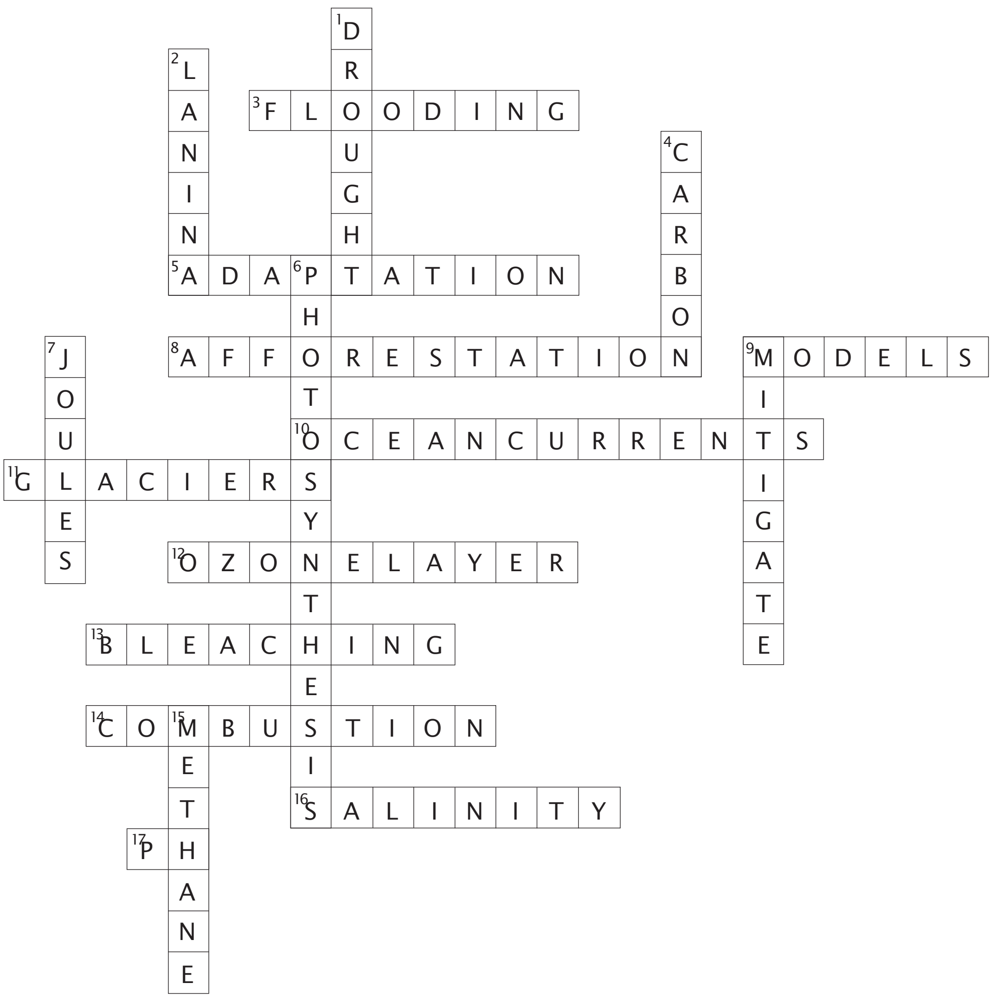
Section 2 – Creating your own climate change quiz

1. Ask each student to call out a word related to the activities you have carried out and what you have learnt during this unit on climate change. Record these words on the board.
2. Each student must pick six words from the board and write a definition for each.
3. Students then pick four more words from the board and write a paragraph describing them. They should highlight their chosen words in the paragraph.
4. Students create a concept map showing all they have learnt about climate change using at least half the words from the board. They should show links between words and write along lines connecting words to show how the terms are related.

Section 3 – Climate change individual unit review

What about you?	**Drawing**
Describe your favourite activity during this unit of study.	Create an image that summarises this unit of work for you.
Learning Summary	**Your philosophy**
Write two bullet points of things you learnt about climate change.	Describe your overall thoughts about climate change after completing this unit. Has this unit of work changed your thinking about climate change? Will it change your behaviour in the future? Are you more interested in learning about climate change?
More questions?	**Metacognition**
Write three questions that you still have about climate change or anything else related to this unit of study.	Which activities did you find helped you learn the easiest? Why?

CROSSWORD ANSWERS



NOTES

NOTES

NOTES

NOTES

CLIMATE CHANGE

Climate change is the greatest ecological, economic, and social challenge of our time.

Climate change research over many years shows links between human activities and warming of the atmosphere and oceans. This warming has caused changes to the climate system, such as changes in rain and wind patterns, and reductions in Arctic sea ice.

Climate change adaptation involves taking action to adapt to climate change and to plan and prepare for the risk of future change.

Climate change mitigation refers to actions that aim to limit greenhouse gases in the atmosphere, either by reducing emissions or by increasing the amount of carbon dioxide stored in natural sinks.

Drawing on peer-reviewed literature contributed to by thousands of researchers, *Climate Change: Science and Solutions for Australia* provides the latest scientific knowledge on a series of climate change topics relevant to Australia and the world.

CSIRO