Regina
Catholic Schools
www.rcsd.ca

# CARBON CYCLE AND THE ENVIRONMENT

## GRADE 10

Made for sharing!

Regina
Catholic Schools
www.rcsd.ca

# CARBON CYCLE AND THE ENVIRONMENT

# GRADE 10

## Grade 10 Authors

**Heather Haynes**
*Miller Comprehensive High School*

**Leah Maier**
*Archbishop M.C. O'Neill High School*

**Mark Wernikowski**
*Archbishop M.C. O'Neill High School*

## Project Team

**Paul Owens**
*St. Jerome School*

**Elizabeth Stephenson**
*St. Mary School*

**Christine Treptau**
*St. Gabriel School*

## Project Consultant

**Donna Ell**
*Regina Catholic School Division*

**These materials were externally reviewed by**
**Kirsty Anderson**
*Global Carbon Capture and Storage Institute*

## Table of Contents

Introduction ........ 3

Curricular Connections........ 4

Carbon Capture and the Environment Module Tentative Day Plan ........ 5

Carbon Capture and the Environment PowerPoint ........ 6

Bottled Greenhouse Effect TEACHER VERSION ........ 15

Bottled Greenhouse Effect Lab ........ 20

Bottled Greenhouse Effect Student Handout ........ 21

Nature’s Carbon Capture *Plants* TEACHER VERSION ........ 22

Nature’s Carbon Capture *Plants* Student Handout........ 24

Carbon Capture and Storage Web Quest TEACHER VERSION ........ 26

Carbon Capture and Storage Web Quest Student Handout ........ 29

Measuring the Permeability of $CO_2$ Caps Lab TEACHER VERSION ........ 31

Measuring the Permeability of $CO_2$ Caps Lab ........ 35

Measuring the Permeability of $CO_2$ Caps Lab Student Handout ........ 36

Ecological Footprint TEACHER VERSION ........ 37

Ecological Footprint Student Handout........ 42

Carbon Capture and Storage- Differing Perspectives TEACHER VERSION ........ 46

Carbon Capture and Storage- Differing Perspectives ........ 48

# Introduction

Global climate change is one of the most challenging environmental issues facing today's society. Although there have been numerous calls over the last two decades to reduce greenhouse gas emission, global emissions continue to increase. As the world's energy needs increase, we must look not only at ways to reduce carbon but also ways of sequestering carbon to minimize the impact that human activity has on the environment. Carbon capture and storage together with renewable energy, efficient technology, and behavioral changes will play an increasingly vital role in reducing carbon dioxide emission both locally and globally.

Carbon Capture and Storage (CCS) is a relatively new technology and as such, introduction must start at the level of education.  When new technologies become available one of the greatest challenges is incorporating them into our pre-existing knowledge base. This resource has been developed by teachers for teachers to help science ten teachers incorporate carbon capture and storage into their pre-existing course. The module provides lessons and activities for teachers to introduce CCS to their students.  The module was developed in order to help students understand the interrelationship among science, technology, society and the environment. Such an understanding will bring about a deeper scientific literacy for our students.

## Curricular Connections

The carbon capture and storage module was designed to be aligned with Science 10 core unit *Life Science: Sustainability of Ecosystems.* Specifically, the following foundational and learning objectives are explored in this module.

### Foundational and Learning Objectives

**SE1 Explore cultural perspectives on sustainability**

1. Examine how various cultures view the relationships between living organisms and their ecosystems. (PSD, CD 9.3)
2. Explain changes in the scientific worldview (paradigm shift) of sustainability and human's responsibility to protect ecosystems. (TL, CCT)
5. Identify multiple perspectives that influence environment-related decisions or issues. (CCT, TL)

**SE2 Examine biodiversity within local ecosystems**

9. Demonstrate a sense of personal and shared responsibility for maintaining a sustainable environment. (PSD)

**SE4 Identify cycles, change, and stability in ecosystems**

1. Illustrate the cycling of nutrients and matter through biotic and abiotic components of an ecosystem by tracking carbon, nitrogen, and oxygen.
3. Identify and respect various cultural perspectives on the cycling of nutrients and matter through the environment. (CCT)

**SE5 Investigate human impact on ecosystems**

4. Compare the risks and benefits to society and the environment of applying scientific knowledge or introducing a technology. (TL)
5. Propose a course of action on social issues related to sustainability, taking into account human and environmental needs. (IL, PSD, TL)
6. Predict the personal, social, and environmental consequences of a proposed action. (PSD)
8. Describe how Canadian research projects in science and technology are funded. (TL)

**WD5 Identify consequences of global climate change**

1. Identify current issues related to global climate change. (PSD)
2. Identify the most important natural and human factors that influence global climate. (TL)

**CR5 Investigate chemical reactions involving acids and bases**

2. Work co-operatively with team members to develop and carry out a plan, and troubleshoot problems as they arise. (CD 2.3)
3. Evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making. (CCT, TL)
6. Describe the process of neutralization and identify practical examples

## Carbon Capture and the Environment Module Tentative Day Plan

1) PowerPoint Slides 1 – 14
   Pre- lab Activity 1: Bottled Greenhouse Effect
2) Activity 1: Bottled Greenhouse Effect
   - complete lab
   - post-lab discussion
   - if time, start PowerPoint Slides 15 – 27
3) PowerPoint Slides 15 – 27
   Pre-lab Activity 2: Nature's Carbon Capture *Plants*
4) Activity 2: Nature's Carbon Capture *Plants*
   - set up lab

   PowerPoint Slides 28 – 39

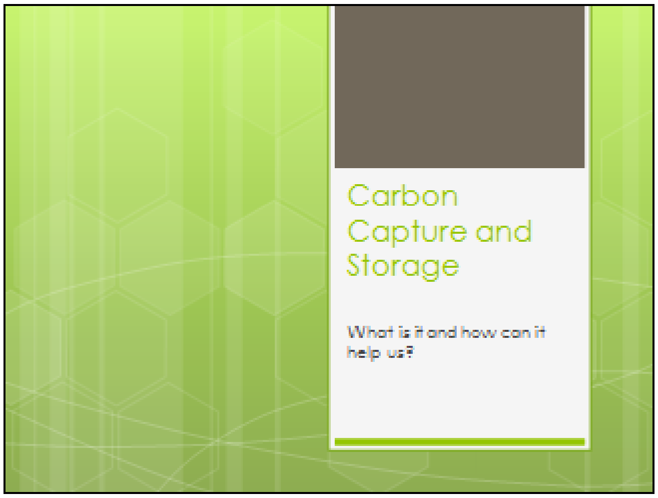
   If time, introduce Activity 3: Carbon Capture and Storage Web Quest and if time pre-lab Activity 4: Measuring the Permeability of $CO_2$ Caps
5) Activity 3: Carbon Capture and Storage Web Quest
   - complete activity in a computer lab or on portable devices
6) Activity 4: Measuring the Permeability of $CO_2$ Caps
   - pre-lab if not done on previous days
   - set up lab

     NOTE: Students will need to leave this experiment for 2 – 4 hours and then collect their results. Alternatively, the teacher could turn off the hot plates after 2 – 4 hours and students could collect their data the next day.

   Collect data for Activity 2: Nature's Carbon Capture *Plants.* Alternatively, data for this activity could be completed tomorrow instead.
7) Activity 2: Nature's Carbon Capture *Plants* if this was not done yesterday.
   - collect data
   - complete lab
   - post-lab discussion

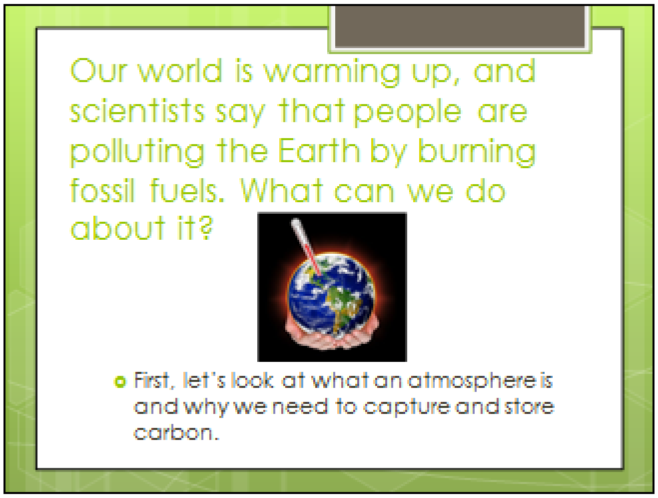
   PowerPoint Slides 41 – 50
8) Activity 5: Ecological Footprint
   - complete activity in a computer lab or on portable devices
9) Activity 6: Differing Perspectives
   1. Examination of Aboriginal Perspective
   - watch the Elder Video and take jot notes that they will use later in their "Perspective Summary" and "Reflection Questions"
   2. Internet research of a different perspective
   - complete activity in a computer lab or on portable devices
10) Activity 6: Differing Perspectives (Day 2)
    - continue internet research if additional time is required
    3. Completion of perspective summary and reflection questions
    - alternatively you could have students complete research and answer questions outside of class time

# Carbon Capture and the Environment PowerPoint



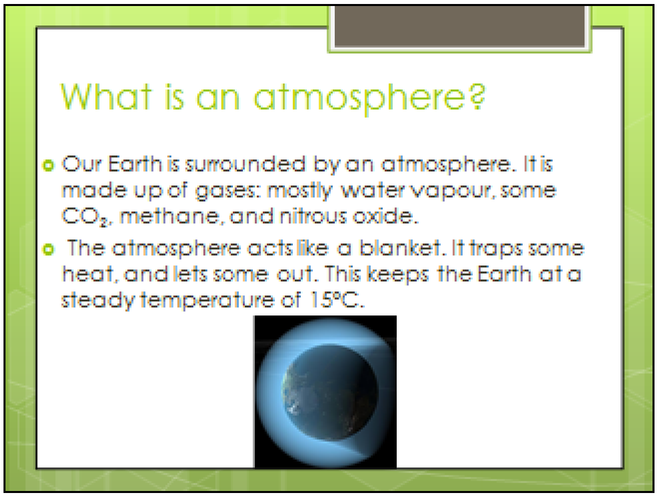
## Carbon Capture and Storage

What is it and how can it help us?



## Our world is warming up, and scientists say that people are polluting the Earth by burning fossil fuels. What can we do about it?

- First, let's look at what an atmosphere is and why we need to capture and store carbon.

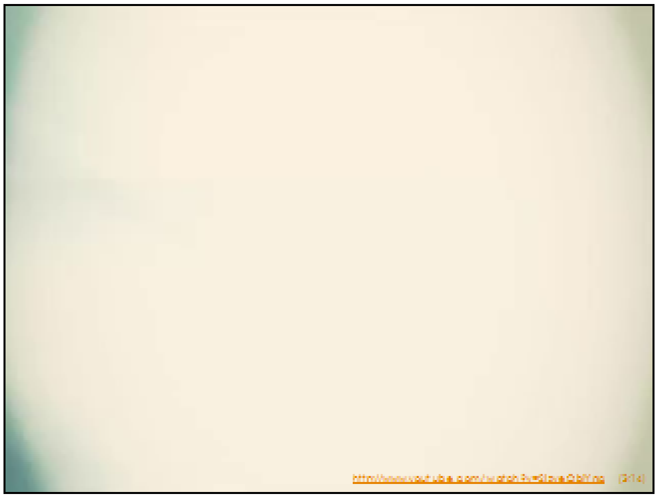


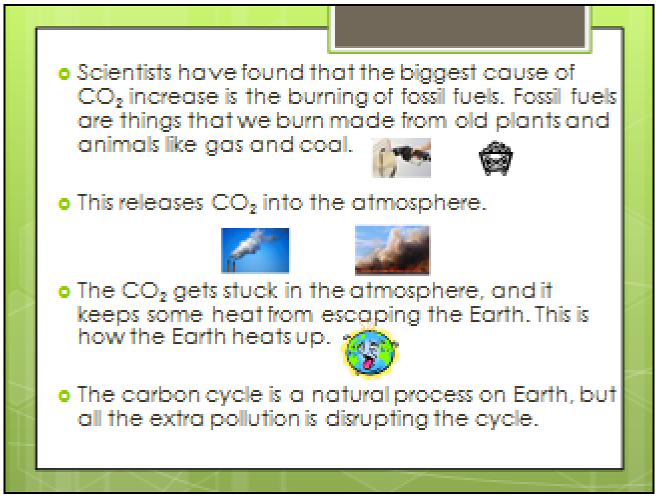
## What is an atmosphere?

- Our Earth is surrounded by an atmosphere. It is made up of gases: mostly water vapour, some $CO_2$, methane, and nitrous oxide.
- The atmosphere acts like a blanket. It traps some heat, and lets some out. This keeps the Earth at a steady temperature of 15°C.

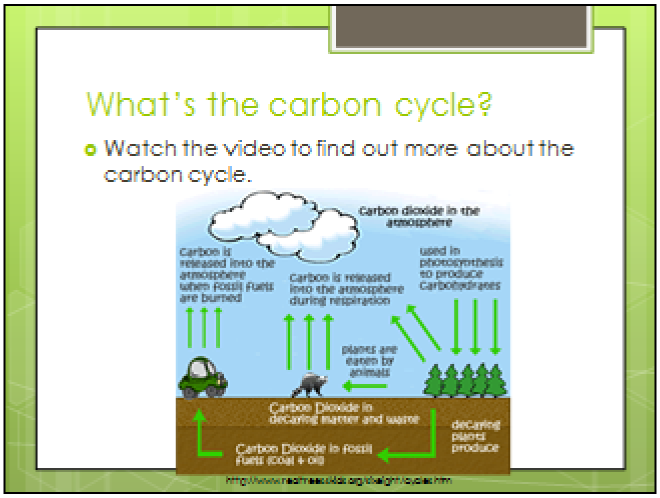
## What is $CO_2$?

- $CO_2$ is natural in the atmosphere, and we need it in small amounts to keep our planet warm. BUT when people cut down trees, mine for metals and minerals, and burn fossil fuels; it adds too much $CO_2$ to the atmosphere.





- Scientists have found that the biggest cause of $CO_2$ increase is the burning of fossil fuels. Fossil fuels are things that we burn made from old plants and animals like gas and coal.
- This releases $CO_2$ into the atmosphere.
- The $CO_2$ gets stuck in the atmosphere, and it keeps some heat from escaping the Earth. This is how the Earth heats up.
- The carbon cycle is a natural process on Earth, but all the extra pollution is disrupting the cycle.



## What's the carbon cycle?

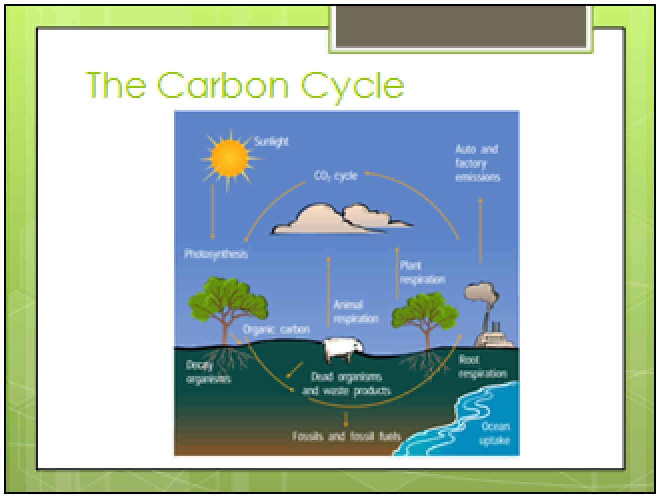
- Watch the video to find out more about the carbon cycle.

http://www.realtrees4kids.org/dwight/cycles.htm

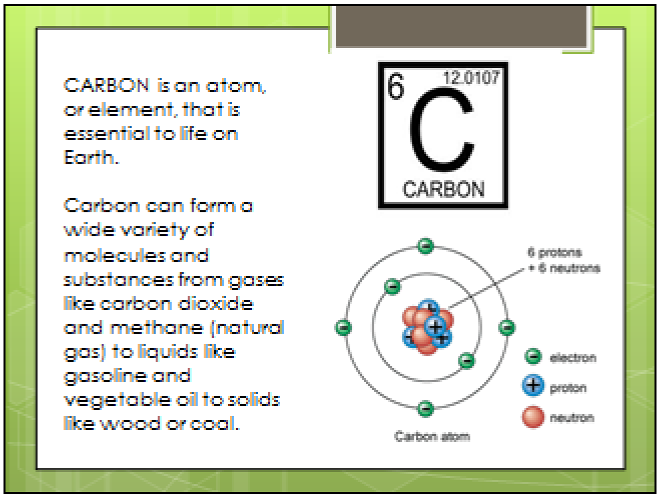
## Matter Cycles

Matter: anything that has mass and takes up space.

- Unlike energy that flows through a food web never returning to the source (sun), matter does not leave the food web; it cycles.
- As it cycles it changes from one form to another within the web.
- In this manner, matter is used over and over again in a community.
- Matter travels in cycles from the non-living (abiotic) environment into the living (biotic) food web and back to the non-living.



## The Carbon Cycle



CARBON is an atom, or element, that is essential to life on Earth.

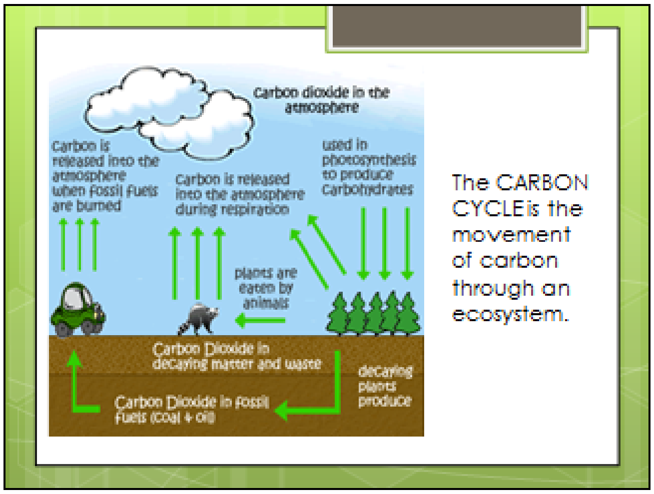
Carbon can form a wide variety of molecules and substances from gases like carbon dioxide and methane (natural gas) to liquids like gasoline and vegetable oil to solids like wood or coal.

Carbon can be found in things such as:

Soda

Vegetable Oil

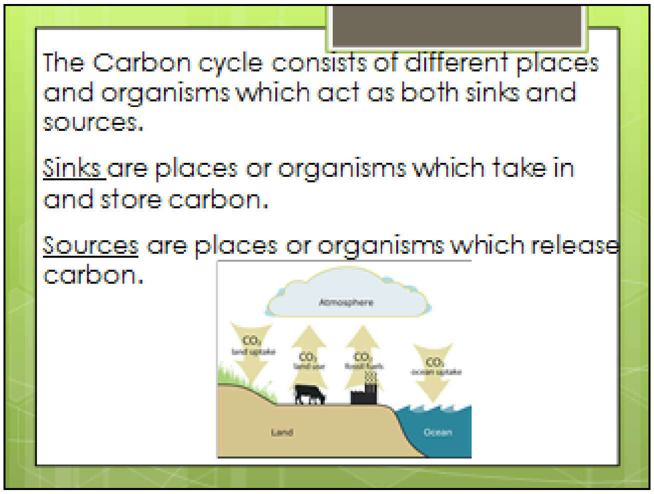
Gasoline



The CARBON CYCLE is the movement of carbon through an ecosystem.

## Why worry about global warming?

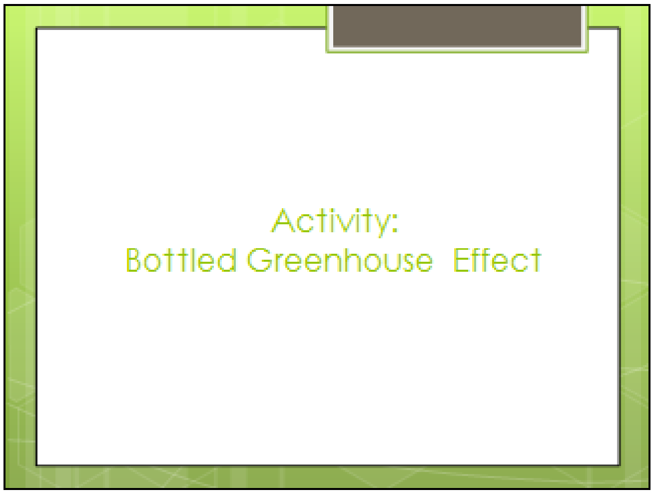
- We need to do something about global warming because an increased temperature in the world can have the following effects:
  - More extreme weather like tornadoes and hurricanes
  - Worsened smog causing higher rates of asthma
  - Increased spread of disease
  - Droughts



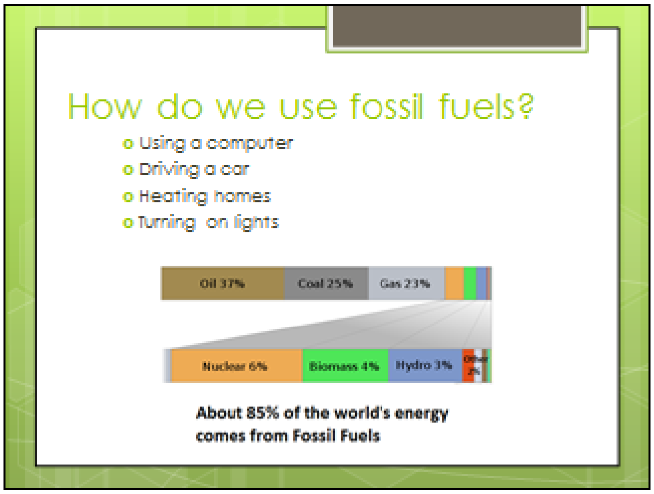
The Carbon cycle consists of different places and organisms which act as both sinks and sources.

Sinks are places or organisms which take in and store carbon.

Sources are places or organisms which release carbon.



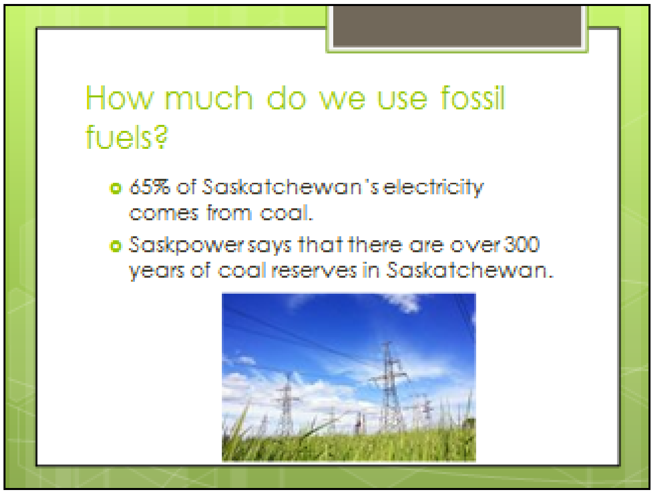
## Activity:
## Bottled Greenhouse Effect



## How do we use fossil fuels?

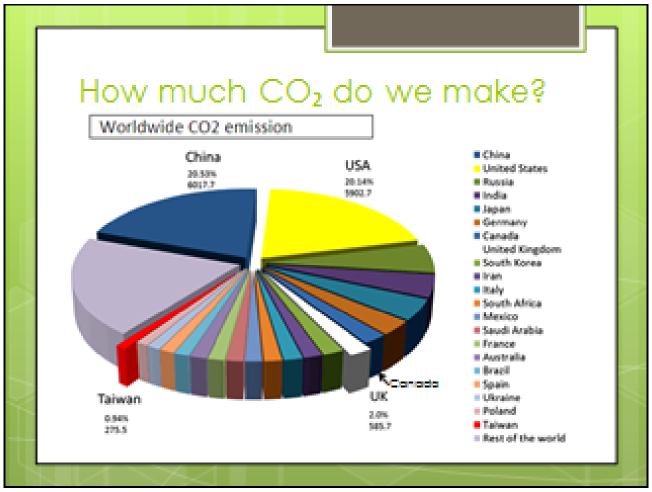
- Using a computer
- Driving a car
- Heating homes
- Turning on lights

**About 85% of the world's energy comes from Fossil Fuels**

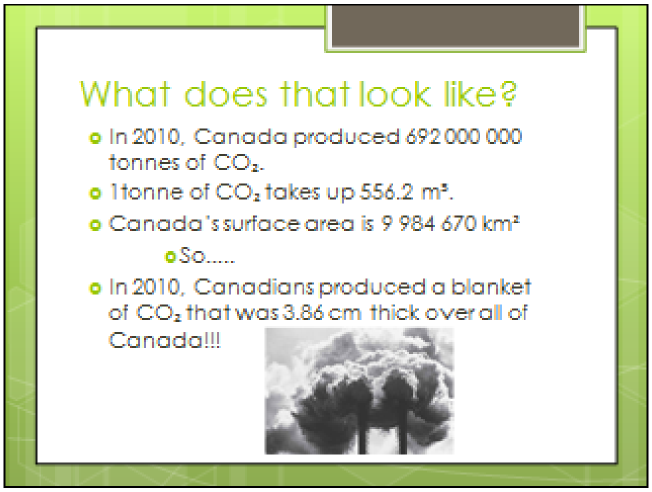


## How much do we use fossil fuels?

- 65% of Saskatchewan's electricity comes from coal.
- Saskpower says that there are over 300 years of coal reserves in Saskatchewan.



## How much $CO_2$ do we make?

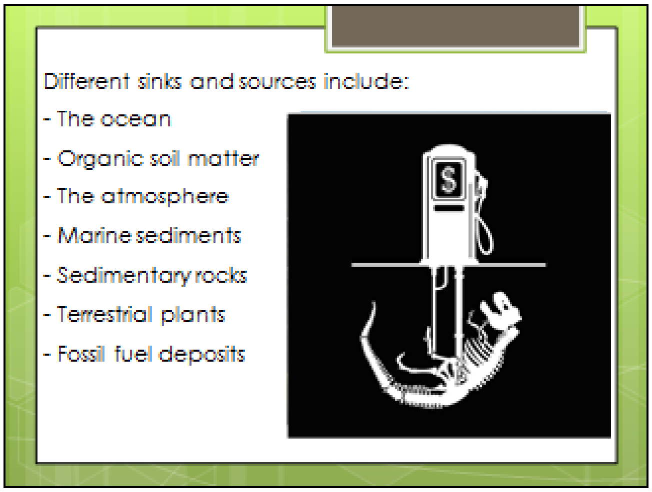


## What does that look like?

- In 2010, Canada produced 692 000 000 tonnes of $CO_2$.
- 1 tonne of $CO_2$ takes up 556.2 $m^3$.
- Canada's surface area is 9 984 670 $km^2$
  - So.....
- In 2010, Canadians produced a blanket of $CO_2$ that was 3.86 cm thick over all of Canada!!!

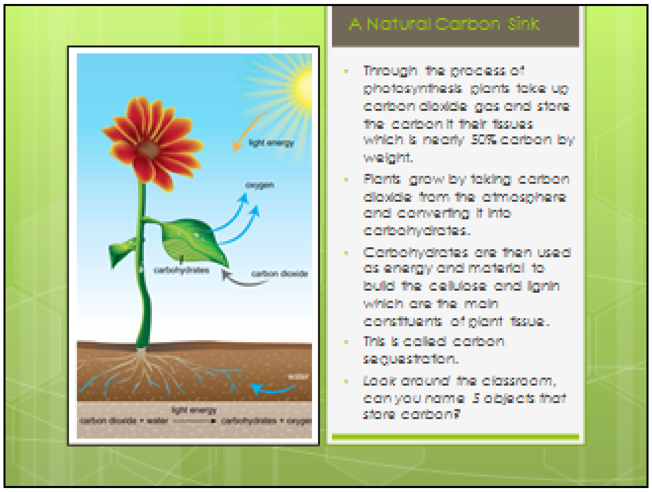
## What about Saskatchewan?

- Saskatchewan produced 72 100 000 tons of $CO_2$ in 2010.
- This is enough to build a skyscraper of $CO_2$ with a base the size of Taylor Field. That skyscraper would be over 4000km high!
- The tallest building in Regina is the Delta Hotel, and it's only 83.8 m high!
- That's a lot of $CO_2$!!!



Different sinks and sources include:

- The ocean
- Organic soil matter
- The atmosphere
- Marine sediments
- Sedimentary rocks
- Terrestrial plants
- Fossil fuel deposits

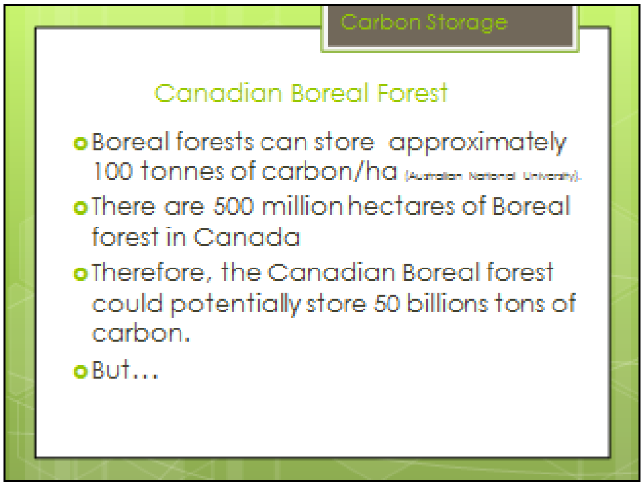


## A Natural Carbon Sink

- Through the process of photosynthesis plants take up carbon dioxide gas and store the carbon it their tissues which is nearly 50% carbon by weight.
- Plants grow by taking carbon dioxide from the atmosphere and converting it into carbohydrates.
- Carbohydrates are then used as energy and material to build the cellulose and lignin which are the main constituents of plant tissue.
- This is called carbon sequestration.
- Look around the classroom, can you name 5 objects that store carbon?

## Fast Facts

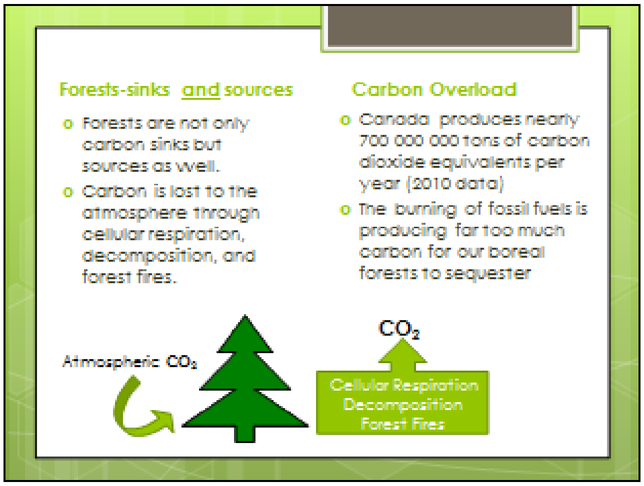
- 10 % of the world's forest are found in Canada
- *Canada's Boreal Forest* covers 53% of Canada and 75% of all forests in Canada are boreal forests
- There are 993.63 million acres of forest and other wood land in Canada



Carbon Storage

### Canadian Boreal Forest

- Boreal forests can store approximately 100 tonnes of carbon/ha (Australian National University).
- There are 500 million hectares of Boreal forest in Canada
- Therefore, the Canadian Boreal forest could potentially store 50 billions tons of carbon.
- But…

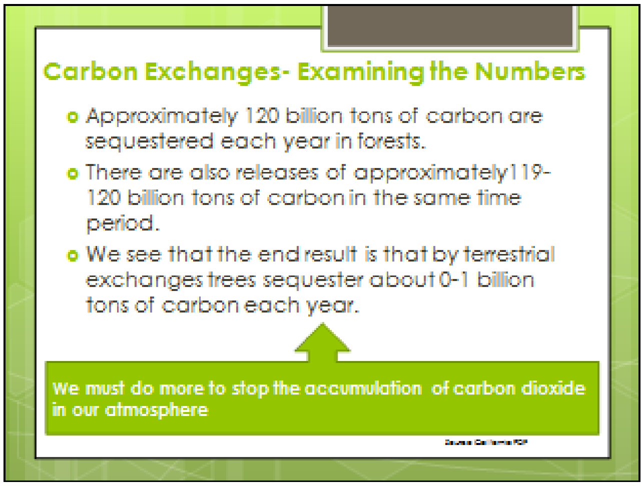


### Forests-sinks and sources

- Forests are not only carbon sinks but sources as well.
- Carbon is lost to the atmosphere through cellular respiration, decomposition, and forest fires.

### Carbon Overload

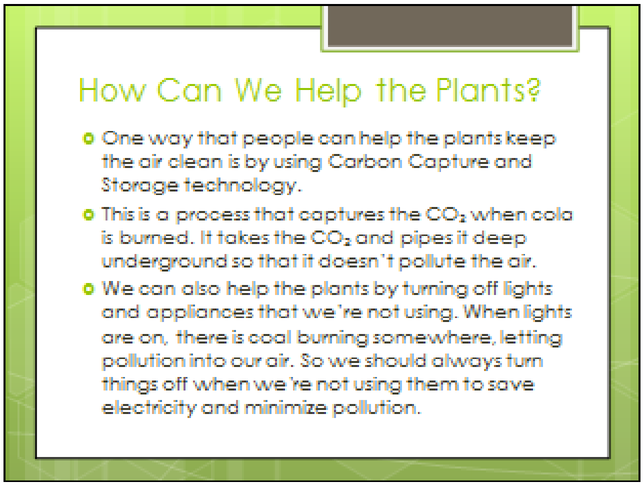
- Canada produces nearly 700 000 000 tons of carbon dioxide equivalents per year (2010 data)
- The burning of fossil fuels is producing far too much carbon for our boreal forests to sequester



### Carbon Exchanges- Examining the Numbers

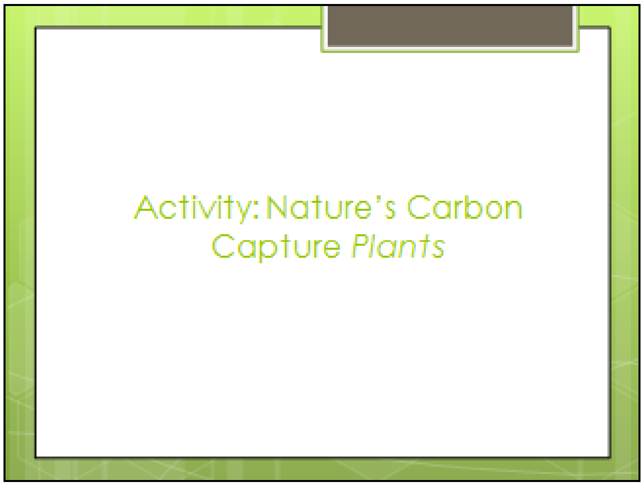
- Approximately 120 billion tons of carbon are sequestered each year in forests.
- There are also releases of approximately119-120 billion tons of carbon in the same time period.
- We see that the end result is that by terrestrial exchanges trees sequester about 0-1 billion tons of carbon each year.

**We must do more to stop the accumulation of carbon dioxide in our atmosphere**

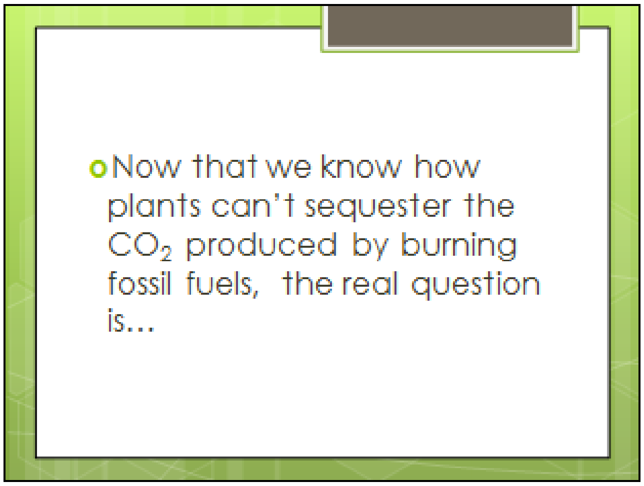


### How Can We Help the Plants?

- One way that people can help the plants keep the air clean is by using Carbon Capture and Storage technology.
- This is a process that captures the $CO_2$ when cola is burned. It takes the $CO_2$ and pipes it deep underground so that it doesn't pollute the air.
- We can also help the plants by turning off lights and appliances that we're not using. When lights are on, there is coal burning somewhere, letting pollution into our air. So we should always turn things off when we're not using them to save electricity and minimize pollution.



### Activity: Nature's Carbon Capture *Plants*



- Now that we know how plants can't sequester the $CO_2$ produced by burning fossil fuels, the real question is…

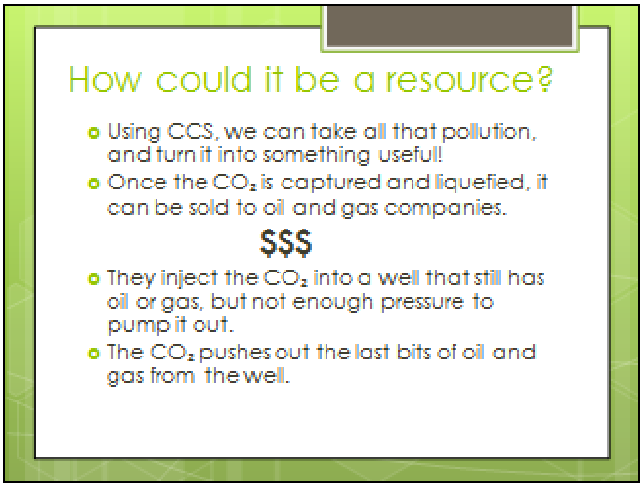
## Is $CO_2$ a waste or a resource?

## It must be a waste..

- All of that $CO_2$ used to go up into our atmosphere and pollute our air…

[illegible] Refinery

Boundary Dam
www.agefotostock.com

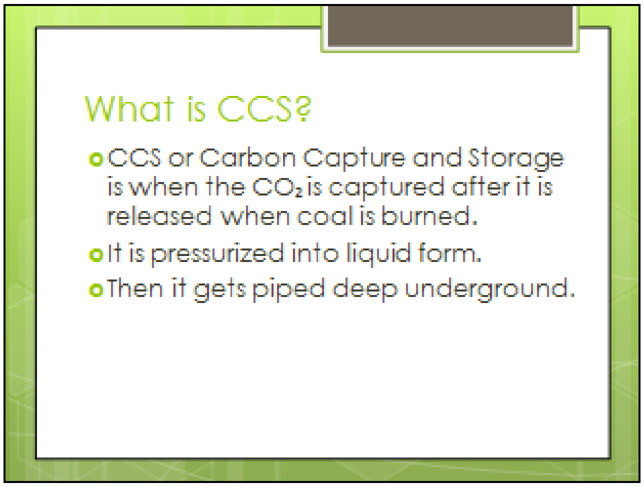


## How could it be a resource?

- Using CCS, we can take all that pollution, and turn it into something useful!
- Once the $CO_2$ is captured and liquefied, it can be sold to oil and gas companies.

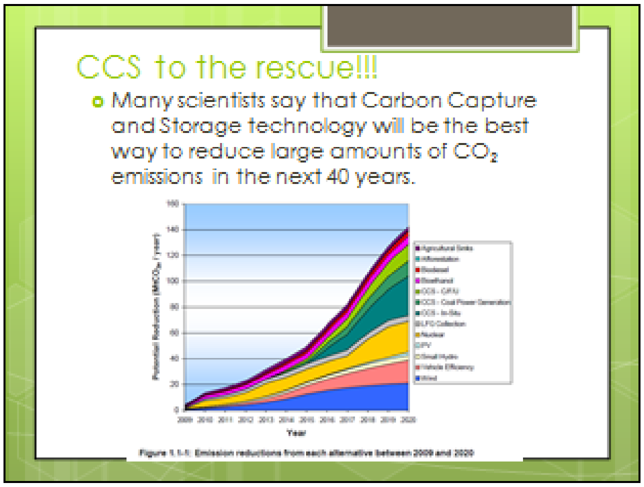
$$$

- They inject the $CO_2$ into a well that still has oil or gas, but not enough pressure to pump it out.
- The $CO_2$ pushes out the last bits of oil and gas from the well.



## What is CCS?

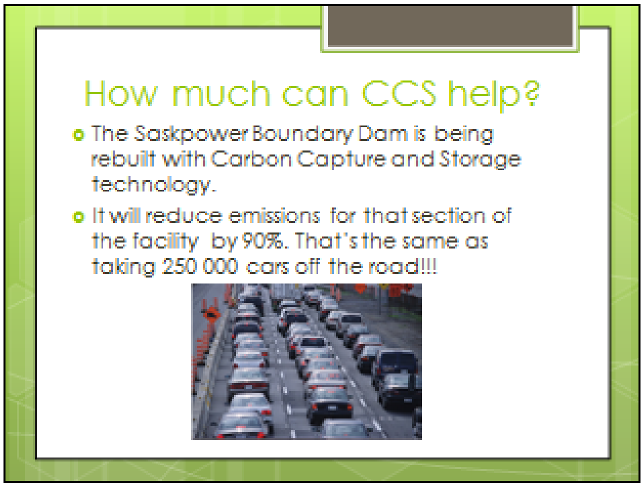
- CCS or Carbon Capture and Storage is when the $CO_2$ is captured after it is released when coal is burned.
- It is pressurized into liquid form.
- Then it gets piped deep underground.



## CCS to the rescue!!!

- Many scientists say that Carbon Capture and Storage technology will be the best way to reduce large amounts of $CO_2$ emissions in the next 40 years.

Figure 1.1-1: Emission reductions from each alternative between 2009 and 2020



## How much can CCS help?

- The Saskpower Boundary Dam is being rebuilt with Carbon Capture and Storage technology.
- It will reduce emissions for that section of the facility by 90%. That's the same as taking 250 000 cars off the road!!!

## How does the storage of $CO_2$ work?

- Watch the following video to find out.
  - Safe storage: Closing the carbon loop

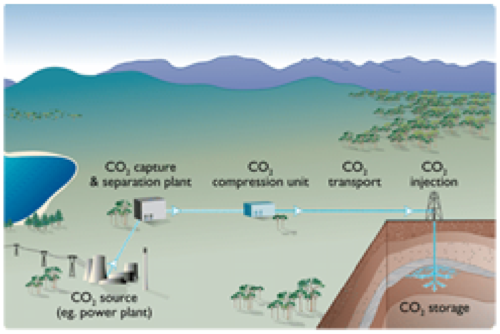
# Safe storage

## Closing the carbon loop

Zero emissions platform

European Technology Platform for Zero Emission Fossil Fuel Power Plants

[illegible]

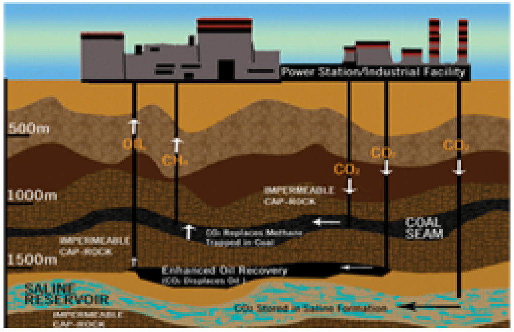


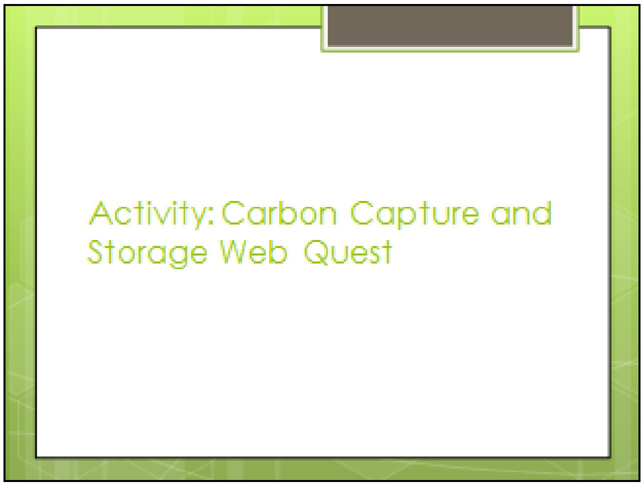
CO2 Capture Visual - http://www.lgeo-co2.com/about-co2-storage/how-ccs-works

[illegible]

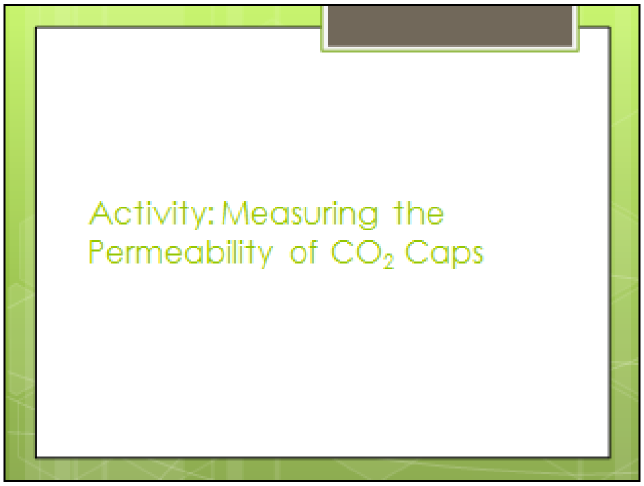
## Where does the $CO_2$ go?

- It needs to go deep underground into a stable formation.
- It can't be stored near the edges of plate tectonics.
- It sometimes get stored in old oil fields.
  - It needs to be deep enough and sealed properly so that the $CO_2$ doesn't escape.

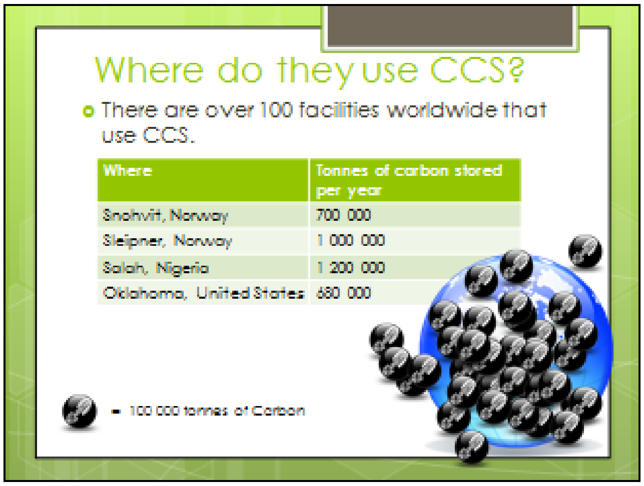




## Activity: Carbon Capture and Storage Web Quest



## Activity: Measuring the Permeability of $CO_2$ Caps



## Where do they use CCS?

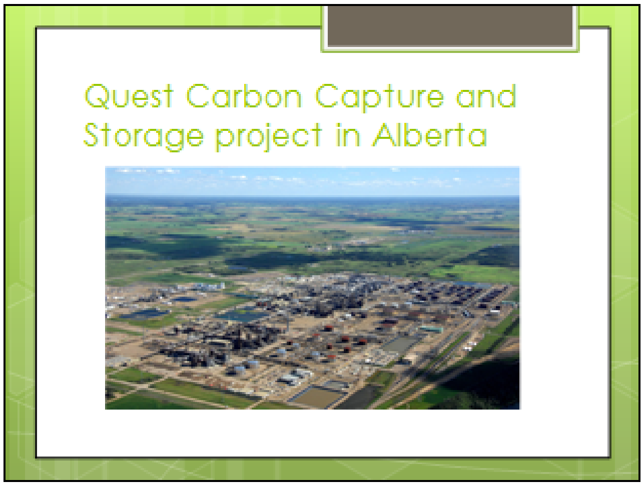
- There are over 100 facilities worldwide that use CCS.

| Where | Tonnes of carbon stored per year |
|---|---|
| Snohvit, Norway | 700 000 |
| Sleipner, Norway | 1 000 000 |
| Salah, Nigeria | 1 200 000 |
| Oklahoma, United States | 680 000 |

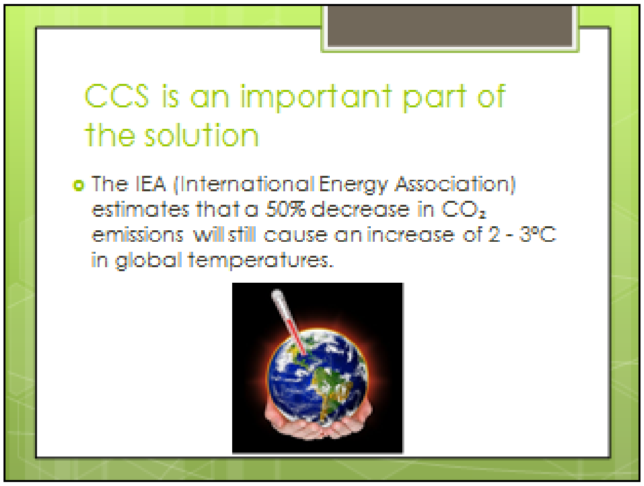
● = 100 000 tonnes of Carbon

## Do we use CCS in Canada?

| Where? | Tonnes of carbon that will be stored per year | When? |
|---|---|---|
| Weyburn, Sask. | 2 000 000 | 2010 |
| Boundary Dam in Southern Sask. | 1 000 000 | 2014 |
| Quest in Central Alberta | 1 200 000 | 2015 |
| Agrium and Enhance in Central Alberta | 580 000 | 2014 |
| Lloydminster, Alberta | 100 000 | 2012 |

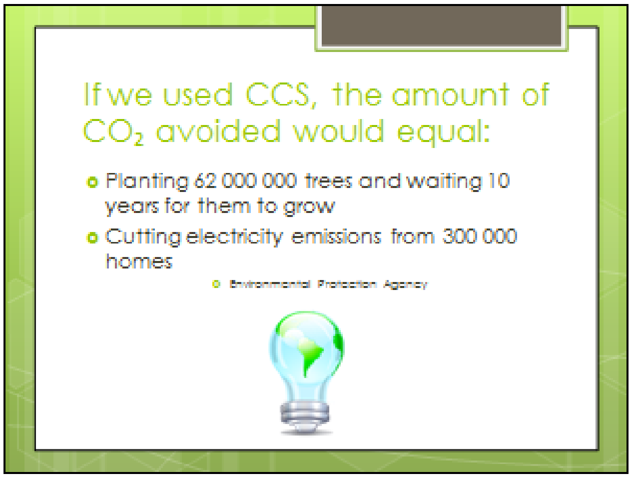


## Quest Carbon Capture and Storage project in Alberta



## CCS is an important part of the solution

- The IEA (International Energy Association) estimates that a 50% decrease in $CO_2$ emissions will still cause an increase of 2 - 3°C in global temperatures.



## If we used CCS, the amount of $CO_2$ avoided would equal:

- Planting 62 000 000 trees and waiting 10 years for them to grow
- Cutting electricity emissions from 300 000 homes
  - Environmental Protection Agency

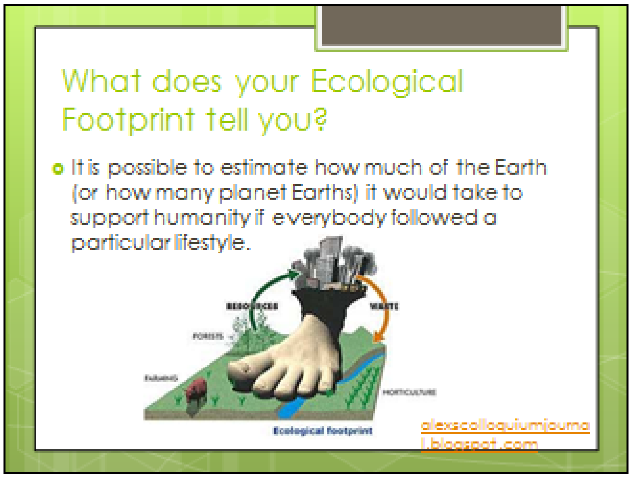
## Let's take care of the Earth…

- "We don't inherit the Earth from our ancestors; we borrow it from our children."
  David Brower

## An ecological footprint is a measure of human demand on the Earth's ecosystems.

lgmacweb.env.uea.ac.uk

- It represents the amount of biologically productive land and sea area necessary to supply the resources a human population consumes and to absorb associated waste.

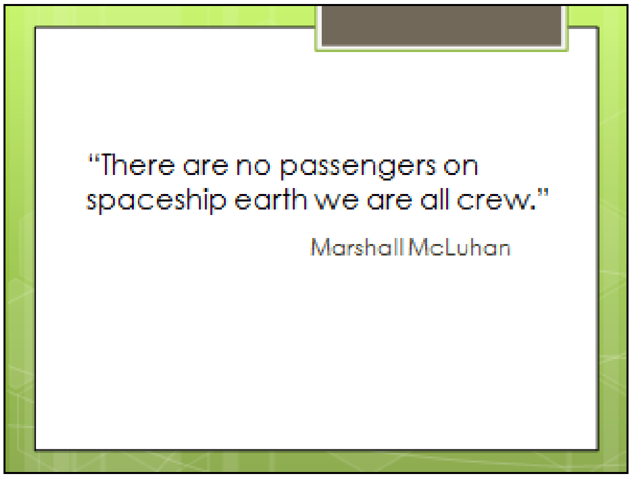


## What does your Ecological Footprint tell you?

- It is possible to estimate how much of the Earth (or how many planet Earths) it would take to support humanity if everybody followed a particular lifestyle.

alexscolloquiumjournal.blogspot.com

- Knowing your ecological footprint can help you learn how to conserve more and help protect ecosystems

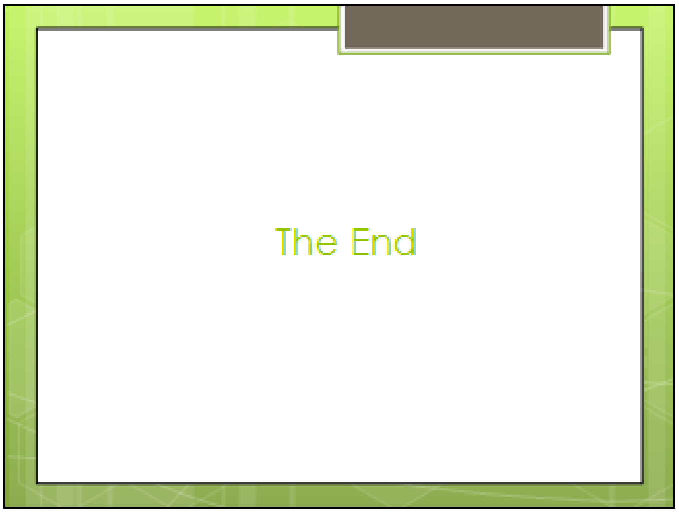


"There are no passengers on spaceship earth we are all crew."

Marshall McLuhan


Activity: Ecological Footprint


Activity: Differing Perspectives


The End

# Bottled Greenhouse Effect TEACHER VERSION

**Objective:** To assist in summing up the overall effect of greenhouse gases and bring understanding to why carbon capture is important.

**Foundational and Learning Objectives**:

**Science 10 Unit: Life Science: Sustainability of Ecosystems**

**SE4 Identify cycles, change, and stability in ecosystems**

1. Illustrate the cycling of nutrients and matter through biotic and abiotic components of an ecosystem by tracking carbon, nitrogen, and oxygen.

**SE5 Investigate human impact on ecosystems**

4. Compare the risks and benefits to society and the environment of applying scientific knowledge or introducing a technology. (TL)
5. Propose a course of action on social issues related to sustainability, taking into account human and environmental needs. (IL, PSD, TL)
6. Predict the personal, social, and environmental consequences of a proposed action. (PSD)
8. Describe how Canadian research projects in science and technology are funded. (TL)

**Science 10 Unit: Earth and Space Science: Weather Dynamics**

**WD5 Identify consequences of global climate change**

3. Identify current issues related to global climate change. (PSD)
4. Identify the most important natural and human factors that influence global climate. (TL)

**Background Information:**

The plastic bottle performs the role of the greenhouse gas layer, the paper represents the earth's adsorptive and reflective properties, the light acts as the sun and the air inside of the bottle represents the earth's atmosphere.

**Activity Overview:**

1. View PowerPoint Slides 1 – 14
2. Bottled Greenhouse Effect Activity
    a. Set up the experiment
    b. Collect data during the experiment
3. Complete analysis questions

**Assessment:**

The assessment can be based on the observation and analysis section. Assessment for learning can be realized through a classroom discussion surrounding student’s answers for this section. Alternatively, assessment of learning can take the form of a formal lab write up.

**Laboratory Details**

**Materials:**

- 2 L Pop Bottles x 2
    - 1 for Bottle #1
    - 1 for Bottle #2
- thermometer for each bottle
- #4 stopper with a thermometer hole
- any size stopper with a thermometer hole
- 1 lamp
- 100 watt bulb
- tape
- timer
- black paper x 2
- scissors

**Procedure:**

- **Bottle #1**
    1. Use scissors to create a slit in the 2 L bottle where the neck and the body meet. Take scissors and cut all around so that the bottle is now in two parts.
    2. Place a piece of black paper inside the body so that it curves around **half** of the inside of the bottle.
    3. Leave the top half OFF of the bottle.
    4. **CAREFULLY** place a thermometer inside a black stopper (that has a pre-prepared hole the size of the thermometer) and use this as the bottle cap. **DO NOT FORCE THE THERMOMETER. BE SURE TO LUBRICATE THE STOPPER WELL AND GENTLY PUSH IT THROUGH THE STOPPER.**

- **Bottle #2**
    5. Use scissors to create a slit in the 2 L bottle where the neck and the body meet. Take scissors and cut all around so that the bottle is now in two parts.
    6. Place a piece of black paper inside the body so that it curves around **half** of the inside of the bottle.
    7. Tape the two pieces of the bottle back together.
    8. **CAREFULLY** place a thermometer inside a black stopper (that has a pre-prepared hole the size of the thermometer) and use this as the bottle cap. **DO NOT FORCE THE THERMOMETER. BE SURE TO LUBRICATE THE STOPPER WELL AND GENTLY PUSH IT THROUGH THE STOPPER.**

- **Both Bottles**
  9. Set the bottles 10 cm away from the lamp. Turn the bottles so **that the black paper is on the side furthest from the lamp**.

**Expected Results**:

Bottle #1 (open bottle):
Temperature will increase as a result of the direct light on the thermometer, but will not increase as fast as the temperature in the closed bottle.

Bottle #2 (closed bottle):
Temperature will increase faster than the opened bottle. This bottle will get hotter than the other one and the temperature will increase at a much faster rate.

**Additional Information:** This lab could be completed either using a traditional approach or an inquiry approach. Both approaches are summarized below.

| Traditional Approach | Inquiry Approach |
|---|---|
| • Explain to students all the components of each of the two bottles, their functions and what they represent (as indicated in the purpose).<br>• Ask students to make a prediction about what is going to happen in each of the bottle scenarios.<br>• Set up the demonstrations so that both bottles are running simultaneously and data can be obtained from both at the same time.<br>• Have students recording data for both of the bottles and record it on the board (data = temperature/every minute).<br>• Compare and contrast the two results as a class.<br>• Were the students' hypotheses correct? | • Set up the demonstration so that both bottles are running simultaneously and data can be obtained from both at the same time.<br>• Have students recording data on the board (data = temperature/every minute).<br>• Ask the students to explain what was shown by this demonstration?<br>• Ask them what the different components of the demo represent? bottle? black paper?<br>• Have students propose different approaches to either mitigate or enhance the degree of temperature change. Students could be provided with an opportunity to then build their own bottles and test their predictions (ie. extension idea). |

**Extension Idea:**

An extension to this activity could be to inquire about the greenhouse effect on plants. This would provide the students with an opportunity to understand the cascading effects of greenhouse gases on ecosystems and how climate change can affect specific species. This adaptation would involve placing a plant with soil inside the greenhouse bottle in which the atmosphere or climate changes. Note: This extension would turn this demo into a long term project.

# Bottled Greenhouse Effect

**Name: ______KEY_____________**

**Purpose:**

- What is the overall effect of the greenhouse effect?

**Background Information:**

- The paper represents the earth's adsorptive and reflective properties, the light acts as the sun and the air inside of the bottle represents the earth's atmosphere.

**Hypothesis:** ___The greenhouse effect will cause a significant increase in temperature.______________

**Observations:**

| Time (min) | Bottle #1 (°C) | Bottle #2 (°C) |
|---|---|---|
| 0 | 24 | 24 |
| 1 | | |
| 2 | 27 | 29.5 |
| 3 | | |
| 4 | 28.5 | 33 |
| 5 | | |
| 6 | 30 | 35.5 |
| 7 | | |
| 8 | 30.5 | 37.5 |
| 9 | | |
| 10 | 31.5 | 39 |

**Results will vary**

**Analysis:**

1. Which experiment resulted in the largest temperature *change*?

   **Bottle #1** **OR** [✓ **Bottle #2**]

2. Compare the general trend your temperatures took over time.

   **Bottle #1 –** Increased at a slow rate.

   **Bottle #2 –** Increased at a fast rate.

3. Explain **<u>WHY</u>** there was a difference in warming between bottle #1 and bottle #2.
   Bottle #1 - Temperature will increase as a result of the direct light on the thermometer, but will not increase as fast as the temperature in the closed bottle because the heat is able to escape.
   Bottle #2 - Temperature will increase faster than the opened bottle. This bottle's temperature will increase at a much faster rate because the heat is trapped.

4. The bottle that exhibited the greenhouse effect was **open** **OR** [✓ **closed.**]
   What physical similarity is there between the earth and the bottle that caused the greenhouse effect?
   The earth has a layer of greenhouse gases and the closed bottle has a layer of plastic. They both function to trap the heat.

5. Would the earth be better off if the greenhouse gases were not present? What effect would this have on life on earth?
   Look for evidence of a basic understanding of how the natural greenhouse effect results in a life-sustaining average global temperature.

# Bottled Greenhouse Effect

**Purpose:**

- What is the overall effect of the greenhouse effect?

**Background Information:**

The paper represents the earth's adsorptive and reflective properties, the light acts as the sun and the air inside of the bottle represents the earth's atmosphere.

**Materials:**

- 2 L Pop Bottles x 2
  - 1 for Bottle #1
  - 1 for Bottle #2
- thermometer for each bottle
- #4 stopper with a thermometer hole
- any size stopper with a thermometer hole
- 1 lamp
- 100 watt bulb
- tape
- timer
- black paper x 2
- scissors

**Setup:**

- **Bottle #1**
  1. Use scissors to create a slit in the 2 L bottle where the neck and the body meet. Take scissors and cut all around so that the bottle is now in two parts.
  2. Place a piece of black paper inside the body so that it curves around **half** of the inside of the bottle.
  3. Leave the top half OFF of the bottle.
  4. **CAREFULLY** place a thermometer inside a black stopper (that has a pre-prepared hole the size of the thermometer) and use this as the bottle cap. **DO NOT FORCE THE THERMOMETER. BE SURE TO LUBRICATE THE STOPPER WELL AND GENTLY PUSH IT THROUGH THE STOPPER.**

- **Bottle #2**
  5. Use scissors to create a slit in the 2 L bottle where the neck and the body meet. Take scissors and cut all around so that the bottle is now in two parts.
  6. Place a piece of black paper inside the body so that it curves around **half** of the inside of the bottle.
  7. Tape the two pieces of the bottle back together.
  8. **CAREFULLY** place a thermometer inside a black stopper (that has a pre-prepared hole the size of the thermometer) and use this as the bottle cap. **DO NOT FORCE THE THERMOMETER. BE SURE TO LUBRICATE THE STOPPER WELL AND GENTLY PUSH IT THROUGH THE STOPPER.**

- **Both Bottles**
  9. Set the bottles 10 cm away from the lamp. Turn the bottles so **that the black paper is on the side furthest from the lamp**.

## Bottled Greenhouse Effect

**Name:** ____________________

**Purpose:**

- What is the overall effect of the greenhouse effect?

**Background Information:**

- The paper represents the earth's adsorptive and reflective properties, the light acts as the sun and the air inside of the bottle represents the earth's atmosphere.

**Hypothesis:** ________________________________________________________________________________

________________________________________________________________________________

**Observations:**

| **Time (min)** | **Bottle #1 (°C)** | **Bottle #2 (°C)** |
|---|---|---|
| **0** | | |
| **1** | | |
| **2** | | |
| **3** | | |
| **4** | | |
| **5** | | |
| **6** | | |
| **7** | | |
| **8** | | |
| **9** | | |
| **10** | | |

**Analysis:**

1. Which experiment resulted in the largest temperature *change*?

   **Bottle #1** **OR** **Bottle #2**

2. Compare the general trend your temperatures took over time:

   **Bottle #1**

   **Bottle #2**

3. Explain why there was a difference in warming between bottle #1 and bottle #2.

4. Which bottle exhibited the greenhouse effect?
   The bottle that exhibited the greenhouse effect was **open** **OR** **closed**.
   What physical similarity is there between the earth and the bottle that caused the greenhouse effect?

5. Would the earth be better off if the greenhouse gases were not present? What effect would this have on life on earth?

**Objective:** What is the role of plants in the in the carbon cycle?

**Foundational and Learning Objectives**:

**Science 10 Unit: Life Science: Sustainability of Ecosystems**

**SE4 Identify cycles, change, and stability in ecosystems**

1. Illustrate the cycling of nutrients and matter through biotic and abiotic components of an ecosystem by tracking carbon, nitrogen, and oxygen.
2. Select and use appropriate vocabulary and modes of representation to communicate scientific ideas.

**Background Information:**

It may be obvious that plants need sunlight to grow, but what may not be so obvious is that plants also need carbon dioxide. In this lab we will explore how plants, through photosynthesis, absorb carbon dioxide from their environment. As a result, plants are nature's way of sequestering carbon.

**Lesson Overview:**

1. View PowerPoint Slides 15 – 27
2. Elodea plant activity
   a. Set up experimental specimens
   b. Let the experiment progress for 24-48 hours
   c. Finish the experiment and conduct observations
3. Complete analysis questions

**Assessment:**

The assessment can be based on the observation and analysis section. Assessment for learning can be realized through a classroom discussion surrounding student's answers for this section. Alternatively, assessment of learning can take the form of a formal lab write up.

**Laboratory Details:**

**Materials:**

graduated cylinder
aquarium water or distilled water
3 – 250 mL beakers
drinking straw
*Elodea* (2 sprigs 5-8 cm long)
2 small test tubes
rubber stoppers for test tubes
test tube rack
bromothymol blue indicator solution (0.1%)
aluminum foil

**Note**

Bromothymol blue is and acid-base indicator that turns a greenish-yellow colour in the presence of an acid, but remains blue in the presence of a base. When carbon dioxide is dissolved in water it forms an acid called carbonic acid. Therefore, bromothymol blue can be used to indicate the presence or absence of carbon dioxide.

**Procedure**:

1. Measure 125 mL of aquarium or distilled water in a graduated cylinder and pour it into a beaker. Add enough bromothymol blue solution to turn the water in the beaker pale blue.
2. Using a straw, blow into the solution in the beaker until it just begins to turn yellow. Do not suck any of the solution into your mouth.
3. Fill the two test tubes within about 2 cm of the top with this solution.
4. Add an *Elodea* sprig to each tube and stopper it. Wrap one of the tubes with aluminum foil so that no light can enter.
5. Place both tubes in a test tube rack in direct light and leave for 24 to 48 hours.

**Observations and Analysis:**

1. Once 24 to 48 hours have passed observe the contents of both tubes.

   Water Colour in Uncovered Tube: ________water turns blue________

   Water Colour in Covered Tube: ______water turns even more yellow________

2. Add bromthymol blue to two beakers of tap water until the water turns blue. Bubble pure carbon dioxide through the water in one beaker. Bubble pure oxygen through the water in the other beaker. Comparing the colour changes that occur, what gas must you have exhaled into the aquarium water earlier on in the experiment?

   Water Colour in $CO_2$ Beaker: _____water turns greenish-yellow_______

   Water Colour in $O_2$ Beaker: ______no change in colour________

   Gas You Exhaled: ____ water turns greenish-yellow ______

3. Examine the colour of the water in the two test tubes. Explain the change in colour with respect to the presence or the absence of a gas.

   Explanation for Uncovered Tube:
   While exposed to the light the plant was photosynthesizing. One of the reactants in photosynthesis is carbon dioxide and one of the products is oxygen. As a result the plant took up the carbon dioxide that was in the water, causing the water to become less acidic. This was indicated by the change in colour of the bromthymol blue from greenish-yellow back to blue.

   Explanation for Covered Tube:
   While in the dark the plant was only able to respire. One of the products of respiration is carbon dioxide. As a result the plant released carbon dioxide into in the water, causing the water to become more acidic. This was indicated by the change in colour of the bromthymol blue from greenish-yellow to an even more yellow colour.

4. What experimental evidence do you have that plants naturally capture carbon (are earth's natural carbon capture *plants*)?
   The *Elodea* was able to take the carbon dioxide that was in its environment and trap it in its tissues.

5. If the earth already has a natural way of capturing and recycling carbon dioxide, why do you think it is still necessary to invest in carbon capture facilities?
   - Plants are both carbon sinks and carbon sources
     - Plants release carbon into the atmosphere through cellular respiration, decomposition and forest fires
   - Deforestation is decreasing the number of plants.
   - Far too many fossil fuels are being burned for trees to sequester.

Name: ____________________

# Nature’s Carbon Capture Plants Student Handout

**Objective of the Lesson:**
What is the role of plants in the in the carbon cycle?

**Background Information:**
It may be obvious that plants need sunlight to grow, but what may not be so obvious is that plants also need carbon dioxide. As a result plants are nature’s carbon capture *plants*!

**Materials:**
graduated cylinder
aquarium water or distilled water
3 – 250 mL beakers
drinking straw
*Elodea* (2 sprigs 5-8 cm long)
2 small test tubes
rubber stoppers for test tubes
test tube rack
bromothymol blue indicator solution (0.1%)
aluminum foil

**Note**
Bromothymol blue is and acid-base indicator that turns a greenish-yellow colour in the presence of an acid, but remains blue in the presence of a base. When carbon dioxide is dissolved in water it forms an acid called carbonic acid. Therefore, bromothymol blue can be used to indicate the presence or absence of carbon dioxide.

**Procedure:**
1. Measure 125 mL of aquarium or distilled water in a graduated cylinder and pour it into a beaker. Add enough bromothymol blue solution to turn the water in the beaker pale blue.
2. Using a straw, blow into the solution in the beaker until it just begins to turn yellow. Do not suck any of the solution into your mouth.
3. Fill the two test tubes within about 2 cm of the top with this solution.
4. Add an *Elodea* sprig to each tube and stopper it. Wrap one of the tubes with aluminum foil so that no light can enter.
5. Place both tubes in a test tube rack in direct light and leave for 24 to 48 hours.

**Observations and Analysis:**
1. Once 24 to 48 hours have passed observe the contents of both tubes.

   Water Colour in Uncovered Tube: ____________________________

   Water Colour in Covered Tube: ______________________________

2. Add bromothymol blue to two beakers of tap water until the water turns blue. Bubble pure carbon dioxide through the water in one beaker. Bubble pure oxygen through the water in the other beaker. Comparing the colour changes that occur, what gas must you have exhaled into the aquarium water earlier on in the experiment?

   Water Colour in $CO_2$ Beaker: ____________________________

   Water Colour in $O_2$ Beaker: _____________________________

   Gas You Exhaled: _________________________

3. Examine the colour of the water in the two test tubes. Explain the change in colour with respect to the presence or the absence of a gas.

   Explanation for Uncovered Tube:

   Explanation for Covered Tube:

4. What experimental evidence do you have that plants naturally capture carbon (are earth's natural carbon capture *plants)?*

5. If the earth already has a natural way of capturing and recycling carbon dioxide, why do you think it is still necessary to invest in carbon capture facilities?

## Carbon Capture and Storage Web Quest TEACHER VERSION

**Objectives:**

To investigate the process of carbon capture; a way in which humans can help to counteract some of the effects of the additional carbon dioxide that is being put in the air through industry and other man-made processes.

**Foundational and Learning Objectives**:

**Science 10 Unit: Life Science: Sustainability of Ecosystems**

**SE1 Explore cultural perspectives on sustainability**

3. Explain changes in the scientific worldview (paradigm shift) of sustainability and human's responsibility to protect ecosystems. (TL, CCT)
6. Identify multiple perspectives that influence environment-related decisions or issues. (CCT, TL)

**SE4 Identify cycles, change, and stability in ecosystems**

2. Illustrate the cycling of nutrients and matter through biotic and abiotic components of an ecosystem by tracking carbon, nitrogen, and oxygen.

**SE5 Investigate human impact on ecosystems**

7. Compare the risks and benefits to society and the environment of applying scientific knowledge or introducing a technology. (TL)
8. Propose a course of action on social issues related to sustainability, taking into account human and environmental needs. (IL, PSD, TL)
9. Predict the personal, social, and environmental consequences of a proposed action. (PSD)

**Science 10 Unit: Earth and Space Science: Weather Dynamics**

**WD5 Identify consequences of global climate change**

5. Identify current issues related to global climate change. (PSD)

**Background Information:**

When fossil fuels (coal, oil, or natural gas) are burned, $CO_2$ is released into the atmosphere. As the $CO_2$ concentration in the atmosphere has been increasing, so has the average temperature of the earth, resulting in significant climate change. To lessen the impacts of climate change, we would have to reduce our emissions of carbon dioxide by as much as 80%, however the use of fossil fuels is not decreasing, but rather is increasing. Although alternative energy sources are being used (nuclear, hydroelectric, wind, solar power), most serious analysts have concluded that there is no way to reduce $CO_2$ without the continued use of coal. CCS (Carbon Capture and Storage) is one way of removing carbon from fossil fuels in the form of $CO_2$ either before or after combustion. (http://www.ccsreg.org.html)

**Lesson Overview:**

1. View PowerPoint Slides 28 – 39
2. Complete Activity 3: Carbon Capture and Storage Web Quest

**Assessment:**

Assessment can be based on the "**Carbon Capture and Storage Web Quest**"

**Visit www.co2captureproject.org/a/digital_in_depth_tool.html.** **Name: _______KEY______**

1. Click on "Site Selection"
    a. The most effective way to ensure permanent safe storage of $CO_2$ is to choose a site that has these three qualities:
        1) Sufficient depth (typically deeper than 800 meters)
        2) Adequate capacity
        3) An overlying sealing system to ensure containment of fluids

    b. What kinds of sites are **highly suited** for geological storage of $CO_2$?
    Depleted hydrocarbon reservoirs, such as oil and gas fields

    c. What are the three other potential storage sites for storage of $CO_2$?
        1) saline formations
        2) permeable rock formations, which contain salty waters in their pore spaces
        3) unmineable coal beds

**Note that as you scroll down you can see just how deep the $CO_2$ is being stored!**

2. Scroll down to "Capture"
    a. What percent of the $CO_2$ produced by fossil fuels at large fixed installations can be captured and prevented from reaching the atmosphere? 90%

There are three main technology types available - **pre-combustion**, **post-combustion** and **oxy-firing**

    b. Post-combustion can be installed on both new and existing power plants. Why is this of vital importance?
    The average power plant operates for 40 years.

    Follow the capture process down through the ground (scroll down the page) and answer the following:

    c. Groundwater is important because it is the source of spring and well water. With reference to the water table, how is the groundwater protected?
    Extra barriers of steel casing and cement around the well

    As $CO_2$ is injected the pressure increases with depth.

    d. Between 800-1000m the $CO_2$ is naturally compressed to what percent of its surface volume?
    1%

    e. What is this density similar to? The volume of a liquid rather than a gas

3. Transport and Injection
    a. Today $CO_2$ is transported by truck, ship or pipeline. However, to transport the large amounts of $CO_2$ from power plant emissions, what is the only practical solution?
    Pipelines

    b. Is the above process well understood? When has it been used since?
    Pipeline transportation is well understood. It has been used since the 1970s.

    c. How many tons of $CO_2$ a year can be safely and reliably carried by US pipeline infrastructure?
    50,000,000 tons of $CO_2$

Injection

The oil and gas industry has years of experience injecting $CO_2$ underground into geological formations, a process used to enhance oil recovery (techniques for increasing the amount of crude oil that can be extracted from an oil field).

d. Millions of tons of $CO_2$ are injected annually. What are the two regulations that surround this process?
The regulations protect local communities and the environment

e. Why has the industry rapidly developed precise drilling practices?
Because oil and gas have become more difficult to access

4. Storage

Mechanisms

a. What two conditions deep underground (typically more than 800 meters) allow for injected $CO_2$ to be stored safely?
    1) It is absorbed and then trapped in minute pores or spaces in the rock structure.
    2) Impermeable caprock acts as the ultimate seal to ensure safe storage for millions of years.

There are four main storage mechanisms for trapping $CO_2$:

1) Structural Trapping
Fluid $CO_2$ rises to the top of the formation until it reaches what kind of layer which securely traps the $CO_2$? Caprock

2) Residual Trapping
$CO_2$ moves up through the geological storage site towards the caprock, some of it is trapped in the microscopic pore spaces in the rock, similar to what?
Similar to air becoming trapped in a sponge.

3) Dissolution
What happens when the $CO_2$ begins to dissolve in the surrounding salty water?
It becomes heavier and sinks.

4) Mineral Trapping
When does mineral storage occur?
When the $CO_2$ binds chemically and permanently with the surrounding rock.

5. Monitoring

A wide array of monitoring technologies have been used by the oil and gas industry to track fluid movement in the subsurface. These techniques are readily adaptable to $CO_2$ storage to monitor the behaviour of $CO_2$ underground.

a. For example, seismic surveying provides an image of the subsurface, often allowing what?
The behaviour of stored $CO_2$ to be mapped and predicted.

b. Other monitoring technologies include down hole and surface $CO_2$ sensors. Also, new technologies such as satellite imaging are being developed which can detect movements of less than how much?
1mm in the Earth's surface

## Carbon Capture and Storage Web Quest Student Handout

Name: _______________

**Visit www.co2captureproject.org/a/digital_in_depth_tool.html**.

1. Click on "Site Selection"
    a. The most effective way to ensure permanent safe storage of $CO_2$ is to choose a site that has these three qualities:

    b. What kinds of sites are **<u>highly suited</u>** for geological storage of $CO_2$?

    c. What are the three other potential storage sites for storage of $CO_2$?

**Note that as you scroll down you can see just how deep the $CO_2$ is being stored!**

2. Scroll down to "Capture"
    a. What percent of the $CO_2$ produced by fossil fuels at large fixed installations can be captured and prevented from reaching the atmosphere?

    There are three main technology types available - **pre-combustion**, **post-combustion** and **oxy-firing**

    b. Post-combustion can be installed on both new and existing power plants. Why is this of vital importance?

    Follow the capture process down through the ground (scroll down the page) and answer the following:

    c. Groundwater is important because it is the source of spring and well water. With reference to the water table, how is the groundwater protected?

    As $CO_2$is injected the pressure increases with depth.

    d. Between 800-1000m the $CO_2$ is naturally compressed to what percent of its surface volume?

    e. What is this density similar to?

3. Transport and Injection
    a. Today $CO_2$ is transported by truck, ship or pipeline. However, to transport the large amounts of $CO_2$ from power plant emissions, what is the only practical solution?

    b. Is the above process well understood? When has it been used since?

    c. How many tons of $CO_2$ a year can be safely and reliably carried by US pipeline infrastructure?

Injection

The oil and gas industry has years of experience injecting $CO_2$ underground into geological formations, a process used to enhance oil recovery (techniques for increasing the amount of crude oil that can be extracted from an oil field).

d. Millions of tons of $CO_2$ are injected annually. What are the two regulations that surround this process?

e. Why has the industry rapidly developed precise drilling practices?

4. Storage

Mechanisms

a. What two conditions deep underground (typically more than 800 meters) allow for injected $CO_2$ to be stored safely?

There are four main storage mechanisms for trapping $CO_2$:

1) Structural Trapping

Fluid $CO_2$ rises to the top of the formation until it reaches what kind of layer which securely traps the $CO_2$?

2) Residual Trapping

$CO_2$ moves up through the geological storage site towards the caprock, some of it is trapped in the microscopic pore spaces in the rock, similar to what?

3) Dissolution

What happens when the $CO_2$ begins to dissolve in the surrounding salty water?

4) Mineral Trapping

When does mineral storage occur?

5. Monitoring

A wide array of monitoring technologies have been used by the oil and gas industry to track fluid movement in the subsurface. These techniques are readily adaptable to $CO_2$ storage to monitor the behaviour of $CO_2$ underground.

a. For example, seismic surveying provides an image of the subsurface, often allowing what?

b. Other monitoring technologies include down hole and surface $CO_2$ sensors. Also, new technologies such as satellite imaging are being developed which can detect movements of less than how much?

# Measuring the Permeability of $CO_2$ Caps Lab TEACHER VERSION

**Objectives:**

1) Which material will provide the greatest permeability when being used to cap carbon dioxide?
2) Why do we need to investigate the materials involved in carbon capture?

**Foundational and Learning Objectives**:

**Science 10 Unit: Life Science: Sustainability of Ecosystems**

**SE1 Explore cultural perspectives on sustainability**

2. Explain changes in the scientific worldview (paradigm shift) of sustainability and human's responsibility to protect ecosystems.

**SE2 Examine biodiversity within local ecosystems**

9. Demonstrate a sense of personal and shared responsibility for maintaining a sustainable environment. (PSD)

**SE5 Investigate human impact on ecosystems**

4. Compare the risks and benefits to society and the environment of applying scientific knowledge or introducing a technology. (TL)
5. Propose a course of action on social issues related to sustainability, taking into account human and environmental needs. (IL, PSD, TL)
6. Predict the personal, social, and environmental consequences of a proposed action. (PSD)

**Background Information:**

Carbon dioxide can be stored permanently underground with proper site selection. When carbon dioxide gas is pumped deep underground its buoyancy causes it to rise. The carbon dioxide gas rises through porous rock until it becomes trapped by an impermeable layer of rock, often referred to as the cap rock. In this activity you will examine the permeability of various substances and the importance of selecting a site where an impermeable cap rock exists.

**Lesson Overview:**

1. View PowerPoint Slides 28 – 39 and complete Activity 3: Carbon Capture and Storage Web Quest
2. Measuring the Permeability of $CO_2$ Caps Lab
    a. Set up experiment let stand for 24 hours
    b. Set up the carbon capture apparatus, heat for 2-4 hours
    c. Finish the experiment and conduct observations
3. Complete "Measuring the Permeability of $CO_2$ Caps Lab Student Handout"

**Assessment:**

Assessment can be based on the "Measuring the Permeability of $CO_2$ Caps Lab Student Handout"

**Laboratory Details:**

**Materials:**

Inflating needle (like those used to inflate a ball) (4)
Pop bottles (4)
Rubber tubing ($\frac{1}{4}$ x $\frac{1}{16}$) (4 x 40 cm)
Capping Material: cotton balls and vegetable bags
Graduated cylinder (100 mL) (4)
Large Hot plate
Large beakers (800 mL or larger) (8)
Sticky Tac

**Procedure:**

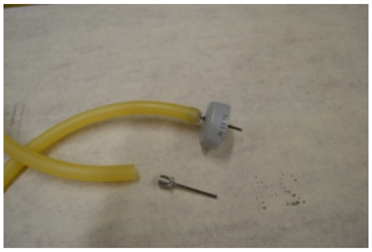
1. Obtain four pop bottles (do not shake!)
    a. 1st bottle: open the bottle and seal with vegetable “green bags”, fasten with an elastic band or duct tape
    b. 2nd bottle: open the bottle and stuff cotton to approximately 4 cm thick in the neck
    c. 3rd bottle: open the bottle and leave open (no cap)
    d. 4th bottle: open the bottle and then replace the cap.

    NOTE: SAVE THE BOTTLE CAPS FOR LATER!!

2. Leave the bottles stand for 24 hours

3. Insert the threaded end of the needle into one end of 40 cm rubber tubing so that you have a good seal.

4. Repeat step #3 for each bottle

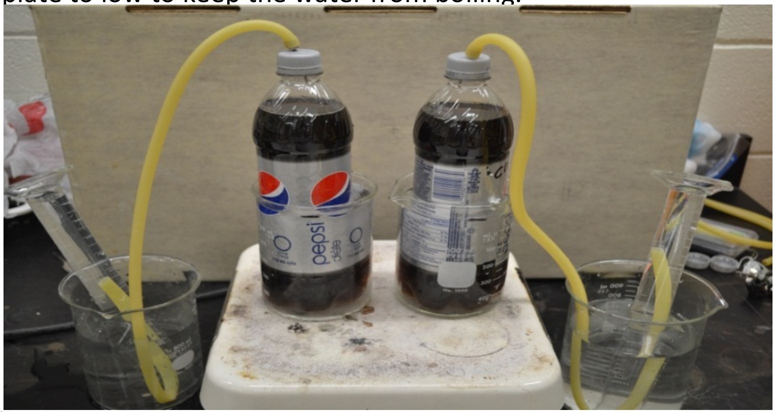


5. Put the other end of the tubing in a graduated cylinder full of water. Turn the graduated cylinder upside down in a tub of water, being careful not to let any air enter. The graduated cylinder should have **nothing but water in it**.

6. Place the pop bottle in a beaker of water on a hot plate.

7. Heat the inflating needle with a lighter and puncture each of the four bottle caps with the inflating needles so that the tip of the needles are in the soda's head space. Make sure nothing is obstructing the flow of carbon dioxide into the tip of the needle. Use sticky tac to seal the hole in the bottle around the needle.

8. Turn on the hot plate to low to keep the water from boiling.



9. Heat the water for 2-4 hours

    Note: Carbon dioxide is less soluble at higher temperatures, so after an hour of heating, most of the carbon dioxide should be driven out. The gas will displace the water in the graduated cylinder so you can measure its volume.

10. Record your data on the student worksheet.

**Measuring the Permeability of $CO_2$ Caps Lab Student Handout** **Name:__KEY____**

**Objectives:**

1) Which material will provide the greatest permeability when being used to cap carbon dioxide?
2) Why do we need to investigate the materials involved in carbon capture?

**Hypothesis:**

1) Rate the following in order of highest to lowest permeability

_______ pop that was sealed with vegetable "green bag"

_______ pop capped with cotton ball

_______ pop without a cap

_______ pop that was opened and then had cap replaced

2) We need to investigate the materials involved in carbon capture because

**Data Table:**

| Type of Cap | Volume Displaced (mL) |
|---|---|
| bottle that was sealed with vegetable "green bag" | |
| bottle capped with cotton ball | |
| bottle without a cap | |
| bottle that was opened and then had cap replaced | |

**Questions:**

1. By examining your data table, list the bottle caps by increasing permeability for carbon dioxide.

___1___ pop without a cap

___4___ pop that was opened and then had cap replaced

___3___ pop capped with cotton ball

___2___pop that was sealed with vegetable "green bag"

**Note: Results may vary**

2. What characteristics of the various caps lead to high or low levels of permeability?
How porous the capping material is.

3. Do you think that any $CO_2$ would be left in the bottles if they were left capped for another 3 days? Why or why not?

pop without a cap leftover $CO_2$ [✓ little $CO_2$]

explain: No cap, therefore, $CO_2$ can readily escape

pop that was opened and then had cap replaced [✓ leftover $CO_2$] little $CO_2$

explain: Cap is impermeable, therefore, $CO_2$ should be trapped

pop capped with cotton ball [✓ leftover $CO_2$] [✓ little $CO_2$]

explain: Depending on how much $CO_2$ escaped, student predictions may vary. Answer should relate to the amount of $CO_2$ that was lost and the permeability of the material.

pop that was sealed with vegetable "green bag" [✓ leftover $CO_2$] [✓ little $CO_2$]

explain: Depending on how much $CO_2$ escaped, student predictions may vary. Answer should relate to the amount of $CO_2$ that was lost and the permeability of the material.

4. Why is research into the permeability of rock formations an integral part of carbon capture research?

Non-porous substances must be used as capping material; therefore knowledge about the permeability of capping material is essential.

5. Can you think of possible dangers if carbon dioxide were to escape from storage?
   - Geologic sites are very carefully selected for their ability to trap $CO_2$ over a long period of time so leakage is very unlikely.

   Students may come up with some of the following:
   - $CO_2$ is not toxic, flammable, or explosive, but if it accumulated in enclosed spaces at high concentrations (e.g., 40,000 parts per million or more), $CO_2$ could displace oxygen and cause unconsciousness or asphyxiation.
   - If $CO_2$ leaks into the soil at high enough concentrations it may harm vegetation and crops.
   - $CO_2$ leakage into an aquifer used for drinking water or as a supply for agriculture is doubtful as it is unlikely that $CO_2$ would be injected close to a critical aquifer.

# Measuring the Permeability of $CO_2$ Caps Lab

**Objectives:**

1) Which material will provide the greatest permeability when being used to cap carbon dioxide?
2) Why do we need to investigate the materials involved in carbon capture?

**Background Information**:

Carbon dioxide can be stored permanently underground with proper site selection.  When carbon dioxide gas is pumped deep underground its buoyancy causes it to rise. The carbon dioxide gas rises through porous rock until it becomes trapped by an impermeable layer of rock, often referred to as the cap rock. In this activity you will examine the permeability of various substances and the importance of selecting a site where an impermeable cap rock exists.

**Materials:**

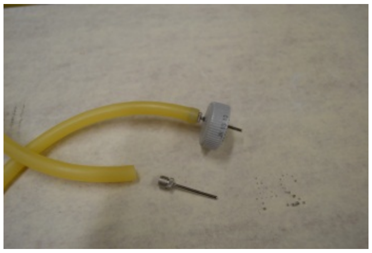
Inflating needle (like those used to inflate a ball) (4)
Pop bottles (4)
Rubber tubing (size?) (4 x 40 cm)
Capping Material: cotton balls and vegetable bags
Graduated cylinder () (4)
Large Hot plate
Large beakers () (8)
Sticky Tac

**Procedure:**

1. Obtain four pop bottles (do not shake!)
    a. 1st bottle: open the bottle and seal with vegetable “green bags”, fasten with an elastic band or duct tape
    b. 2nd bottle: open the bottle and stuff cotton to approximately 4 cm thick in the neck
    c. 3rd bottle: open the bottle and leave open (no cap)
    d. 4th bottle: open the bottle and then replace the cap.

   NOTE: SAVE THE BOTTLE CAPS FOR LATER!!

2. Leave the bottles stand for 24 hours
3. Insert the threaded end of the needle into one end of 40 cm rubber tubing so that you have a good seal.
4. Repeat step #3 for each bottle



5. Put the other end of the tubing in a graduated cylinder full of water. Turn the graduated cylinder upside down in a tub of water, being careful not to let any air enter. The graduated cylinder should have **nothing but water in it**.
6. Place the pop bottle in a beaker of water on a hot plate.
7. Heat the inflating needle with a lighter and puncture each of the four bottle caps with the needle so that the tip of the needle is in the soda's head space. Make sure nothing is obstructing the flow of carbon dioxide into the tip of the needle. Use sticky tac to seal the hole in the bottle around the needle.
8. Turn on the hot plate to low to keep the water from boiling.
9. Heat the water for 2-4 hours
   Note: Carbon dioxide is less soluble at higher temperatures, so after an hour of heating, most of the carbon dioxide should be driven out. The gas will displace the water in the graduated cylinder so you can measure its volume.
10. **Record your data on the student worksheet.**

## Measuring the Permeability of $CO_2$ Caps Lab Student Handout Name:__________

**Objectives:**

1) Which material will provide the greatest permeability when being used to cap carbon dioxide?
2) Why do we need to investigate the materials involved in carbon capture?

**Hypothesis:**

1) Rate the following in order of highest to lowest permeability

______ pop that was sealed with vegetable "green bag"

______ pop capped with cotton ball

______ pop without a cap

______ pop that was opened and then had cap replaced

**Data Table:**

| Type of Cap | Volume Displaced (mL) |
|---|---|
| bottle that was sealed with vegetable "green bag" | |
| bottle capped with cotton ball | |
| bottle without a cap | |
| bottle that was opened and then had cap replaced | |

**Questions:**

1. By examining your data table, list the bottle caps by increasing permeability for carbon dioxide.

______ pop without a cap

______ pop that was opened and then had cap replaced

______ pop capped with cotton ball

______pop that was sealed with vegetable "green bag"

2. What characteristics of the various caps lead to high or low levels of permeability?

3. Do you think that any $CO_2$ would be left in the bottles if they were left capped for another three days? Why or why not?

| | | |
|---|---|---|
| pop without a cap | leftover $CO_2$ | little $CO_2$ |
| explain: | | |
| pop that was opened and then had cap replaced | leftover $CO_2$ | little $CO_2$ |
| explain: | | |
| pop capped with cotton ball | leftover $CO_2$ | little $CO_2$ |
| explain: | | |
| pop that was sealed with vegetable "green bag" | leftover $CO_2$ | little $CO_2$ |
| explain: | | |

4. Why is research into the permeability of rock formations an integral part of carbon capture research?

5. What are the dangers if carbon dioxide were to escape from storage?

# Ecological Footprint TEACHER VERSION

**Objectives:**

1) To calculate the ecological footprint of an individual; the impact that the individual has on the Earth's ecosystems based on their actions.
2) To obtain information about what kinds of activities affect the ecological footprint of an individual.
3) To obtain information about how an individual can reduce their ecological footprint.

**Foundational and Learning Objectives**:

**Science 10 Unit: Life Science: Sustainability of Ecosystems**

**SE1 Explore cultural perspectives on sustainability**

4. Explain changes in the scientific worldview (paradigm shift) of sustainability and human's responsibility to protect ecosystems. (TL, CCT)
7. Identify multiple perspectives that influence environment-related decisions or issues. (CCT, TL)

**SE2 Examine biodiversity within local ecosystems**

10. Demonstrate a sense of personal and shared responsibility for maintaining a sustainable environment. (PSD)

**Science 10 Unit: Earth and Space Science: Weather Dynamics**

**WD5 Identify consequences of global climate change**

3. Identify current issues related to global climate change. (PSD)

**Background Information:**

An ecological footprint is a measure of human demand on the Earth's ecosystems. It represents the amount of biologically productive land and sea area necessary to supply the resources a human population consumes and to absorb associated waste. Through measuring the ecological footprint it is possible to estimate how much of the Earth (or how many planet Earths) it would take to support humanity if everybody followed a given lifestyle. Knowing your ecological footprint can help you learn how to conserve more and help protect ecosystems.

**Lesson Overview:**

a. View PowerPoint Slides 41 – 50
b. Complete Activity 5: Ecological Footprint

**Assessment:**

Assessment can be based on the "Ecological Footprint" Handout

**Name: _____KEY_________**

- Go to myfootprint.org
- On the green banner, go to “Take Action” and then click on “Take the Quiz”
- Answer the “information” questions

2. Choose “**Metric”**
4. US dollars are almost equivalent to Canadian dollars. If you aren’t sure of your parent’s annual income, take a guess.
5. Saskatchewan would fall into the category ” High latitudes with cold winters and cool summers (like Moscow or Stockholm)”
6. When answering “What is the size of your home?” the conversions to square feet are listed below:
    a. 50 - 100 square meters or less (500 - 1000 square feet or less) (apart. or studio)
    b. 100 - 150 square meters (1000 - 1500 square feet) (small home, approx 2-3 bedrooms)
    c. 150 - 200 square meters (1500 - 2000 square feet ) (average home, approx 3 bedrooms)
    d. 200 - 250 square meters (2000 - 2500 square feet) (large home, approx 4 bedrooms)
    e. 250 square meters or larger (2500 square feet or larger) (very large home)
7. Most Saskatchewan households use “Natural gas, propane, or liquefied petroleum gas as sources of energy”
8. The percentage of energy that is generated from renewable hydropower, wind, biomass, or solar sources in Saskatchewan is approximately 33%.
10. After you answer this question, click on “Small lifestyle changes make a big difference. Find out more →” and fill in the following blanks:
    Energy efficient appliances use ___2___ to ___10___ times less energy for the same level of functionality. Line drying clothes saves __3__ to__ 4__ kilowatt hours per load – about __5__ pounds of carbon dioxide. Compact fluorescent bulbs use __4__ times less energy and last __8__ times longer than incandescent bulbs.

11. After you answer this question, click on “More about sprawl and climate change →” and fill in the following blanks:
    Carbon emissions are generally ________highest________ for households living in newer suburbs. This is because spread-out suburbs require far more energy per person for public infrastructure, housing, and both personal and commercial __________transportation__________. Compact urban living is much less energy intensive. In rural areas, greater self reliance on local _______food_______, energy, and water resources and fewer short trips on congested roadways lead to lower energy requirements relative to sprawling suburbs.

12. After you answer this question, click on “More about carbon offsets →” and fill in the following blanks:
    A growing number of organizations are selling offsets that can make you, your car, or your _____ forest______ protection, and energy efficiency projects.

13. After you answer this question, click on “My diet and my footprint →” and fill in the following blanks:
    A plant-based diet is significantly less land and energy intensive than a diet with a high proportion of meat, seafood, and dairy. A recent study found that a low-fat vegetarian diet needs ______0.18______ hectares per person per year while a high-fat diet with lots of meat needs ______0.85______ hectares because animals need so much more room. And because meat production drives __________deforestation__________ and requires high inputs of energy for processing and transportation, it also comes with a high carbon footprint price tag. Globally, it has been estimated that up to ______18%______ of all greenhouse gas emissions are associated with animal product consumption.

14. After you answer this question, click on “Food miles, packaging, and where I shop →” and fill in the following blanks:
    Two important variables affecting your food footprint are food miles (or miles to market) and the amount of processing and ___________packaging__________. If your food comes from far away – such as out of season produce imported from across the world – it requires lots of energy for transportation and ___________refrigeration___________. If it is highly processed and comes in copious paper packaging, it puts a strain on forests. Buying fresh ______local______ foods from farmers markets and other locally owned sources or natural foods markets reduces these impacts.

17. After you answer this question, click on “The Growing Importance of Community Gardens and Local Food →” and fill in the following blanks:
    Small scale food production at the local level relieves the enormous environmental impacts associated with ______industrial______ agriculture and is an essential source of nutrition for those in need. The Food Security Learning Center has found that community gardens address lack of access to fresh produce, making them a critical piece of a community's food security. One study estimates that home or community gardening can add ______$500______ to ______$1200______ worth of produce per year to a family's diet – a big difference for low-income families.

19. After you answer this question, click on “More on Green Buildings →” and fill in the following blanks:
    Passive solar heating, water efficient fixtures, recycled materials and other green design features can generate up to ______30%______ in energy savings, reduce carbon emissions by 35%, and reduce water use by 30 to 50% and save 50 to ______90% ______ in waste disposal costs.

21. After you answer this question, click on “The footprint of water consumption →” and fill in the following blanks:
    Fresh water consumed in households requires energy for both delivery and treatment. Household water use also takes water from other beneficial uses such as irrigation or in-stream flow for fish and wildlife. All of these impacts increase a household’s ecological footprint, so saving water is a key strategy for footprint __________reduction__________. It has been estimated that by installing water saving features and adopting water conservation habits such as those listed here, households can easily reduce their water footprint by ______60%______ or more.

22. After you answer this question, click on “The Why Green Cleaning Products Matter →” and fill in the following blanks:
    Products used to clean floors, carpets, bathrooms, and other building elements often contain __________harmful__________ chemicals that can have serious human health effects and contaminate water supplies, fish, and wildlife if they are poured down ______drains______, circulated through ventilation systems, or disposed of __________outdoors__________. Environmental damage can also occur during the development, manufacture, and transport of these products. Fortunately, biodegradable and non-toxic alternatives can significantly reduce or eliminate these impacts altogether while providing the same level of ___________cleanliness__________.

24. After you answer this question, click on “Planned Obsolescence and Our Economic Footprint →” and fill in the following blanks:
    The faster we buy new items, the faster we ______deplete______ resources and the more likely it is that we are exceeding the Earth’s regenerative capacity. Unfortunately, today’s economy is designed to convince us to buy often and __________replace__________ items that are in perfectly good working order. Planned obsolescence – the __________deliberate__________ manufacturing of products to wear out quickly – adds to the problem. To counter this, we can try to ______repair______ things as much as possible and only buy products that are designed to ______last______.

26. After you answer this question, click on "Towards a Zero-Waste Society →" and fill in the following blanks:
Recycling our wastes has enormous environmental and economic benefits in the form of reduced __________landfill__________ space, fewer demands for raw materials, less energy consumption, less air and water __________pollution__________, lower waste-disposal bills, and cheaper goods. Recycling one metric ton of paper saves ___17___ trees. It takes ___40___ - ___95___% less energy to produce goods with recycled aluminum, glass, plastic, or paper than it does to manufacture them with raw materials. Communities throughout the world are striving for ______zero______-waste economies where the outputs from each resource use are turned into inputs for another use. Zero waste does not aim to simply manage waste, but __________eliminate__________ its creation in the first place.

**Place your cursor over each of the bars of the "My Footprint in Global Hectares by Consumption Category" Bar Graph and fill in the table below:**

| | My Footprint | Country Average |
|---|---|---|
| Carbon Footprint | | |
| Food Footprint | | |
| Housing Footprint | | |
| Goods and Services Footprint | | |

**Place your cursor over each of the bars of the "My Footprint Share by Biome" and fill in the table below:**

| | |
|---|---|
| Marine fisheries footprint | |
| Forestland footprint | |
| Cropland footprint | |
| Pastureland footprint | |

**Questions**:

1. My ecological footprint is _____answers will vary___________________________.
   If everyone on the planet lived my lifestyle, we would need: _ answers will vary _ earths

2. Are you surprised at your impact on the earth? Why or why not?
   answers will vary

3. What is your reaction after completing the activity? Do you think that it is important that everyone should know their impact on the environment? Why or why not?
   answers will vary

4. If people don’t change their ecological footprint what could happen to the earth in the next 50 years?
   answers will vary

5. What can we do to improve our impact on the earth at the level of the:

a) Individual
   answers will vary

b) School
   answers will vary

c) City of Regina
   answers will vary

d) Country of Canada
   answers will vary

6. Click on “Reduce your footprint” and list some things that you <u>are willing to do</u> to reduce your footprint:
   answers will vary

**Ecological Footprint Student Handout Name: _______________**

- Go to myfootprint.org
- On the green banner, go to "Take Action" and then click on "Take the Quiz"
- Answer the "information" questions

2. Choose "**Metric"**
4. US dollars are almost equivalent to Canadian dollars. If you aren't sure of your parent's annual income, take a guess.
5. Saskatchewan would fall into the category " High latitudes with cold winters and cool summers (like Moscow or Stockholm)"
6. When answering "What is the size of your home?" the conversions to square feet are listed below:
    a. 50 - 100 square meters or less (500 - 1000 square feet or less) (apart. or studio)
    b. 100 - 150 square meters (1000 - 1500 square feet) (small home, approx 2-3 bedrooms)
    c. 150 - 200 square meters (1500 - 2000 square feet ) (average home, approx 3 bedrooms)
    d. 200 - 250 square meters (2000 - 2500 square feet) (large home, approx 4 bedrooms)
    e. 250 square meters or larger (2500 square feet or larger) (very large home)
7. Most Saskatchewan households use "Natural gas, propane, or liquefied petroleum gas as sources of energy"
8. The percentage of energy that is generated from renewable hydropower, wind, biomass, or solar sources in Saskatchewan is approximately 33%.
10. After you answer this question, click on "Small lifestyle changes make a big difference. Find out more →" and fill in the following blanks:

    Energy efficient appliances use ______ to ______ times less energy for the same level of functionality.
    Line drying clothes saves ____ to__ __ kilowatt hours per load – about __5__ pounds of carbon dioxide.
    Compact fluorescent bulbs use ____ times less energy and last ____ times longer than incandescent bulbs.

11. After you answer this question, click on "More about sprawl and climate change →" and fill in the following blanks:
    Carbon emissions are generally ________ ________ for households living in newer suburbs. This is because spread-out suburbs require far more energy per person for public infrastructure, housing, and both personal and commercial __________ __________. Compact urban living is much less energy intensive. In rural areas, greater self reliance on local _______ _______, energy, and water resources and fewer short trips on congested roadways lead to lower energy requirements relative to sprawling suburbs.

12. After you answer this question, click on "More about carbon offsets →" and fill in the following blanks:
    A growing number of organizations are selling offsets that can make you, your car, or your ___________ protection, and energy efficiency projects.

13. After you answer this question, click on "My diet and my footprint →" and fill in the following blanks:
    A plant-based diet is significantly less land and energy intensive than a diet with a high proportion of meat, seafood, and dairy. A recent study found that a low-fat vegetarian diet needs ___________ hectares per person per year while a high-fat diet with lots of meat needs ____________ hectares because animals need so much more room. And because meat production drives __________ __________ and requires high inputs of energy for processing and transportation, it also comes with a high carbon footprint price tag. Globally, it has been estimated that up to ____________ of all greenhouse gas emissions are associated with animal product consumption.

14. After you answer this question, click on “Food miles, packaging, and where I shop →” and fill in the following blanks:
Two important variables affecting your food footprint are food miles (or miles to market) and the amount of processing and ______________________. If your food comes from far away – such as out of season produce imported from across the world – it requires lots of energy for transportation and ______________________. If it is highly processed and comes in copious paper packaging, it puts a strain on forests. Buying fresh _____________ foods from farmers markets and other locally owned sources or natural foods markets reduces these impacts.

17. After you answer this question, click on “The Growing Importance of Community Gardens and Local Food →” and fill in the following blanks:
Small scale food production at the local level relieves the enormous environmental impacts associated with _____________ agriculture and is an essential source of nutrition for those in need. The Food Security Learning Center has found that community gardens address lack of access to fresh produce, making them a critical piece of a community's food security. One study estimates that home or community gardening can add ____________ to _____________ worth of produce per year to a family's diet – a big difference for low-income families.

19. After you answer this question, click on “More on Green Buildings →” and fill in the following blanks:
Passive solar heating, water efficient fixtures, recycled materials and other green design features can generate up to _____________ in energy savings, reduce carbon emissions by 35%, and reduce water use by 30 to 50% and save 50 to _____________ in waste disposal costs.

21. After you answer this question, click on “The footprint of water consumption →” and fill in the following blanks:
Fresh water consumed in households requires energy for both delivery and treatment. Household water use also takes water from other beneficial uses such as irrigation or in-stream flow for fish and wildlife. All of these impacts increase a household’s ecological footprint, so saving water is a key strategy for footprint ____________________. It has been estimated that by installing water saving features and adopting water conservation habits such as those listed here, households can easily reduce their water footprint by ____________ or more.

22. After you answer this question, click on “The Why Green Cleaning Products Matter →” and fill in the following blanks:
Products used to clean floors, carpets, bathrooms, and other building elements often contain _____________________ chemicals that can have serious human health effects and contaminate water supplies, fish, and wildlife if they are poured down _____________, circulated through ventilation systems, or disposed of ___________ ___________. Environmental damage can also occur during the development, manufacture, and transport of these products. Fortunately, biodegradable and non-toxic alternatives can significantly reduce or eliminate these impacts altogether while providing the same level of ______________________.

24. After you answer this question, click on “Planned Obsolescence and Our Economic Footprint →” and fill in the following blanks:
The faster we buy new items, the faster we _____________ resources and the more likely it is that we are exceeding the Earth’s regenerative capacity. Unfortunately, today’s economy is designed to convince us to buy often and _____________________ items that are in perfectly good working order. Planned obsolescence – the ___________ ___________ manufacturing of products to wear out quickly – adds to the problem. To counter this, we can try to _____________ things as much as possible and only buy products that are designed to _____________.

26. After you answer this question, click on “Towards a Zero-Waste Society →” and fill in the following blanks:
Recycling our wastes has enormous environmental and economic benefits in the form of reduced ____________________ space, fewer demands for raw materials, less energy consumption, less air and water __________ __________, lower waste-disposal bills, and cheaper goods. Recycling one metric ton of paper saves ______ trees. It takes ______ - ______% less energy to produce goods with recycled aluminum, glass, plastic, or paper than it does to manufacture them with raw materials. Communities throughout the world are striving for ____________-waste economies where the outputs from each resource use are turned into inputs for another use. Zero waste does not aim to simply manage waste, but ____________________ its creation in the first place.

**Place your cursor over each of the bars of the “My Footprint in Global Hectares by Consumption Category” Bar Graph and fill in the table below:**

| | My Footprint | Country Average |
|---|---|---|
| Carbon Footprint | | |
| Food Footprint | | |
| Housing Footprint | | |
| Goods and Services Footprint | | |

**Place your cursor over each of the bars of the “My Footprint Share by Biome” and fill in the table below:**

| | |
|---|---|
| Marine fisheries footprint | |
| Forestland footprint | |
| Cropland footprint | |
| Pastureland footprint | |

**<u>Questions</u>**:

1. My ecological footprint is ________________________________.
   If everyone on the planet lived my lifestyle, we would need: _________________ earths

2. Are you surprised at your impact on the earth? Why or why not?

3. What is your reaction after completing the activity? Do you think that it is important that everyone should know their impact on the environment? Why or why not?

4. If people don’t change their ecological footprint what could happen to the earth in the next 50 years?

5. What can we do to improve our impact on the earth at the level of the:

a) Individual

b) School

c) City of Regina

d) Country of Canada

6. Click on “Reduce your footprint” and list some things that you <u>are willing to do</u> to reduce your footprint:

# Carbon Capture and Storage- Differing Perspectives TEACHER VERSION

**Objective:** To critically examine differing perspectives on carbon capture technology

**Foundational and Learning Objectives**:

Science 10 Unit: Life Science: Sustainability of Ecosystems

SE1 Explore cultural perspectives on sustainability

1. Examine how various cultures view the relationships between living organisms and their ecosystems. (PSD, CD 9.3)
2. Explain changes in the scientific worldview (paradigm shift) of sustainability and human's responsibility to protect ecosystems. (TL, CCT)
5. Identify multiple perspectives that influence environment-related decisions or issues. (CCT, TL)

SE2 Examine biodiversity within local ecosystems

9. Demonstrate a sense of personal and shared responsibility for maintaining a sustainable environment. (PSD)

SE4 Identify cycles, change, and stability in ecosystems

3. Identify and respect various cultural perspectives on the cycling of nutrients and matter through the environment. (CCT)

SE5 Investigate human impact on ecosystems

4. Compare the risks and benefits to society and the environment of applying scientific knowledge or introducing a technology. (TL)
5. Predict the personal, social, and environmental consequences of a proposed action. (PSD)

**Background Information:**

Advances in science and technology do not progress without controversy. Every advancement in science and technology is accompanied by differing perspectives. It is increasingly important in today's society, with information available on demand, that we learn to navigate these perspectives. We must learn to think critically on these issues, in order to make critically informed and scientifically literate decisions. Carbon Capture and Storage is no exception. This final lesson provides differing perspectives with the hope of encouraging students to make informed decisions regarding this technology.

**Activity Overview:**

1. Examination of Aboriginal perspective
2. Internet research of a different perspective
3. Completion of perspective summary and reflection questions

Students will summarize and critically reflect on two differing perspectives.

- a. Aboriginal Perspective: The aboriginal perspective will be sourced from the Elder Video.
- b. Alternative Perspective: Alternative perspectives can be found by conducting an internet search. The alternative perspectives can slightly differ or even oppose the previously discussed material. Remind students that they must be critical when examining any information found on the internet, as information does not have to be properly referenced or verified.

**Perspective Summary:**

For both the alternative and aboriginal perspective, students will answer the following questions in paragraph form.

1. What are the key points or foundational beliefs regarding the environment from this perspective?
2. How do these beliefs regarding the environment support or conflict with what you have come to know about carbon capture technology?
3. How does the perspective support or conflict with your own beliefs?
4. Has the exposure to a different point of view influenced your opinion of carbon capture?

**Reflection Questions:**

1. Why do you think that the Saskatchewan government invested millions of dollars to develop carbon capture technology? Do you believe that this is a valuable spending of Saskatchewan's money? Why or why not?
2. Traditionally, western sciences` perspective has dominated other world views. When examining these issues, do you believe that all perspectives are equal or are some perspectives more valuable than others? Why or why not?
3. Making reference to both the alternative perspective and the Aboriginal perspective, do you believe that all sides must be considered before making an informed decision? Explain.
4. Using what you have learned about carbon capture and storage, in your opinion, do you think that it is a viable solution to climate change in today's society? Why or why not?

# Carbon Capture and Storage- Differing Perspectives

Your task is to summarize and critically reflect on two differing perspectives.

a. Aboriginal Perspective: You will view a video which explores the perspective of an aboriginal elder on people's relationship to the environment and carbon capture technology.
b. Alternative Perspective: Your alternative perspectives can be found by conducting an internet search. The alternative perspectives that you find can slightly differ or even oppose the previously discussed material. Remember, you must be critical when examining any information found on the internet, as information does not have to be properly referenced or verified.

**Perspective Summary:**

For both the alternative and aboriginal perspective, answer the following questions in paragraph form.

1. What are the key points or foundational beliefs regarding the environment from this perspective?
2. How do these beliefs regarding the environment support or conflict with what you have come to know about carbon capture technology?
3. How does the perspective support or conflict with your own beliefs?
4. Has the exposure to a different point of view influenced your opinion of carbon capture?

**Reflection Questions:**

1. Why do you think that the Saskatchewan government invested millions of dollars to develop carbon capture technology? Do you believe that this is a valuable spending of Saskatchewan's money? Why or why not?
2. Traditionally, western sciences` perspective has dominated other world views. When examining these issues, do you believe that all perspectives are equal or are some perspectives more valuable than others? Why or why not?
3. Making reference to both the alternative perspective and the Aboriginal perspective, do you believe that all sides must be considered before making an informed decision? Explain.
4. Using what you have learned about carbon capture and storage, in your opinion, do you think that it is a viable solution to climate change in today's society? Why or why not?