Hands-On Climate Connections

Australian National University

Australian National Centre for the Public Awareness of Science

Introduction

This booklet contains hands-on STEM activities related to climate change and energy. It can be used to support professional development workshops for teachers, programming for informal STEM learning settings such as science centres and school outreach programs, activities for students (note some hazardous activities are only suitable for a teacher demonstrations), as a resource for curriculum development, or for remote/distance education. We would appreciate your feedback on the activities, please complete the survey at https://bit.ly/ClimateConnectionsBook (https://anu.au1.qualtrics.com/jfe/form/SV_eRq51SRiZ5r7s7c). Contact Graham at the Australian National University Centre for the Public Awareness of Science (CPAS) on g.walker@anu.edu.au for any questions or comments. An electronic version of this booklet can be downloaded from http://hdl.handle.net/1885/289738.

With climate change, it's important to teach/communicate the solutions (positives) along with the problems (negatives), so the booklet is divided into two parts:

- What's happening? The science, causes and impacts of climate change
- What we can do – mitigation, adaptation and solutions

You can watch selected activities at https://www.youtube.com/watch?v=voRqIwQgK1E&t=2974s and please see our Youtube page for more resources – including inspiring videos of Pacific teachers trying some of the activities! These activities introduce selected aspects of climate change, but are not intended to be a definitive guide, or to cover all the science behind climate. There are more resources including lesson plans and curriculum related resources online, here's some we'd recommend:

- https://www.climatescience.org.au/content/1090-climate-education-resources
- https://www.sustainableschoolsnsw.org.au/teach/climate-change
- https://www.csiro.au/en/Education/Programs/Sustainable-Futures (free but requires registration)
- https://www.pacificclimatechange.net/countries and https://www.rccap.org/climate-change-update-for-the-pacific/ (country-specific overview of climate change for many Pacific nations).

Materials needed – we've tried to use common everyday items to make the activities as accessible as possible. In many cases you can substitute similar items – be creative – however where the item needs to be exact for safety (e.g. using soft drink rather than water bottles) please take care. We'd love to hear if you make creative use of local resources, please get in touch!

Making it relevant for your country and community

Linking climate change to local contexts and examples – making it *relevant* – is important to engage people, make them aware of impacts at the local level, and generate local solutions for your community. Relevance can be highlighted by:

- connecting the climate science to everyday life
- showing how content can be useful for individuals and communities
- highlighting how it connects more deeply to your community, e.g. to the culture, traditional knowledge or identities of people (this is the most powerful and enduring form of relevance).

Try to highlight local relevance wherever you can, **but also listen to your audience about what is relevant to them.**

We've tried to link the climate science to real-world contexts, but you are the expert on your local or country context. With each activity, think about the below and discuss with your audience/students to get their perspectives:

1. How does it relate to everyday life in your country – how is it relevant to you, and how might it be relevant or useful to students? Could you change things in the activity to make it more relevant?
2. Does the activity link to things that are important in your country and culture (e.g. mangroves)? Could you adapt it to include traditional knowledge or cultural/local elements?
3. Does the activity relate to social and climate justice issues in your country or community (e.g. access to clean and affordable energy)? Could you include discussion on the relevant social issues?
4. How might you use it in the classroom or learning setting, and how does it connect to the curriculum?

Again, we'd love to hear how you make things more relevant in your context – please complete the survey https://bit.ly/ClimateConnectionsBook (https://anu.au1.qualtrics.com/jfe/form/SV_eRq51SRiZ5r7s7c) or email us!

Curriculum connections

The activities in this book link to many standard areas of curriculums for science, technology, chemistry, physics, maths, biology and other STEM subjects. The social and ethical aspects of climate change may also be used in social science and humanities subjects – climate change is not just a 'scientific' issue. Your curriculum may explicitly include climate change, or underlying concepts (e.g. chemical reactions) may feature in different subjects. Key concepts covered in this booklet include **heat, heat capacity of water, thermal expansion of water, acids and bases, chemical reactions, combustion, pressure, forces, energy, energy transformations, energy production, renewable energy, electrolysis and more.** The activities in this book can be used to explore these concepts using climate change as a context. Hands-on activities also involve scientific skills and processes such as lab safety, the scientific method, fair and valid tests, questioning and predicting, processing and analysing data, evaluating and communicating. These may also link with areas of your curriculum. There is scope for teachers to add to the activities to reach other curriculum areas, e.g. asking students to prepare a report or research project based on an activity. We would love to hear how you adapt the content for your students and curriculum, please email us if you'd like to share!

Who we are – a climate message from our team

Climate change affects all of us in different ways. We understand that the countries least responsible for climate change are the ones that stand to be the most impacted. That's part of why we are passionate about sharing these activities. While Australia's fires and droughts have been made worse due to climate change, we know the impacts are different and more immediate for many of our friends around the world. We can't truly see it from your position, but we try our best – and we look forward to **learning from you** and understanding what these activities and climate change more generally mean for you and your community. Please feel free to share via the survey https://bit.ly/ClimateConnectionsBook. To effectively respond to climate change, we need to work as a global team. We've still got a long way to go to do that as a planet, but we hope the activities here can help us see different perspectives, learn from each other, and act collectively. Empathy is a key part of a collective response to climate change.

Six principles for maximising student learning and motivation

Research in climate change education and communication suggests six key principles to foster learning and motivation in students. Have these in mind when you adapt the activities for your students:

1. **Personally relevant and meaningful information:** the activity should enable learners to connect previous knowledge with new material, link to everyday life, be related to or useful for local problems, and/or connect with traditional knowledge and culture and local community.
2. **Engaging, active, and student-centred teaching methods**: the activity involves active participation for *all* students, involves inquiry learning and similar pedagogies, and students have choice/freedom/self-direction in some or all aspects of the activity.
3. **Deliberative discussion**: the activity involves interaction between students, enabling students to think critically, defend and extend their own assumptions, and understand different opinions and perspectives, particularly where scientific and social aspects intersect.
4. **Experience of the scientific process and/or interaction with scientists**: the activity involves an inquiry process, using the scientific method, and/or relating material to real scientific research and professional activity, e.g. connecting with local researchers or climate NGOs.
5. **Perception of associated risks AND possible solutions:** climate risks/impacts and solutions are presented together, risks focus on short-timeframes and avoid alarmism (noting the reality), solutions help empower students and give them agency – even better if they can take action regarding solutions.
6. **Accessibility and practicality of the activity:** the materials of the activity are obtainable, information is adapted for age, and teaching methods and hands-on elements allow participation for all students, including different genders and students with disabilities.

Seeing the big picture – thinking in systems

Climate change is a complex phenomenon that requires consideration of scientific, technological, societal, and ethical aspects. We have included some discussion points/questions in many activities to help audiences to see the big picture and think about climate change as a whole with interconnected parts. For example, who is affected by different climate impacts or potential solutions, or could some solutions have unintended consequences that need to be managed? Systems thinking – examining a system as a network of many interconnected parts that need to be considered simultaneously – offers a useful approach to tackling this issue. By considering the whole system, students can gain a

more holistic perspective on the issue of climate change and develop the skills needed to approach it in a thoughtful and real-world relevant way.

Real-world solutions to climate change must be effective scientifically and/or technologically, and be fair and equitable, while also working for people and communities at the local, country and global level, and considering the wider environment, ecosystems, animals and the Earth as a whole (and more). It is one BIG system and we need responses that find the best balance overall, maximising the good and minimising the bad – we don't want 'solutions' to create new and even bigger problems in the future! Activities such as role plays, debates and similar where audiences can focus on different parts in the system and different points of view can be great ways to explore these ideas.

SAFETY

Some activities can be used directly with students as class activities, while others – especially any with DANGER warnings – are best used as demonstrations by teachers. **Take extra care where DANGER is noted and read the safety notes thoroughly before attempting the activity. Depending on the age of students/audiences, some activities are not suitable for students to try themselves.** TEACHERS SHOULD COMPLETE ANY ADDITIONAL SAFETY AND RISK ASSESSMENT PROCEDURES REQUIRED BY THEIR SCHOOL, MINISTRY OR GOVERNING BODY. We are happy to assist with this wherever possible. Please contact graham.walker@anu.edu.au if you have any questions or concerns about safety.

Index of activities

What's happening? The science, causes and impacts of climate change

These first two activities look at the fundamental science of climate change – how greenhouse gases are causing the atmosphere and oceans to heat up. These activities were created by the Center for the Study of Science and Mathematics (SESIM) in Timor-Leste and are adapted with thanks.

Greenhouse effect ball bounce model – how do greenhouse gases trap heat?

Science Concept: using a model/analogy to show how greenhouse gases like CO_2 trap heat in the atmosphere

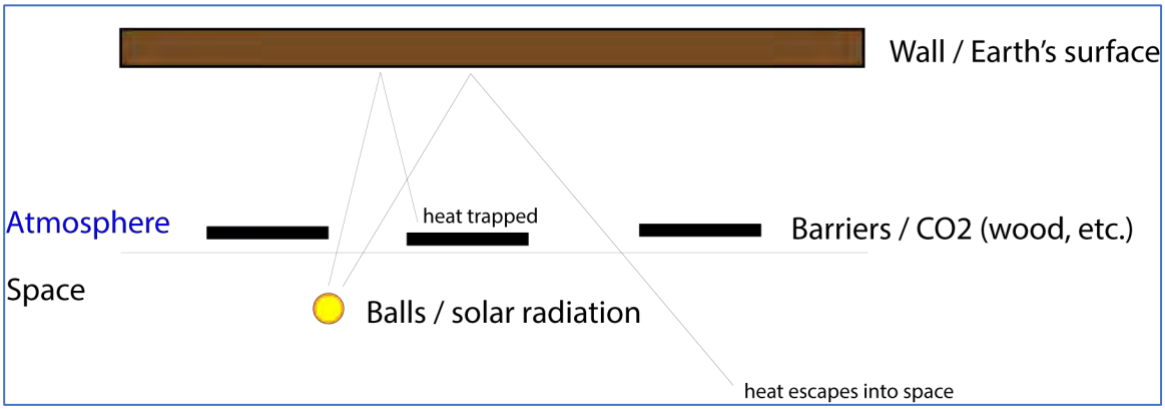
Equipment

- 10-20 (or more) balls, marbles, small stones or similar (to throw gently)
- 5-10 (or more) small pieces of wood, sticks, pencils/pens or anything to make a small barrier/wall
- Tape, chalk or string (to mark a line)
- A wall

What to do

In this activity we'll explore how the Sun's solar radiation interacts with the Earth and the atmosphere producing the greenhouse effect.

1. Begin by having a group discussion about the greenhouse effect, global warming and how these concepts affect our everyday lives. What do students know already? Can they describe the greenhouse effect? Have they heard about global warming in the news? What are some of the causes/problems or sources of greenhouse gases, and what can we do about it? Have they heard which human activities contribute most to the problem?



2. Introduce the idea of a model to the students so they understand what different parts of the model represent – note these are shown in italics here.
3. Clear a space in front of the wall – *the wall represents the surface of the Earth, with the space in front representing the atmosphere.*
4. About 50cm from the wall use tape, chalk or string to mark a line (you may need to be further away depending on the size of the balls/space you have). *This line represents the top of the atmosphere where space begins.*
5. Place 3-4 pieces of wood (or similar) on the line to make a barrier with some gaps. Label the barriers with greenhouse gases like CO_2 and methane. *This represents the way greenhouse gases in the atmosphere can trap the Sun's radiation.*
6. *The balls or similar represent the Sun's radiation.* Standing a bit behind the line, roll the balls along the ground towards the wall. You want to roll them so when they bounce off the wall they roll back past the line along the ground.

7. Roll all the balls you have – record how many go back past the line (i.e. *Sun's radiation escapes into space*), and how many are 'trapped' by bouncing off a barrier and staying between the line and the wall (i.e. *Sun's radiation stays in the atmosphere).*
8. Now place additional pieces of wood (or similar) on the line to make a barrier with fewer gaps. *This represents the additional greenhouse gases humans are adding to the atmosphere.*
9. Repeat step 5 again recording the data (highlight that climate scientists do the same, measuring the greenhouse gas levels in the atmosphere). You should find more balls are trapped this time - *this represents the additional radiation/heat trapped by the added greenhouse gases.*
10. Have another group discussion/Q&A – it is important students understand the different parts of the model/analogy and what they represent (work this into the steps above too):
    - What do the balls/blocks/wall represent?
    - Can they point to parts of the model and then to the actual things they represent outside?
    - Which parts of the model can people affect (i.e. the barrier/CO_2)? End with a discussion of technologies that can reduce greenhouse gas emissions (e.g. solar, wind, hydro power) and highlight those used locally.

To create an extended activity, step 6 can be done several times adding more barriers each time and recording data in a table.

Note the best size and number of balls and barriers and overall area used will depend on the materials used – experiment to find the right balance to make the model effective.

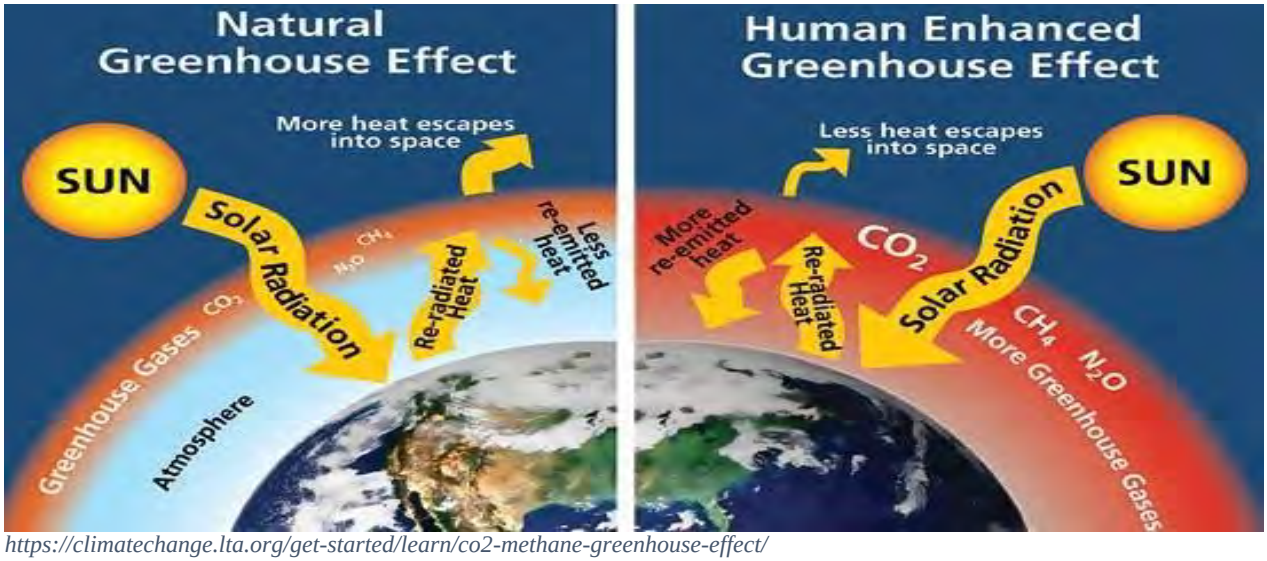
Alternative/extension – to scale up, try:

- replacing the balls with basketball or soccer balls
- replace the barriers with students (they need to stand still on one spot, not move around). Ask the students which greenhouse gas they are representing to reinforce the model.
- Throw the balls at the wall and see how many can be stopped/caught by the students making the greenhouse gas barrier.
- This method will tap into students interests in sport and may appeal to different students than the more 'academic' model – be sure to explain the different parts of the model and what they represent.

What's happening

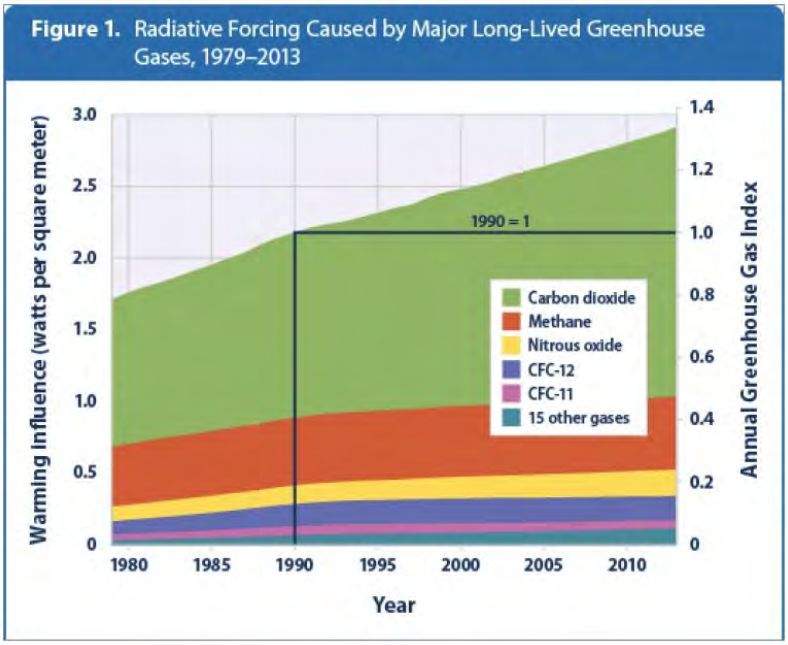
Climate change is primarily caused by the heat-trapping effect of carbon dioxide and other greenhouse gases in the atmosphere. These gases (represented by the barriers) trap more of the Sun's radiation (e.g. light and heat, represented by the balls) as it is radiated from the Earth – they act like a 'blanket' around the planet.

As shown in the diagram over the page, as the Sun's radiation enters Earth's atmosphere some is reflected back into space by clouds and other light-coloured surfaces, but most of the energy reaches Earth's surface (represented by the wall). Earth absorbs the radiation then radiates it as heat back towards space. Greenhouse gases in the atmosphere like CO_2 absorb some of that heat energy, trapping it in the atmosphere and causing warming. This natural process allows the Earth to stay warm enough to support life, however as human activity such as burning fossil fuels, agriculture and land clearing adds more greenhouse gases to the atmosphere, more heat is trapped. This enhanced greenhouse effect is causing Earth's atmosphere and in turn oceans to heat up. This is the primary cause of climate change.



https://climatechange.lta.org/get-started/learn/co2-methane-greenhouse-effect/

The chart below shows the different greenhouse gases responsible. Carbon dioxide (CO_2) is the largest contributor, and the one increasing at the fastest rate. Methane, released during fossil fuel mining and agriculture, also has a warming effect. The structure of a methane molecule means it is 28 times better at trapping heat than CO_2. Nitrous oxide, refrigeration gases like chlorofluorocarbons (CFC-12) and other gases also play a role, but CO_2 is the largest – and one that people can reduce through changing how we make electricity or what forms of transport we use.



https://climatechange.lta.org/wp-content/uploads/cct/2015/02/EPA-climate-forcing-2014.pdf

Other resources:

- NASA Climate Kids YouTube video animation: https://climatekids.nasa.gov/greenhouse-effect/
- More detailed science for upper secondary students: IPCC FAQ What is the Greenhouse Effect? https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-3.html

Greenhouse effect: warming water in a bottle greenhouse

Science Concept: modelling how heat trapped in the atmosphere by greenhouse gases (enhanced greenhouse effect) warms Earth's oceans; that Earth's oceans absorb heat; applying the scientific method and fair tests

Note this activity takes time and works best on a sunny day, it can work well to set it up at the start of a lesson then return to see the results at the end.

Equipment

- 2 x softdrink bottle with lid
- Scissors
- 2 x identical drinking glasses (small enough to fit in the softdrink bottle)
- Water
- Thermometer (useful but not essential)

What to do

1. Have a group discussion about where the extra heat trapped by greenhouse gases in the atmosphere might go, and what effects it may have (connect with the previous activity where possible). If students don't mention oceans, give a clue such as 'what covers most of Earth's surface?'. Ask students what they think will happen to the oceans as the atmosphere warms, and what might be the effects of warming the oceans.
2. Use the scissors to carefully cut the bottoms off both softdrink bottles. Make sure the cut is straight so the bottle can stand up. Make sure both bottles are cut the same so it is a fair test (see What's Happening).
3. Remove the lid from one bottle – *this represents the normal greenhouse effect*. Leave the lid on the other bottle – *this represents the enhanced greenhouse effect with additional heat-trapping gases.*
4. Fill the two glasses with the same amount of cold water.
5. Record the temperature of the water in each glass (if you don't have a thermometer, use your finger for a rough measurement).
6. Find a sunny spot and arrange the two glasses with the bottles over them (like a greenhouse). Make sure both bottles receive the same amount of sunlight and are not shaded unequally or on different surfaces – again this ensures a fair test.

7. Ask students to make a hypothesis – which glass of water will warm fastest?
8. Depending on how sunny it is, leave the glasses for 15-45 minutes, then record the temperature again (if you don't have a thermometer, use your finger to see which is warmer – take care it may be hot).
9. Have a group discussion and ask the students some questions – it is important students understand the different parts of the model/analogy and what they represent. You can work this into the steps above too. What do the two bottles represent, particularly the lid and the water? Was their hypothesis correct? What does this mean for Earth's oceans? How can people prevent the effect of the lid (i.e. reduce greenhouse gases)? Which countries, people or sources of food might be affected as the ocean warms?

Extension – multiple measurements can be taken over time for step 6 with data recorded in a table. This data could then be graphed with temperature on the y-axis and time on the x-axis. This activity can be extended into a full written-up practical with data, graphs, report, etc. – ask students to include a discussion that relates the experiment to climate change, the greenhouse effect and the oceans.

What's happening

As Earth's atmosphere heats up due to rising greenhouse gases, most of the heat is absorbed by the oceans – just like a bath of water in a hot room will warm up. This is modelled in the experiment by the bottle with the lid which traps more heat than the bottle without the lid. The additional heat increases the temperature of the air in the bottle, and as the water absorbs heat from the air it warms too.

As greenhouse gas emissions (e.g. CO_2) rise and trap heat in the atmosphere, most of the additional heat is absorbed by the oceans – just like a bath of water in a hot room will warm up. 90% of the heat trapped by greenhouse gases since 1995 has been taken up by the oceans, with about 2/3 of that stored in depths above 700m. This warming of the water affects animals, plants and ecosystems (e.g. increased risk of coral bleaching) and also threatens people through affecting fish stocks and increasing extreme weather. Water also expands when it warms, so warming oceans also lead to sea level rise (see other activity). More info:

- https://climatekids.nasa.gov/ocean/
- https://www.oceanscientists.org/index.php/topics/ocean-warming
- https://www.iucn.org/resources/issues-briefs/ocean-warming

The scientific method

Several parts of this activity can be used to show the scientific method, control and experimental conditions, and the idea of a fair test. The key idea of a fair test is to understand all variables in the experiment – which one changes (independent variable), what effect it has (dependent variable) and which other variables we need to keep the same (controlled variables). In this experiment time is the independent variable, temperature of the water the dependent variable, and there are other variables (e.g. size of bottle, amount of sunlight, etc.) we try to keep the same – the controlled variables. This lets us see the effect of sunlight over time on the temperature of the water, so that effect can be isolated. For more see https://www.primaryconnections.org.au/resources-and-pedagogies/strategies/conducting-fair-test-investigations. Climate scientists apply the same principles.

The activity also uses a control and experimental condition. The bottle without the lid is the control, representing the greenhouse effect *without* additional heat trapping gases. Whereas the bottle with the lid is the experimental condition, representing the greenhouse effect *with* additional heat trapping gases (having the lid on means more heat is trapped).

Warming Oceans – heat capacity of water

Science Concept: Heat capacity of water, oceans absorbing atmospheric heat

CAUTION: If using this activity with students, take appropriate fire safety precautions when using candles.

Equipment

- Candle, in cup/holder
- 2 balloons
- water (tap or big plastic bottle)
- Matches / lighter

What to do

1. Have a group discussion about where the extra heat trapped by greenhouse gases in the atmosphere might go, and what effects it may have (connect with the previous activities where possible). If students don't mention oceans, give a clue such as 'what covers most of Earth's surface?'. Ask students what they think will happen to the oceans as the atmosphere warms, and what might be the effects of warming the oceans.

2. Blow up one balloon up and tie it off.
3. Fill the other balloon with about 2 cups of water from the tap (or squeeze it in from a full soft drink bottle), pinch it off with your fingers and then blow it up so it contains both air and water. Tie it off.
4. Light the candle / hold out the lighter.
5. Ask students for a hypothesis, then holding by the knot, lower the air-filled balloon slowly until it touches the flame and pops.
6. Repeat the hypothesis and experiment process with the water and air-filled balloon, holding the balloon by the knot so the waterfilled part touches the flame – you should be able to hold it there for some time. Be careful not to touch the wick to the balloon. The balloon shouldn't pop.
7. Why didn't the balloon pop this time? What does this experiment tell us about how water can absorb heat? What does it suggest about what will happen to the ocean as the atmosphere warms?

If using this as a demonstration, once you are confident with the procedure you can do it above a volunteer's head for added impact!

What's happening

This experiment demonstrates the high heat capacity or specific heat of water – it takes a lot of energy to heat water by a small amount. With the first balloon, the flame burns the rubber and causes the air-filled balloon to pop. The second balloon with water doesn't pop because the water absorbs the heat and keeps the balloon cool. While this is good news for the balloon, in the context of global warming it means as the atmosphere heats up, much of that heat will be absorbed by the oceans. More detail can be found in the previous activity.

Sea level rise – thermal expansion of water

Science Concept: water expands as it warms, sea level rise due to warming oceans

In this activity we will build a simple model to show the thermal expansion of water, one of the causes of sea level rise.

Equipment

- Plastic bottle and lid
- Clear tubing or straw
- Something to make a hole the size of the tubing or straw – drill, awl, scissors
- Blutac, glue or other sealant
- 30cm ruler/straight stick with markings
- Food dye (optional)
- Table salt (optional) – to mimic seawater you need about 35 grams per litre of water (I teaspoon = appox. 6 grams)

What to do

1. Begin by having a group discussion about the impacts of global warming and climate change, specifically sea level rise. Why is the sea level rising? Where is the additional volume of water coming from? Which parts of the world are most effected by sea level rise? What can communities affected by sea level rise do?

2. Now to make the model. Make a hole in the lid of the bottle (take care) that will fit the tubing/straw tightly and push it about 5cm into the hole.
3. Put glue/blutack around the tube to make a seal. Make sure it seals well.
4. Fill the bottle with cold water to the top. Optional: to make the model better represent seawater, add about 35 grams / 6 teaspoons of salt and dissolve (salt water expands more when warmed compared to fresh water). You can also add food dye to make the water more visible. Screw the lid on tight.
5. Attach the tube/bottle to a ruler or stick with markings to measure any changes and collect data.
6. Place the bottle in a warm sunny spot, make a hypothesis and see what happens. Alternatively, you can put the bottle into a bowl of hot water to speed up the process, however using the sun provides a better model for student understanding. The water level in the tube should rise as it warms (see small picture, the level is near the 13cm mark).
7. Discuss the results with the students. What happened? What does this suggest about what will happen to Earth's oceans as their temperature increases? What is causing the temperature rise, and what can we do about it?

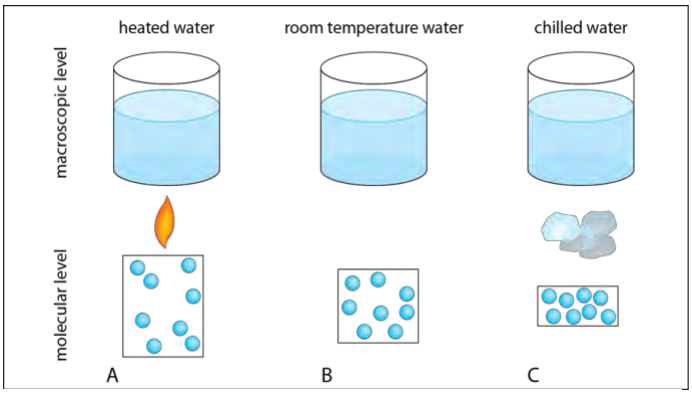
What's happening

One impact of climate change, in particular global warming, is rising sea levels. Sea level rise will happen for two reasons, each responsible for about half the rise:

- glaciers and ice caps melt and add to the ocean
- as the ocean warms it expands – as we see in this activity.

Water expands when heated as the molecules have more energy, move faster and hence have more space between them. This idea can also be linked to teaching the particle model.

Globally, sea level is predicted to rise by 40 to 80cm by 2100 depending on overall global emissions. More info:



https://manoa.hawaii.edu/exploringourfluidearth/physical/density-effects/density-temperature-and-salinity/weird-science-macroscopic-changes-liquid-water-volume

- https://www.pacificclimatechange.net/document/current-and-future-climate-timor-leste
- https://oceanservice.noaa.gov/facts/sealevel.html
- https://www.ipcc.ch/srocc/chapter/chapter-4-sea-level-rise-and-implications-for-low-lying-islandscoasts-and-communities/

Alternative/extension activity:

- https://manoa.hawaii.edu/exploringourfluidearth/physical/density-effects/density-temperature-andsalinity/weird-science-macroscopic-changes-liquid-water-volume

Ocean acidification from dissolved carbon dioxide

Science concept: how CO_2 in the atmosphere can dissolve into water, ocean acidification.

In this activity we will show how CO_2 in the atmosphere can dissolve into water, modelling the process of ocean acidification.

Equipment

- Red cabbage indicator (see instructions in above below) OR lab indicator such as bromothymol blue
- Two clear drinking glasses/jars
- Straw (preferably paper or metal) **OR** soda water

What to do

1. Have a group discussion about how climate change and rising levels of CO_2 are affecting the oceans. If there is more CO_2 in the atmosphere, will some go into the oceans? What are the effects on oceans (see previous activities)? If you live near the ocean, have you seen any changes? Which animals, plants and people might be affected by these changes, and what can be done to help?
2. Add a few centimetres of water to each clear glass.
3. Have a student blow bubbles into one of the containers through a straw for about 3-4 minutes (including breaks). This may make students a bit dizzy or out of breath, so have short rests or take turns with a partner or in a group (but don't share straws). **OR** option two, add some soda water (note the bubbles are CO_2) to one of the containers and an equal amount of tap water to the container.
4. Thinking about the previous activity, make a hypothesis about what will happen when the red cabbage indicator is added to each cup.
5. Pour a small amount of the red cabbage indicator into each cup and mix around (you could also experiment with adding it before blowing to observe the gradual change). What do you notice about the colour of each container? What does the colour tell us? What was in our breath or soda water that might have caused the change? What does this tell us about the effect on the oceans of increased levels of CO_2 in the atmosphere?

What's happening

As we build up CO_2 in the atmosphere, some will dissolve into the oceans. Oceans have absorbed about one third of the CO_2 emitted since the start of the Industrial Revolution. This makes our oceans more acidic, because when CO_2 dissolves in water it forms carbonic acid (H_2CO_3) and bicarbonate ions (HCO_3^-), which dissociate creating hydrogen ions (H^+). The chemical process/equation is:

$$CO_{2(aq)} + H_2O \leftrightarrow H_2CO_3 \quad (1)$$

$$H_2CO_3 \leftrightarrow HCO_3^- + H^+ \quad (2)$$

$$HCO_3^- \leftrightarrow CO_3^{2-} + H^+ \quad (3)$$

In this experiment we are mimicking the process of ocean acidification. As CO_2 is gradually added to the jar or container, it dissolves in the water, producing carbonic acid. The indicator then turns a pink/purple colour while the regular water is bluer. Note that the difference may be quite subtle which is why it's important to have a control (no bubbles) to compare to.

Slight changes in the pH of the ocean can affect the growth and survival of many organisms including corals, some plankton, and other animals that form or use shells. This will also cause issues further up the food chain, including for people – damage to coral reefs and other ecosystems affects fish numbers, reducing food availability and livelihoods for people who catch them. Ocean acidification may also affect

the way sound travels underwater, amplifying the sounds of both marine mammals and human industrial activity.

Acid or base? Making acid base indicators from common items

DANGER: Boiling water can cause serious burns. Take extra care when making the cabbage indicator. Be careful when chopping the cabbage.

Science Concept: acids and bases, pH, pH indicators (see the next activity for the link to climate change)

Equipment

- Red cabbage indicator (make this ahead of time, or do as a class activity)
  - Finely chopped red cabbage (substitutes that work well include frozen blueberries, red onion (skin and flesh) and turmeric)
  - Boiling water
  - Large heatproof container
  - Strainer or porous cloth (e.g. cheese cloth)
- At least three clear cups/drinking glasses/jars
- Some known acids and bases (e.g. lemon juice, vinegar, baking soda)

What to do

1. Begin by having a group discussion about acids and bases and how we identify them. What are acids and bases? What are some everyday examples?
2. Place chopped up red cabbage in a heatproof container and cover with boiling water. The outer leaves have the most anthocyanin pigment so be sure to include them. You can also try boiling the cabbage on a stove – this can create a more concentrated indicator.
3. Wait about 10 minutes for the colour to leach out of the cabbage and into the water.
4. Strain out the cabbage/other vegetable/fruit so you have just the purple coloured liquid and allow to cool (note liquid can be used while hot, extra care should be taken).
5. Put a few centimeters of water in each of your three clear containers and label as *acid, base* and *neutral.*
6. Add in a known acid to one container of water and mix, add in a known base to another container and mix.
7. Pour some of the indicator solution into each container and observe what happens – what colour is the liquid in each container? How could you use the indicator to identify whether an unknown substance is an acid or base?

What's happening

The indicator solution is coloured by pigments called *anthocyanins* which are commonly found in fruits and vegetables that are red, blue or purple in colour. They change colour based on the pH:

- In acidic solutions *anthocyanins* turn red/pink.
- In a neutral solutions *anthocyanins* are purple-blue in colour.

- In very alkaline solutions they turn green/yellow (note for turmeric the chemical responsible for colour change is called *curcumin,* and only one colour change will take place – yellow to red when introduced to an alkaline solution).

The pH scale quantifies this spectrum from very acidic (pH=0) to very alkaline/basic (pH=14). It is a logarithmic scale meaning that each step is 10 times more or less acidic/alkaline than the previous step.

Knowing whether a substance is acidic (more H^+ ions) or basic (more OH^- ions) can be useful information in many situations. For example, some plants grow better in a slightly alkaline soil (e.g. violets) while others thrive in a slightly acidic environment (e.g. pineapples). Swimming pools must be kept at a neutral pH so that they are safe to swim in and concrete used in construction is very alkaline and must be treated to prevent other substances like water and CO_2 reacting with it and weakening its structural integrity. Can you think of some everyday substances (e.g. coffee, milk, egg whites, cleaning products) and guess where they fall on the pH scale? What about substances in the body like blood or stomach acid?

Indicator key

The table below shows what kinds of colour changes you can expect from using different vegetables/fruits to create a pH indicator. To create an acid, white vinegar was dissolved in water. To create the base, washing detergent was dissolved in water.

Indicator	Base	Neutral	Acid
Red cabbage			
Frozen blueberries			
Red onion			
Tumeric powder			

Colour changing noodles using red cabbage pH indicator

Visit our Youtube Channel for instructions on how to make colour changing noodles using a modified method of the above activity. This video was created by ANU student intern Ruby Rainbird (thanks Ruby!).

https://youtu.be/5IrZ6sVgSW8

Ocean Acidification – effect on marine life

Science concept: CO_2 from the atmosphere dissolves into oceans making them more acidic; effect of ocean acidity of sea life

Equipment

- white vinegar
- egg shells / coral pieces (source of calcium carbonate)
- two clear cup/glass/jars

What to do

In this activity we will investigate the effect that the increased acidity of the oceans (as seen in the previous activity) is having on marine life.

1. Begin by having a group discussion about how the climate change and rising levels of CO_2 are affecting the oceans and marine life. If there is more CO_2 in the atmosphere, will some go into the oceans? What are the effects on oceans (see previous activities)? Do you think these changes affect plants and animals in the ocean? Will people be affected? If you live near the ocean, have you seen any changes?
2. Quarter fill the glass with vinegar, then fill up to half with water. *This represents the increased acidity of the ocean as more carbon dioxide dissolves (note this solution is <u>much</u> more acidic than seawater – see below).*
3. Half fill a second glass with water as a control.
4. Make a hypothesis, then put some a similar piece of eggshell or coral in each glass. *This represents the skeletons of aquatic animals and shells (which are made of calcium carbonate).*
5. Wait. Observe! What happens to the eggshell/coral? Do you notice anything on the surface of the eggshell/coral? Can you guess what it is? Remembering our vinegar solution is <u>much</u> more acidic than seawater, what does this tell us about what might happen to marine life if the ocean becomes more acidic? Which kinds of marine life might be affected? How might these changes to marine habitats and animals affect everyday life and food availability for coastal communities?

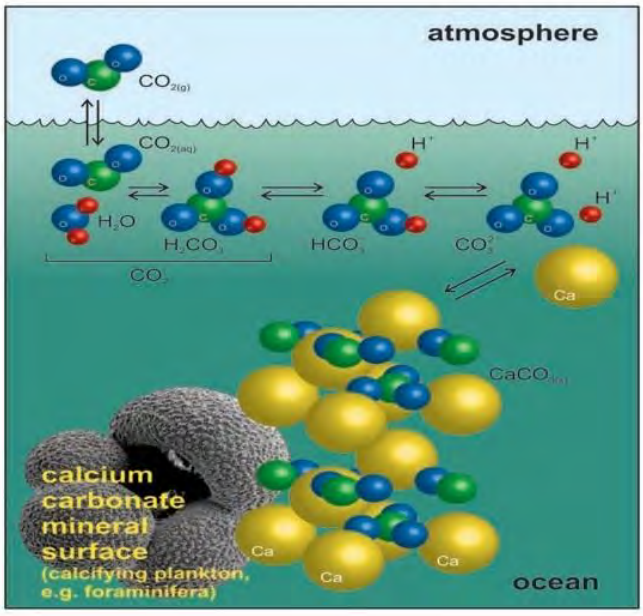
What's happening

As we build up CO_2 in the atmosphere, some dissolves into the oceans. Oceans have absorbed about one third of CO_2 emitted since the start of the Industrial Revolution. This makes our oceans more acidic, because when CO_2 dissolves in water it forms carbonic acid (H_2CO_3) and bicarbonate ions (HCO_3^-), which dissociate creating hydrogen ions (H^+) (see the Nature link below for a full details). The chemical process/equation is:

$$CO_{2(aq)} + H_2O \leftrightarrow H_2CO_3 \ (1)$$

$$H_2CO_3 \leftrightarrow HCO_3^- + H^+ \ (2)$$

$$HCO_3^- \leftrightarrow CO_3^{2-} + H^+ \ (3)$$



This acidity is bad for animals like shellfish, algae and coral, as it can attack their skeletons and shells which are made mainly of calcium carbonate, which reacts with acids. Increasing acidity also affects the amount of energy all organisms need to use to maintain the pH in their cells, and affects how sound travels in water affecting whales. The reaction taking place is:

$2H^+$ (acid) + $CaCO_3$ (shell/coral) ---> Ca^{2+} (calcium ions) + H_2O (water) + CO_2 (carbon dioxide)

Globally, ocean acidity has increased by about 30% since the beginning of the Industrial Revolution. Due to the logarithmic scale, this represents a pH change from 8.2 to 8.1 (becoming more acidic, or less basic). Ocean acidity is predicted to continue to increase depending on overall emissions.

IMPORTANT: Note the vinegar (pH 2.5) is much more acidic than the ocean (pH 8.1) – which technically is not acidic (i.e. below pH of 7) but is becoming more acidic – however small changes in acidity over long time periods have significant effects on sea life.

More info:

- https://www.nature.com/scitable/knowledge/library/ocean-acidification-25822734/ (picture below)
- www.nova.org.au/earth-environment/climate-change-and-ocean-acidification
- http://oceans.digitalexplorer.com/events/coral-live-2018/live-investigations/dissolving-coral-andshells-in-vinegar/
- https://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F

Fossil fuels: natural gas cannon

DANGER: This activity involves fire and pressurised, flammable gases. We recommend it is performed as a demonstration by adults, not by students. Follow standard fire and gas safety. The marshmallows fly fast – don't shoot at people. When igniting the gas, take care to just wave the flame over the hole – do not hold the flame to the hole too long or the bottle may melt or catch fire. Always use a long handled lighter or candle so your hand is well clear of the ignition hole. Always use a bottle from carbonated (fizzy) soft drink, these are stronger than un-carbonated bottles (e.g. still water). Wear eye protection. CONTACT US IF YOU HAVE ANY QUESTIONS ABOUT SAFETY BEFORE TRYING THIS.

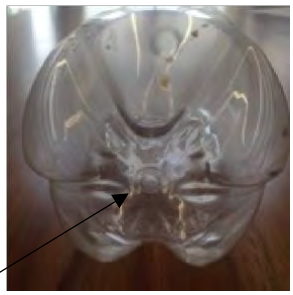
Science Concept: fossil fuels create carbon dioxide emissions, combustion reactions, pressure

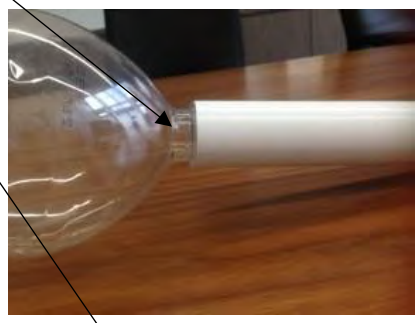
Equipment

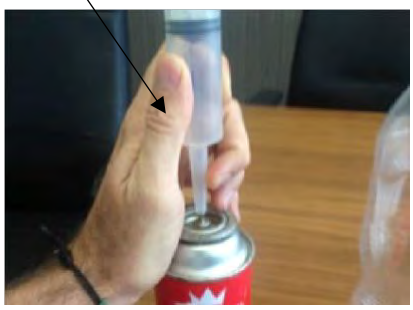
- 1.25 or 2 litre softdrink bottle and lid (from carbonated/pressurised fizzy drink, NOT water, etc.)
- Butane/propane gas (disposable cylinders for camping/DIY work best)
- Long handled BBQ lighter OR candle
- Large syringe
- 25mm PVC pressure pipe, approx. 20cm long – diameter should fit tight over the bottle lid and just fit a marshmallow
- Eye protection
- Something to make holes – drill, awl, scissors
- Marshmallows (or other SOFT non-flammable projectile

What to do

(video at https://www.facebook.com/DrGrahams/videos/754423691644658)







1. Begin by having a group discussion about fossil fuels (e.g. coal, oil, diesel, petrol and natural gas) and how they contribute to climate change. What is a fossil fuel? Do you use fossil fuels in your country/region? What happens when fossil fuels are burned? What effect does this have on climate change? What alternatives are there to fossil fuels (show the solutions to the problem)?

To make the cannon:

2. Make a ~6mm hole in the base of the bottle. We used a drill to make the hole. The base is the strongest/thickest part of the bottle so make the hole there, not on the side.
3. Make a large hole in the drink bottle lid, making sure not to damage the threaded area where the lid screws on. Most lids have an internal rim/ring next to the thread which you can use as a guide.
4. Place the lid upright on the table and push the tube over it until it goes all the way in – it should fit tightly as shown in the picture
5. Remove the collar of the lid that is still on the bottle, then screw the lid/pipe all the way onto the bottle. Then, push the tube as far as it will go onto the bottle.
6. Put on eye protection. Place a marshmallow into the tube. Explain the next steps and ask students for a hypothesis.
7. Use the syringe to measure the butane – to match the stoichiometry/chemical equation you need: gas volume (ml) = bottle volume (ml) x 0.0312. Take care all the butane is in the gas phase. For senior secondary, there is some fabulous maths involved in working out the ratio – try and work it out, or contact us for a copy.
8. Inject the butane into the bottle through the hole in the bottom. Hold the bottle and press the syringe to it firmly so there is a seal.
9. Hold the bottle firmly. Aim it away from people and fragile objects. Check again for safety, then light the long handled lighter and wave the flame near the hole – it should ignite quickly with a satisfying pop, shooting the marshmallow.
10. Have another group discussion to get students' observations. Connect the combustion of the natural gas in the bottle with the combustion of fossil fuels in energy production and transport. Students will be excited about the marshmallow but need to understand the wider relevance of fossil fuel burning. How can we tell the reaction created energy? What forms of energy were made? How is a similar process used to make electricity or power a vehicle/internal combustion engine? What effect do the products of the combustion reaction have on the environment? What are alterative sources of energy?

What's happening

Fossil fuels release energy when burned (combustion). The energy is stored in every carbon-carbon and carbon-hydrogen bond, which is released when these bonds break. Fossil fuels like petrol and diesel are burned in internal combustion engines in many forms of transport, transforming the chemical energy in the fuels into kinetic (moving) energy. Fossil fuels like coal and gas are used in power stations – the chemical energy in the fuels is used to create heat which is used turn generators and produce electricity. We see similar energy transformations in the marshmallow cannon.

When the butane reacts with oxygen (combusts), it creates carbon dioxide and steam.

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_20$$

The products of the reaction have a much greater volume than the reactants for two reasons:

- There are more moles of gas in the products (18) compared to the reactants (15). Every mole of any gas has the same volume at a given temperature and pressure.
- The reaction is exothermic (produces heat), meaning the gaseous products are hot, which again increases the volume of the gaseous products due to Charles Law – the volume of a gas is proportional to its temperature.

The reaction creates pressure due to the increase in volume of gas inside the bottle, which pushes the marshmallow out. The speed of the reaction, sharp pop and ballistic marshmallow are all due to the volume of butane being injected being stoichiometrically right for the volume of oxygen in the bottle. The reaction also goes very quickly as all the reactants are in the gas phase so many collisions are occurring.

STEM! This activity is all about STEM – technology and engineering in the setup, chemistry and physics launching the marshmallow, and maths tells us how much fuel we need. The maths is really neat – email us on the email in the footer if you'd like a copy of the calculations!

Comparing Fossil Fuel CO2 emissions

Science Concept: comparing emissions from fossil fuels; putting the M(aths) in STEM

In this activity you'll find out how much carbon dioxide (CO_2) two common fossil fuels make – coal and natural gas – by looking at the volume of CO_2 made when used to power an iPhone charger.

Equipment

- 2 balloons
- 2 large (2 litre) jugs or buckets, with measurements
- Water

CO_2, fossil fuels and making electricity

Electricity is measured in 'kilowatt hours' or kWh – the amount of electricity in kilowatts and how long it's used for in hours. You can think of it like how much water is coming out of a tap and for how long. This table shows the mass and volume of CO_2 coal and natural gas make when used to produce 1 kWh of electricity – it's quite different! Note 1 kilowatt equals 1000 watts.

	Amount of electricity made	Mass of CO_2	Volume of CO_2 gas (at $27^{\circ}C$)
Coal	$1\ kWh$	$317\ g$	$177\ Litres$
Natural Gas	$1\ kWh$	$184\ g$	$103\ Litres$

What's this got to do with iPhones?

An iPhone charger uses 5 watts (0.005 kilowatts) of electricity when charging, so in one hour it uses 0.005 kWh. Using the table above, we can work out the volume of CO_2 gas an iPhone charger creates…

- For coal, 177 litres of CO_2 is produced to make 1 kWh of electricity
- Charging an iPhone uses 0.005 kWh
- So for the volume of CO_2 produced by the charger in one hour, we multiply 177 by 0.005 = **0.9 litres**

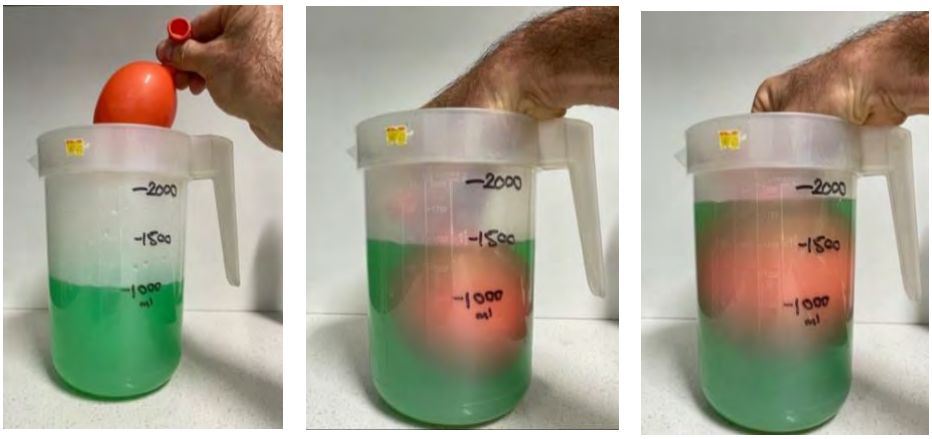
We can repeat this for natural gas…

- For natural gas, 103 litres of CO_2 is produced to make 1 kWh of electricity
- Charging an iPhone uses 0.005 kWh
- So for the volume of CO_2 produced by the charger in one hour, we multiply 103 by 0.005 = **0.5 litres**

What to do

This activity lets you visualise the volume of CO_2 made by different fossil fuels during an everyday activity like charging a phone.

1. Begin by having a group discussion about how electricity/energy is made where you live. Do you use fossil fuels in your country, and if so which ones? What do students know about different kinds of fuels used? How is electricity/energy made in other places? Which items in your school or home use the most electricity; how can you find out how much (tip: check the label)? How can we reduce energy use?
2. We'll use two balloons to visualise the different volumes of carbon dioxide produced by making electricity with different fuels – coal and natural gas. The volume of the balloons will be measured by displacing water in the jug.
3. If you don't have a large 2 litre measuring jug, use a small measuring jug and a permanent marker to make a 'measuring bucket' by marking 0.5 litre graduations (or 0.1 to be more accurate) on the inside of the bucket (only needed for between 1 and 2 litres for this activity).
4. To measure the balloons volume, start by adding 1 litre of water in the jug/bucket.
5. Take a balloon and blow it up to about the size of your hand. Pinch off the end but don't tie it up yet.
6. Push the balloon completely into the water being careful not to submerge your fingers.



Measure the volume of the balloon by pushing it into the water (we added colour so you can see it easily) – the middle balloon is 0.5 litres representing natural gas, and the right balloon is 0.9 litres representing coal.

7. You're aiming to increase the water level by 0.9 litres – the volume of CO_2 made when using coal to make electricity. Add or remove air as needed, retest, then tie the balloon off.
8. Repeat with a second balloon to get 0.5 litre volume – the volume of CO_2 made when using natural gas to make electricity.
9. Mark the two balloons as coal and natural gas.
10. Discuss what the two balloons represent – make sure students understand what they represent and its connection to the real world. What does this say about how people should make energy or power transport? What alternatives are there to using fossil fuels to make electricity or provide transport?

What's happening

Different fossil fuels create different amounts of CO_2, and hence have different effects on climate change. While natural gas is creates fewer CO_2 emissions than coal, it still creates a lot of CO_2. Natural gas and coal extraction (mining) also releases methane, adding to warming – we need to think of the whole system. Humans need to rapidly move away from fossil fuels as a source of energy production, but the mix of fuels we use while achieving that also makes a difference.

Relevance reminder!

This is the end of science/causes/impacts section. If you haven't already please review the previous activities and note down any points that will enhance the relevance when you use them with an audience or in the classroom. Here's some questions that might help:

1. How does the activity relate to everyday life in your country – how is it relevant to you, and how might it be relevant or useful to students? Could you change things in the activity to make it more relevant, useful or linked to everyday life?
2. Does the activity link to things that are important in your country and culture (e.g. mangroves)? Could you adapt it to include traditional knowledge or cultural/local elements?
3. Does the activity relate to social and climate justice issues in your country or community (e.g. access to clean and affordable energy)? Could you include discussion on the relevant social issues?
4. How might you use it in the classroom or learning setting, and how does it connect to the curriculum?

You might find other reasons its relevant and meaningful too – **if you would like to share your insights and provide other feedback please complete the survey at** https://bit.ly/ClimateConnectionsBook. We are grateful for your input!

What we can do – mitigation, adaptation and solutions

While climate change is a serious issue, the good news is there are many things we can do to reduce emissions. The world is transitioning to cleaner sources of energy, but we need to do it faster. Some of these sources like biofuels still produce CO_2, but less of it for the same amount of energy produced. Other fuels like hydrogen have the potential to create no emissions at all and can be made from just sunlight and water – but the technology to do this efficiently and cheaply at scale needs development. The biggest opportunity right now is replacing fossil fuels with renewable energy – existing and proven technologies. Solar, wind, hydro and wave power (renewable energies) don't produce any emissions as they make energy. But we still need to consider the amount of energy that goes into making them, sustainability of materials needed for manufacture, and other environmental impacts such as where infrastructure is located – e.g. it doesn't make climate sense to cut down a rainforest so you can build a solar energy plant.

New technologies like those discussed above are only part of the response to climate change, people are the other part. The activities in this book might give you ideas for things you, your family, community, or country could do differently – like swapping to renewable forms of electricity if you have that option, or walking or riding a bike rather than using a car. These small behaviours can add up to a big difference when lots of people do them. The other place we can make a difference is trying to affect the choices politicians and other decision makers take – this could be for voting (if you're old enough) for parties committed to climate action, lobbying or protesting for action, joining groups doing good for the climate and environment, or being a force for good influencing others in your community. We hope to add some activities in this area soon and would welcome your ideas!

Biofuels

Biofuels are made from renewable organic sources like plants, organic waste products or other biomass. This makes biofuels a renewable energy source. Although burning biofuels creates CO_2, the plants grown to produce them capture CO_2 through photosynthesis – this makes the process approximately carbon neutral or sometimes reduces overall atmospheric carbon as plants store carbon in the soil as they grow. When we look at the whole cycle it is much better for the emissions than a fossil fuel, which essentially takes carbon that is stored stably in the Earth and releases it into the atmosphere. A common biofuel is ethanol, made by fermenting suitable biomass, which can be used for everything from transport – including planes and shipping – to a cooking fuel.

A key consideration of biofuels is managing possible negative effects. These could include biofuels competing with food crops (e.g. using sugar cane for fuel rather than food), environmental damage such as deforestation (e.g. clearing forests to grow crops for biofuels), or displacing local communities to make way for biofuel plantations. *Like many aspects of climate and energy, we need to look at the whole system.*

Biofuel cylinder engine exploding can

DANGER: The vapour in the can is highly flammable. Flame will come out of the hole and top of the can when ignited – keep it clear of your body and use a candle or stick lighter so your hand is away from the hole. Never ignite with matches or a cigarette lighter – your hand will be too close. Be very careful to pour out all the liquid ethanol as otherwise the can will remain on fire. Take standard precautions with flammable liquids – replace the lid after adding the fuel and store away from the area used for the activity. THIS ACTIVITY SHOULD ONLY BE PERFORMED BY TEACHERS/ADULTS AS A DEMONSTRATION.

Science Concept: biofuels, states of matter, volume-state relationships, combustion

Equipment

- Aluminium can
- Methylated spirits - ethanol (biofuel)
- Drill, knife or scissors to make a hole
- Plastic or paper disposable cup that fits on can
- Candle / stick lighter (NOT matches or a cigarette lighter)
- Eye protection
- Safety gloves

What to do

1. Begin by having a group discussion about the different kinds of fuels used in transport, and how they are burned in an internal combustion engine. Where do these fuels come from? What sorts of transport make the most CO_2 emissions locally and globally? Are any of these fuels renewable? Do you know we can produce fuel from plants? What might be the pros and cons of different fuels when thinking about climate change?

2. To make the biofuel cylinder, put a small 5mm hole in the side of the can 1cm above the bottom (see pictures). Take care with cutting and the sharp edges of the can hole.
3. Put on eye protection.
4. Pour a small amount ~5ml of biofuel/ethanol into the can, swirl it all around the sides **then pour the remaining ethanol out the top and tap to get the last drips out.** A tiny bit of liquid ethanol may remain, but make sure it is only a very small amount. Safety: wash your hands and clean the area if any spills.
5. Make sure the lid is on the ethanol/methylated spirits bottle and place it a safe distance away.
6. Place the disposable cup upside down on top of the can.
7. Hold the can in two hands to use the warmth of your hands to help evaporate the ethanol (this may not be required in hot climates). While doing this, ask students to make a hypothesis about what might happen when the can is ignited.

8. Put on safety gloves (do this quickly but safely so the remaining ethanol doesn't evaporate).
9. Place the can on a flat, non-flammable surface well away from your body, flammable items and other people (the cup will shoot upwards when ignited).
10. Wave a candle or BBQ stick lighter near the hole at the bottom, the ethanol vapour inside should ignite and shoot the cup off.
11. What have we observed? What made the cup shoot upwards? What forms of energy can you identify? How could these forms of energy be used for transport? Thinking about CO_2 emissions from production to use of biofuels, how is it different from a fossil fuel like petrol?

What's happening

When you rinse and warm the methylated spirits (95% ethanol) it evaporates and fills the can with ethanol vapour, which remains even after you tip out the liquid ethanol. The ethanol vapour is very flammable because it is mixed with air/oxygen. When you ignite it, the ethanol burns rapidly creating hot gases in the chemical reaction. The hot gases produced have a greater volume than the ethanol gas you started with so the pressure inside the can increases. This causes gas to shoot out of the opening at the top and push the cup into the air. The can and cup work in a similar way to a cylinder and piston in an internal combustion engine.

Ethanol can be obtained through the fermentation of biomass. The ethanol made through this process is called bioethanol and can be used as a fuel source. Biofuels such as bioethanol can be produced from crops (such as sugar cane) or even 'waste' organic matter. Although the burning of biofuels still produces CO_2, the overall emissions are lower as plants capture and store CO_2 as they grow. This means that biofuels produce less greenhouse gas emissions overall than fossil fuels. That said, people need to be careful as growing crops for biofuels can create negative effects such as reducing food available for people or leading to deforestation to make space for biofuel crops – we need systematic solutions.

Mangrove adaptations

Equipment

- Eggplant/aubergine, zucchini/courgette, carrot or sweet potato (our favourite)
- Salt
- Lip balm, chapstick, pawpaw ointment, Vaseline or similar

What to do

In this activity we will explore the effect of salinity (increased salt concentration) on plants.

1. Begin by having a group discussion about the effect sea level rise will have on coastal plants as well as the impact of the increased salinity (salt levels in the soil, often affected by sea level rise or inundation with seawater). Which coastal plants handle salt well? What kinds of plants/crops may be negatively affected? How might people be affected? Who might be affected most; is this an issue where you live? What can people do to address this problem?
2. Cut your vegetables into three ~1-2cm thick slices. If you are using carrot, peel the skin/outside layer off for best results. Try to make them the same/similar size and thickness to ensure a fair test.
3. Sit your three pieces on a plate/piece of paper and label them as follows (see the scientific method section below for more):
    a. Control
    b. No adaptation
    c. With adaptation
4. For the "control" piece, leave it on the plate/paper and do nothing to it
5. For the "no adaptation" piece, sprinkle some salt on top
6. For the "with adaptation" piece, cover the surface with lip balm/Vaseline and then sprinkle the same amount of salt on top.

Before: experiment setup

After: Control surface is dry, no adaptation surface is very wet and water has been extracted, with adaptation surface has only a few water droplets on the surface and is otherwise preserved

7. Make a hypothesis – what will happen to each of the pieces?

8. Observe after 15-30 minutes and then after a few hours – what has happened? To collect data more rigorously, observations could be made at intervals to see the change over time.
9. What have we observed? How do the pieces exposed to salt compare to the control piece? What impact has the 'adaptation' had on the piece? Where did the water come from? What does this tell us about how plants might be affected by salt?

What's happening?

Many plants that typically grow in freshwater environments (like garden vegetables) cannot tolerate salty environments. Salt draws water out via osmosis and will cause plants to become dehydrated (just like your mouth feels dry after you eat something salty). Some plants are well adapted to living in a salty environment though – like mangroves, which live in intertidal areas. Red mangroves are a good example. To prevent salty sea water from being absorbed at high tide (by capillary action), red mangroves cover their leaves in a waxy substance called suberin which acts as a protective layer and prevents the mangrove trees from drying out. A key ingredient of suberin is glycerin, which is also a main ingredient in lip balm. The lipbalm helps to protect the vegetables from dehydration for longer. Without this kind of adaptation, plants in intertidal zones would not be able to survive. Rising sea levels and increasing floods and storms expose plants outside of the intertidal zone to salt water. Although plants like mangroves have adapted to a salty environment, this process has taken a long time. How quickly do you think plants can adapt to saltier environments on their own? What kinds of things can humans do to protect plants from salt water?

The scientific method

Why do we use three samples? Three samples of the same/similar size are used so that valid conclusions can be made on the effect that salt has on plants. The 'control' represents a plant that is exposed to no salt and has no lipbalm protection - it is used as a comparison for the other two pieces. Comparing 'adaptation' to 'no adaptation' lets us see the effect salt has with or without lip balm respectively, and these can then be compared with the 'control' to see the effect of no salt. Scientists do the same when conducting experiments by ensuring that there is a control. For more see https://www.primaryconnections.org.au/resources-and-pedagogies/strategies/conducting-fair-test-investigations.

Solar Ovens – solar thermal energy

Science Concept: using heat energy from the sun – solar thermal energy

Note this activity takes time both to make and test and works best on a sunny day. It works well to make the solar oven in one session/lesson, then test it in a second.

Equipment

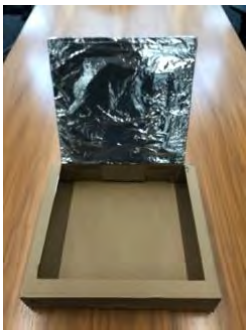
- Cardboard box like a pizza box (flat shape, but most will work)
- Aluminium foil
- Glue (or tape)
- Tape
- Cling film / Gladwrap
- Black paper, plastic or similar
- Scissors or Stanley knife / box cutter
- Ruler
- Skewer or stick
- Marshmallows, biscuits, chocolate or similar to cook

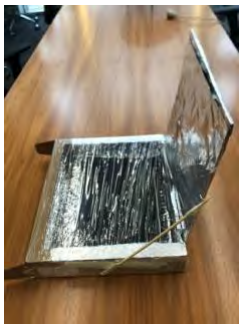
What to do

(for pizza box model visit https://www.sciencebuddies.org/stem-activities/solaroven#instructions)

This activity uses the heat energy from the sun to cook food, demonstrating the idea of solar thermal energy.

1. Begin by having a group discussion about alternatives to fossil fuels. What forms of renewable energy have we seen in our community or on the news? What kinds of energy can we get from the Sun (solar energy)? How can we collect solar energy? Does anyone use the Sun to heat water at home?
2. Cut a square out of the top of the box using the knife and ruler, but don't cut the rear edge. Leave about 2cm around the edge.
3. Fold the square upwards and cover the inside with aluminium foil, fold the edges over and tape/glue to secure. This foil will reflect sunlight into the box.
4. Cover the inside of the box with foil and secure. Ensure the whole inside of the box is covered in foil to reflect heat.
5. Cover the opening left by the hole with cling wrap and use glue or tape to secure. Ensure a good seal so heat won't escape.
6. Open the box (if it's a pizza box just open the lid; the box we found had another flap that opened at the front) and place the black paper in the middle. The black surface will absorb and concentrate the heat.
7. Attach the skewer to the side of the box with tape to hold the lid open. Tape lightly so you can adjust the angle of the lid for experiments or different sun angles.
8. Place the food you'd like to cook – we tried a chocolate square on a biscuit – on a square of foil in the centre of the black square. Note the oven shouldn't be used to prepare meat or other foods requiring thorough cooking.
9. Have another group discussion and ask the students some questions. Why are the different parts of the solar oven important? What form of energy does it collect? Are there other applications where people use heat from the Sun?





Extension – this simple design lends itself to inquiry approaches – e.g. altering the angle of the reflector lid, angle to the sun, or changing the colour or material of the heat concentrator. As with other activities, data such as temperature could be recoded and plotted over time by adding a thermometer to the oven.

What's happening

The solar oven is designed to reflect and concentrate *heat* energy from the sun. Typically, solar energy can be collected in the form of heat ('solar thermal' such as the oven here or a solar hot water system) or light ('solar photovoltaic' such as solar panels which turn light into electricity). Note heat (infrared radiation) is a form of light or electromagnetic radiation, it's just that we can't see it with our eyes, but can feel it on our skin.

In the oven, heat energy from the Sun is both collected directly as light hits the inside of the box, and reflected off the shiny lid into the box. The foil lined inner of the box ensures this heat is reflected into the black material, while the foil lining and clingwrap window trap the heat allowing the oven to get hotter inside. Due to its colour, the black material acts as a heat sink and warms the food on top of it.


Left: Solar thermal plant in the UAE showing mirrors focussing sunlight onto a central point to collect energy (abc.net.au). Right: a solar hot water system in Fiji (www.facebook.com/WesternSolarSystemFiji)

While this oven will only melt chocolate, the concept can be scaled up to power a whole town. Massive dish shaped mirrors or arrays of mirrors can concentrate massive amounts sunlight to superheat special fluids and/or create steam to drive turbines, producing emission free electricity. The same principle can also be used at the home scale for water heating, giving emissions-free and cost-free hot water.

Other resources:

- More oven designs https://www.sunshineonmyshoulder.com/6-homemade-solar-oven-projects-forkids/

Hydrogen fuel and electrolysis of water

Science Concept: production of hydrogen from water (electrolysis), clean fuels and energy storage

In this activity we'll make a small electrolysis cell. Electrolysis is the process of using electricity to break water molecules into hydrogen and oxygen. In our activity we'll use a battery to provide the electricity, but renewable energy such as solar and wind can also be used. 'Green' hydrogen made using renewable energy can provide an emissions-free fuel source (note hydrogen can also be made from fossil fuels, but this creates $C0_2$). We already have the technology to make green hydrogen at scale. This allows us to effectively 'bottle' the Sun's energy into clean hydrogen fuel for transport and industry such as steel making, replacing fossil fuels like petrol and coal. Currently, green hydrogen is fairly expensive – a problem scientists and engineers are working on right now. Making technologies like hydrogen cheaper means more people and industries will use them, but also allows access by people or countries with less money – it's important that climate solutions are fair and equitable, including between countries.

For climate-friendly transport, green hydrogen has advantages as the main inputs are water and renewable energy, whereas technologies like batteries require large amounts of elements such as lithium to be mined which has other environmental impacts. Batteries can also be hard to recycle, but we are getting better at it. That doesn't mean battery powered vehicles are a bad idea – we need a range of solutions – but like all new technologies we need to consider the whole system, not just one solution in isolation.

Equipment

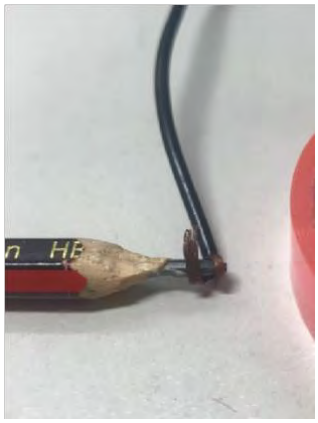
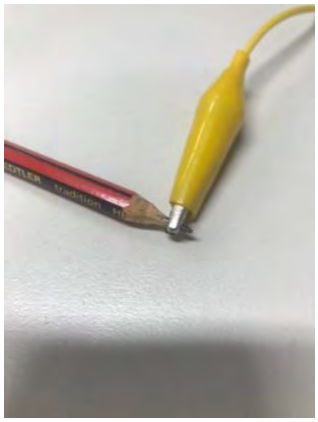
- 2 x standard pencils
- Pencil sharpener
- Stanley knife / box cutter
- 9v battery
- 9v battery clip with wires OR extra electrical wire OR 2 x alligator clip wires

- Glass
- Water
- Tape
- Epsom salts (magnesium sulphate, sold as bath salts at chemists/supermarkets) – note table salt / sodium chloride can be substituted but will produce a very very small amount of chlorine gas during the experiment, if using table salt conduct in a well-ventilated area and only run the cell for short periods less than one minute.

What to do

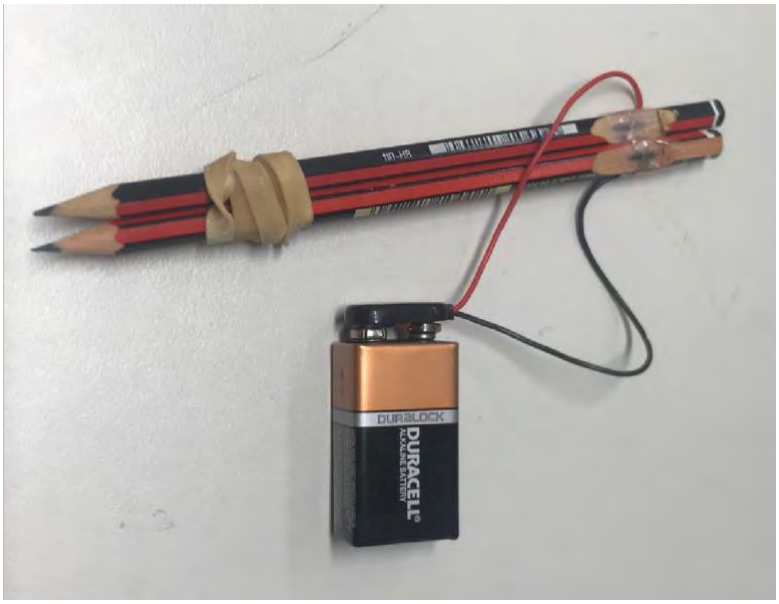
1. If possible, watch https://www.pbs.org/newshour/classroom/2022/04/could-hydrogen-be-the-clean-fuel-of-the-future/ - what do students see as the advantages and disadvantages of hydrogen fuel? Are there applications where hydrogen might be more or less useful than other green technologies?
2. Sharpen the two pencils – the exposed graphite ends will be the electrodes (electrodes are conductors which provide a path for electricity).
3. Next connect the wires to the graphite core at the other end of the pencil. Depending on the wires you use this can be done in different ways (see pictures):
    - use the box cutter to shave off the wood exposing the graphite core, then strip the insulation off the end of the electrical wire and wrap around so it is in contact with the graphite, and tape to secure.
    - sharpen the other end of the pencil, strip the insulation off the end of the electrical wire, wrap around so it is in contact with the graphite and tape to secure (picture 3, before taping, this seems to give the best connection).
    - sharpen the other end of the pencil, then attach an alligator clip to the exposed graphite.



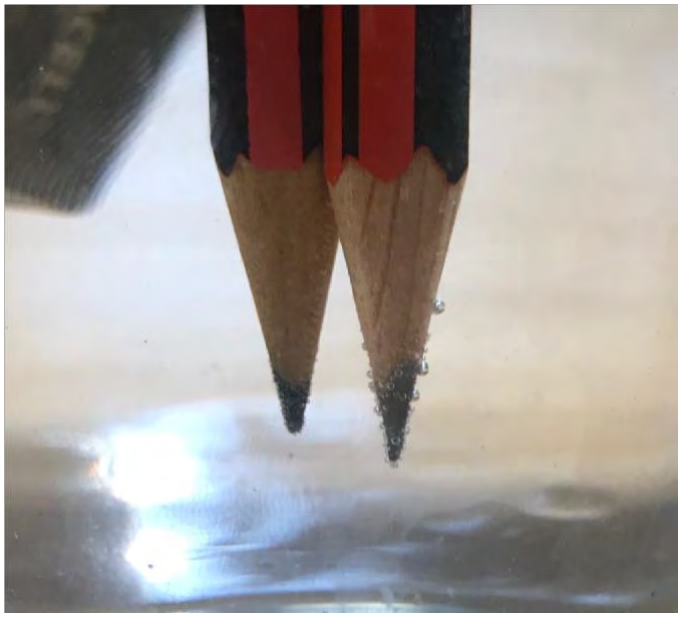



4. Attach the battery to the other end of the wires – this is easy if using 9v battery clip, but if using electrical wire strip insulation and wrap around the terminals securing with tape, or clip an alligator clip onto the battery terminals.


5. Use a rubber band or tape to stick the two pencils together lengthways. Your finished setup should look something like this:



6. Fill the glass with water and add two heaped teaspoons of Epsom salts, stir to dissolve (its ok if some doesn't dissolve). The Epsom salts (magnesium sulphate, $MGSO_4$) is an electrolyte and helps the water better conduct electricity.
7. Ask students for a hypothesis: what do we think will happen when the pencils are placed in the water?
8. Place the pencil electrodes in the water. You should notice small bubbles forming on the electrodes (if none form check your wire connections – we had to press the wires into the pencil using our fingers in our test model).
9. Have another group discussion. What was observed? What might the bubbles be? Are there the same number of bubbles on both electrodes (pencil heads)? Can you trace the circuit the electricity is travelling through? What do we think is happening? Here we've used a battery to provide energy – what do we need to consider if using different sources of energy like solar, wind, fossil fuels, etc.?



What's happening

Passing electricity through water creates a chemical reaction on each electrode. The water (H_20) is broken into in hydrogen H_2 and oxygen O_2 – as water contains twice as much hydrogen than oxygen more bubbles will form on the electrode where hydrogen is produced (see picture above). The chemical reaction overall (combining the reactions at each electrode) is:

$2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$

For every two molecules of water, we get two molecules of hydrogen gas and one molecule of oxygen gas.

On one electrode a reduction reaction occurs; the electrons (e^-) are supplied by the battery – the electric current drives the reaction:

$2\ H^+(aq) + 2e^- \rightarrow H_2(g)$

While on the other an oxidation reaction occurs; the electrons going out complete the electrical circuit:

$2\ H_2O(l) \rightarrow O_2(g) + 4\ H^+(aq) + 4e^-$

For more on the science and chemistry, see http://en.wikipedia.org/wiki/Electrolysis_of_water.

In the activity we used energy from a battery, however we could use renewable energy such as solar and wind instead. Large-scale green hydrogen plants using renewable energy are being planned and developed around the world. Scientists and engineers are working to make the process more efficient (e.g. not 'wasting' too much energy in the process) on a large scale at a cheap price. Green hydrogen made this way can be used in vehicles to produce electricity in a fuel cell (https://en.wikipedia.org/wiki/Fuel_cell) rather than a combustion engine. It could also replace the use of coal in steel production – a large source of emissions around the world.

Making hydrogen from renewables also stores renewable energy so it can be available anytime – you can use solar power at night, or wind energy when it's not windy – however batteries are usually used for this purpose. One advantage of hydrogen compared to batteries, however, is that it can be more easily transported.

Renewable tinkering

These activities use a method/pedagogy called 'tinkering' – creative, fun, open-ended design and making integrating scientific principles. Tinkering is a great way to create integrated STEM, where scientific and mathematical ideas are used in simple engineering and technology applications – and is also heaps of fun! You can substitute equipment and change the design as suits materials locally available, your context and the age group involved.

When facilitating/teaching using tinkering methods, try to ask questions rather than give answers, turn 'mistakes' into learning opportunities to work through problems, encourage collaboration, celebrate success (and 'failures'), and allow space for freedom and personalisation in designs – these things help develop participants' creativity, problem solving, teamwork, motivation and many other 21st century skills. For more on tinkering as a method and activities see this CPAS/UNESCO Hands-On Online workshop https://www.youtube.com/watch?v=prR95UDYtJ0&t=2597s.

Tinkering is also an excellent approach to use when exploring climate change as it encourages creative problem solving using scientific principles – a skill useful for addressing climate change in the real world. But don't forget climate change change isn't just a scientific/technological issue, we also need to consider the social and 'human' dimensions.

DIY wind turbines

Science concept: renewable energy, energy transformations, using wind energy to make energy/electricity, creative design, integrated STEM

Equipment

- Stuff to make a rotor/propellor, e.g. cup (preferably paper), bottle, etc.
- Stuff to make an axle, e.g. straw (preferably paper) and wooden skewer
- Stuff to make a base and stand, e.g. toilet roll, carboard, container
- String
- Masking tape
- Scissors (safety: take care making holes)
- Fan, breath or other source of wind
- Blutack, press-stick or similar (not essential but useful)
- Small weight, e.g. lolly/paper/small stone/paperclips (optional)
- Extension option - electric motor and multimeter/voltmeter

What to do

In this activity we'll build a device that converts wind energy into mechanical energy that can be used to do work lifting a small weight. This shows the principle of wind turbine.

1. Have a group discussion about different forms of renewable energy and how they can be a way to reduce greenhouse gases. How many forms of renewable energy can you think of? What kinds of energy transformations are involved? Do you make/use renewable energy in your country or community? Has anyone seen a wind turbine in your area? How do you think wind turbines work? What issues do we need to think about when building wind turbines and where should they be put?
2. Make a rotor/propellor:
    - Discuss what allows the rotor to 'catch' the wind: should the blades be angled? Will blade size/number affect how much wind you 'catch'? Draw some diagrams and try some simple tests to think through the physics and how that informs your design. Try to ask questions and discuss rather than give answers – tinkering is all about empowering people to solve problems themselves.
    - A simple design good for young kids is to use scissors to cut the sides of a cup to create strips, then twist/angle the strips the same way all round.
    - You can also use the bottom of a softdrink bottle, try folding one from paper, or come up with a novel design.

Paper cup rotor – how do the blades need to be angled to catch the wind? (clue: not like this!)

3. Make an axle (way for the rotor to spin freely):
    - Think through some ideas to make an axle so your rotor can spin. How will you attach it to the rotor? How can you minimize friction? What materials might you use?

- One example: use a skewer poke a hole through the base of the paper cup, then secure using two short pieces of straws and tape (see pictures), or just use press-stick or tape.
- Test your axle and rotor spins easily by blowing on your rotor.

4. Make a base/stand:
    - The base will hold the rotor and axle up. How will you attach the axle? Does it matter if the base bottom is narrow or wide? For stability, where should the weight be? What materials could you use?
    - One example: sticky tape a toilet roll to a disposable container, add a piece of cardboard or a weight on the bottom if it's unstable, then make a hole to insert the axle straw through (see picture). Safety: take care making holes with scissors/skewers.
    - Almost anything can be used for this part, even simple folded cardboard.

5. Assemble the rotor, axle and base – then test with a source of wind. You may find problems with you design (a valuable part of the tinkering process) – continue adjusting things until it spins freely.
6. To show how wind turbines can do work, attach string to the other end of the axle and add a small weight. As the rotor spins, the weight will be lifted (showing potential or stored energy). What else can you wind turbine lift/move/do?
7. Extension option – attach a small electric motor to the other end of the axle (we use tape or tubing to connect it). As the rotor spins, the motor will act as a generator making electricity that can be measured using a amp/voltmeter. Note in a real wind turbine both the size and use of gears creates a LOT more electricity. If you are running this with a group/class, having a competition for whose design makes the most electricity can be great fun!

We would LOVE to see the designs you come up with – please complete the survey at https://bit.ly/ClimateConnectionsBook and/or email any pictures to graham.walker@anu.edu.au!

What's happening

You've just created a machine that turns wind energy (kinetic energy) into energy you can use to do work, in this case raising a small weight. As the weight is lifted its potential energy increases, showing how the wind energy can be stored. If you added a small generator (motor) to the model wind turbine, the wind energy is converted into electrical energy – this is the process in a real-world wind turbine but on a MUCH larger scale.

The model wind turbine involves some other fundamental physics concepts in its design:

- The blades on the rotor need to be angled so that as the moving air (wind) hits them it turns the rotor. As the force of the moving air hits the turbines, and equal and opposite force is applied to the rotor – showing Newton's third law. Do you see differences based on the angle, size or number of blades?

- The axle needs to spin freely with a minimum of friction. Any friction in your design will mean that some of the wind's kinetic energy is instead used to create sound or heat, and too much friction may mean it doesn't turn at all. How did you minimise friction in your design?

Solar Toys – solar photovoltaic energy

Science concept: renewable energy, using sunlight to make electricity (solar photovoltaic energy), integrated STEM, upcycling, electric circuits, series and parallel circuits.

This activity is under development – if you are doing creative and accessible teaching or communication using solar panels we would love to share ideas and collaborate, please get in contact! Our team are working on making this activity and materials used more accessible – small solar panels for educational use can be hard to find in some locations. Stay tuned for new activities in an updated booklet.

Equipment

- Small solar panels*
- Old battery powered toys/devices (1-2 AA or AAA battery models are most accessible for solar powering) – we found this talking dinosaur!
- Salvaged electric motors, small speakers, buzzers, LEDs, etc. (from broken toys, etc.) – these can be substituted for the toy or added to the circuits! We just use a toy below.

* Small solar panels can be found in some hardware, electronics and camping stores and can be purchased online, however can also be salvaged from solar powered device such as garden lights, toys, gadgets, etc. Take care pulling things apart. SAFETY: never experiment with large household/commercial/12v camping solar panels unless you have suitable electronics safety background.

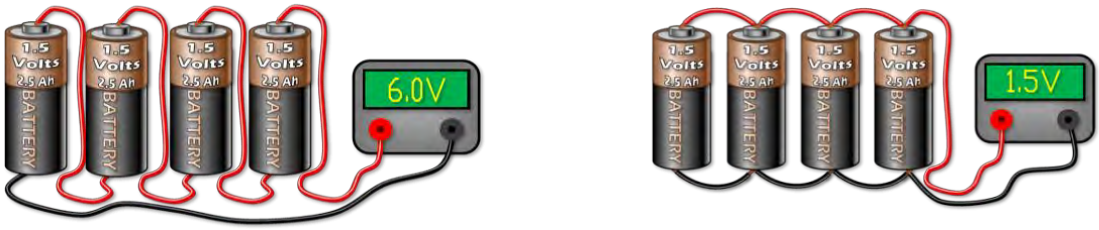
This activity includes a range of fundamental electricity concepts. Key ideas are discussed briefly below, but for more info and teaching resources on electricity, circuits, and series and parallel circuits, see https://tryengineering.org/teacher/series-and-parallel-circuits/.

What to do

1. Have a group discussion about different forms of renewable energy and how they can be a way to reduce greenhouse gases. What forms of renewable energy use energy from the Sun? What kinds of energy transformations are involved? Do you make/use solar energy in your country or community? Are there big picture things we need to think about with solar energy, e.g. who has access to the technology and the Sun's 'free' energy, where do we get materials to make solar panels, and how do we recycle them?
2. In this activity we'll replace the batteries a toy runs on with small solar panels, so let's start by exploring those two things.

Batteries:

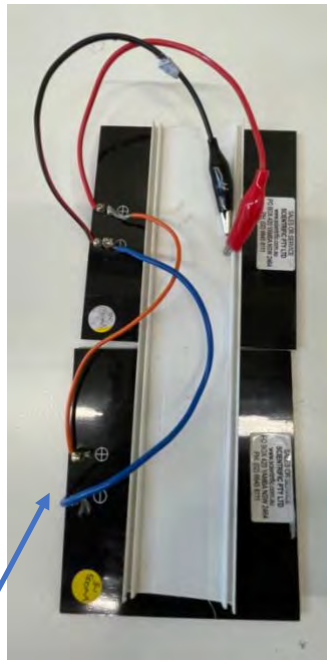
3. Investigate your battery powered toys/devices. How many batteries and of what size/voltage do they use? Can you tell if the batteries are all connected in a long chain with negative joining to positive (*series* circuit – most common in toys)? Or, are they connected side by side with all positives and negatives connected (*parallel* circuit)? Our toy (right) had two AA batteries in series – the bottom connectors join the batteries together in a chain, while the top connectors are where the electricity goes into the toy. Inspect the battery contacts to see which just join the batteries in series and which provide power to the toy – you may need to experiment with where to connect the panel.



Batteries in series (left) - most toys and household items have this arrangement – and parallel (right). Voltage is added when in series, so four 1.5v batteries make 6v. https://forum.digikey.com/t/overview-of-batteries-in-series-or-parallel/1995

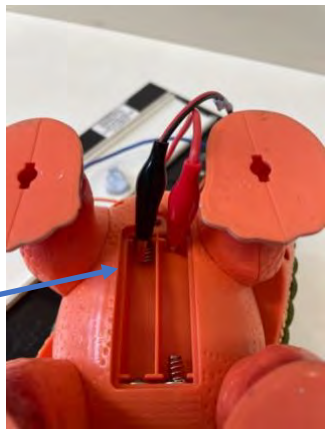
4. Most toys and household items use a series circuit where the batteries are connected in a chain – connecting in series means the voltage of each battery (e.g. 1.5v for AA) is added up, so a toy taking four 1.5 AA batteries runs on 4 x 1.5 volts = 6 volts. When connected in parallel, however, the current (or amperage) increases. Note in many battery holders the batteries are side by side so may appear to be in parallel, however it you follow the circuit you will find they are in series.

Solar panels:



5. Next check the voltage your solar panels make – you want the *overall* voltage produced by your panels to be the same as the *overall* voltage your toy uses. You can see if the voltage is listed on the panel itself, try and find its voltage based on where you got the panel from (e.g. if from a garden light, does it say on the box?), or measure it with a voltmeter while in direct sunlight. Most small panels will have a standard voltage like 1.5v, 3v or 6v.
6. If the voltage doesn't match your toy, like with batteries, you can join solar panels in series to make the voltage add up (e.g. two 3 volt panels in series = 6 volts) or parallel to keep the same voltage but increase the current (e.g. two 3 volt panels in parallel = 3 volts, but with more current). How will you wire up your panels to match the battery needs of your toy? Do not use panels with a voltage higher than the toy, and NEVER use large household/commercial/12v camping solar panels unless you have electrical training/knowledge.

Example:



7. Our toy talking dinosaur took two 1.5 volt AA batteries in *series* = 3 volts. Our solar panels also made 3 volts, so we decided to make a circuit with two solar panels in *parallel* so they would provide more electrical current to the toy. If you have more than one panel and don't need more voltage like in this example, wiring the panels in parallel gives extra electrical energy. This makes the toy work better with less light or if it has high power needs.
8. Connect the solar panel to where the batteries used to go by twisting wire and taping or using alligator clips. Note in most battery holders some contacts create the series connections between batteries, while others send power to the toy – you need to connect to these ones (ours were at the top, see picture). Recheck all connections.
9. Place the panel in direct sunlight. If you don't have sunlight, a 150w high power floodlight globe can be used. Depending on your toy, you may need to switch it on or press a button to make it work (just like when using batteries). Did it work? Was it the same as when using batteries? What happens if you block some or all of the panel?

What's happening

You've just replaced battery (chemical) energy with solar energy. The solar panel turns the Sun's light energy into electricity, which then powers the toy. You might notice your toy works differently and changes how it operates based on how much light is on the panel – try shading some of the panel or moving it in and out of direct sunlight (our talking dinosaur sounds like a DJ scratching!). Unlike the battery, the solar panel's energy output will vary depending on how much light energy it receives (the law of conservation of energy in action). This is why solar panels are usually used with rechargeable batteries or other ways to store the energy, so solar power – once stored – is consistent and can even be used at night! Solar energy storage like batteries can be done on a smaller local level (e.g. charging a battery in a car or for a home) or on a large scale (e.g. a solar 'farm' where a large group of panels is connected to a massive battery connected to the power grid). Alternatively, solar power can be used where it is made with any extra returned (usually sold) back into the power grid for use elsewhere. These different setups have different considerations – which setup would you prefer if your power grid is unreliable, or if companies selling energy are greedy and only driven by profits?

Hydropower Contraption Challenge

Science concept: renewable energy, energy transformations, using water energy to make energy (hydropower/hydroelectric energy - https://education.nationalgeographic.org/resource/hydroelectric-energy), creative design, integrated STEM

This activity is highly adaptable and open-ended, please use these instructions as a general guide and feel free to try other ideas!

Equipment

- A source of moving water, e.g. tap, pouring from a bucket, river, water pistol, etc.
- Waterproof stuff to make a water wheel/propellor, e.g. softdrink bottle, scrap plastic, wood, large stiff leaves, etc.
- Stuff to make an axle, e.g. wire, wooden skewer, broom handle
- Stuff to make a base/stand, e.g. a bucket, wood, your hands (just hold it)
- Construction materials to suit your design (e.g. string, masking tape, blutac/press-stick, nails, hot glue, etc.)
- Tools to suit your design (e.g. scissors, craft knife, hammer, etc.)

What to do

1. Have a group discussion about different forms of renewable energy and how they can be a way to reduce greenhouse gases. How many forms of renewable energy can you think of? What kinds of energy transformations are involved? Do you make/use renewable energy in your country or community? Does your country produce hydroelectricity? How do you think hydroelectricity works? When deciding where to build hydroelectric plants, what issues do we need to think about and who/what might be affected?
2. Brainstorm your design! *You need to build an invention that turns moving water into a form of energy.* Start with some questions to get creative:
    - Where can you find moving water nearby, or how could you create moving water where you are?
    - What kind of machine can you invent to transform the water's kinetic (moving) energy into another form of energy? What kinds of materials will work best with water?

- What forms of energy might be possible to produce; could you make a machine that lifts things (potential energy) or makes a noise (sound energy) and which other forms might be possible?

3. After researching, thinking about and discussing these questions, draw or make a basic model of your design. Try to come up with at least three designs.
4. Now pick your favorite to make! For your chosen design, note down any important points like what materials will be used, how you'll design tricky bits, any problems you can see, etc.
5. Make your Hydropower Contraption! You might like to test how it is working along the way (blowing with your mouth can be a less messy substitute for water's kinetic energy). Don't worry if things don't work how you expected – things going wrong is a great way to learn and refine your design. Talk about your design, making process and any challenges as you go and be sure to celebrate your successes.
6. When everyone is finished, share your designs as a group and demonstrate your Hydropower Contraption with your moving water source. Doing this a simple presentation can be an opportunity to develop communication skills and share successes – things to include could be:
    - talk through the design and making processes, including how you solved problems
    - explaining the science involved (types of energy, forces, etc.)
    - discussing how design be improved and scaled up for use in the real world
    - talking about where you could install a scaled-up version in the real world and what you need to think about, e.g. would people, animals or the environment be affected? What would you build the scaled up version out of and what do you need to consider?

What's happening

Your contraption shows a series of energy transformations – energy changing the form it is in – and also energy moving from one place to another. The kinetic energy of the moving water is converted in other forms of energy – such as making a sound (sound energy) or lifting a weight (potential energy). Any part of your design where friction occurred may result in small amounts of heat or sound as well. Can you trace where the energy goes and which forms it is in in your design?

A historical waterwheel in Syria (https://www.1001inventions.com/devices/)

Real-world hydropower uses energy from moving water and coverts that into other forms of energy people can use – typically electricity (hydroelectricity). The water's kinetic energy is used to spin a turbine/generator which makes electricity. Water power has also been used for grinding grain (converting water's kinetic energy into kinetic energy in machinery and friction to grind seeds), lifting water out of rivers (converting water's kinetic energy into gravitational potential energy), and many other applications – people have been using this technology for thousands of years! It's also technology that can be used into the future, replacing fossil fuels.

Like any technology or solution, we need to think about the whole system and any unintended consequences of using hydroelectricity. Often large dams and other construction is required – will people need to be relocated or could it cause other problems for communities, such as affecting water availability downstream? Environmental effects are also a major consideration – which animals, plants, habitats and ecosystems might be affected? Finally, who will build, own and operate the hydroelectric station – will the materials used have effects of the environment, and will the energy produced be affordable and available to all? Thinking about these issues early minimises problems later.