SCIENCE GALLERY

TEACHING CARBON IN THE CLASSROOM

INSTRUCTOR GUIDE

DRAFT 1

GCRF Global Challenges Research Fund

UKRI Economic and Social Research Council

TE|SF Transforming Education for Sustainable Futures

iihs INDIAN INSTITUTE FOR HUMAN SETTLEMENTS

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Introduction

This Guide consists of eight exercises that educators can use in the classroom to practically demonstrate and teach some concepts related to carbon and climate change. These exercises can be used to teach different subjects and across different grades. Exercises range from calculating individual carbon footprints to analysing the community impact of climate change.

Each of these exercises can be conducted in conjunction with different modules on carbon that are available on SGB's Open Courseware website. Each exercise mentions the modules that are connected to it.

The table below will give you a sense of which exercise you might want to conduct depending on the subject and grade you teach, and the amount of time you are able to spend on an activity of this nature.

	Classes	Disciplines	Prep time	Exercise time
Locating the Sources of our Food	6 – 8	Geography, Environmental Studies, Biology, Economics	30 mins	1.5 hrs
Thinking about our Futures with Energy	6 – 10	Chemistry, Physics, Political Science, Environmental Studies	30 mins	1.5 hrs
Calculating the CO_2 Captured by Trees	6 – 10	Biology, Mathematics, Environmental Studies	1.5 – 2.5 hrs	2 hrs
Creating a Mini-Ecosystem	6 – 10	Biology, Chemistry, Environmental Studies	1.5 hrs	2 hrs
Observing the Health of a Lake	8 – 10	Geography, Environmental Studies, Chemistry, Biology	2 hrs	2 – 3 hrs
Recognising the Carbon in Your Room	8 – 10	Chemistry, Environmental Studies	1 hr	2 hrs

Tracking our Ecological Footprints	9 – 12	Biology, Chemistry, Political Science, Environmental Studies	30 mins	2 hrs
Tracing Climate Change in the Sundarbans Island	9 – 12	Political Science, Economics, Environmental Studies	1.5 hrs	1 – 2 hr(s)

This Instructor Guide is an accompaniment to the carbon-related modules in the free, online Open Courseware created by Science Gallery Bengaluru, with the funding support of Transforming Education for Sustainable Futures (TESF), Indian Institute of Human Settlements (IIHS), and Economic and Social Research Council, UK Research and Innovation (ESRC - UKRI).

1. Locating the Sources of Our Food

The food we eat today can come from places we have never seen or don't know about. For example, vegetables, milk, and grains reach us primarily through shops, and tracing their source is difficult. This exercise asks us to think critically about the packaging, geographical origin, and ingredients of the food we eat. It also asks students to think about food through the lens of sustainability.

Class: 6 – 8
Discipline: Geography, Environmental Studies, Biology, Economics
Prep time: 30 mins
Exercise time: 1.5 hours

Background

https://www.foodunfolded.com/article/trace-your-food-back-to-its-source
This article talks about how we can trace our food, and how our food is tracked. This can serve as useful prep material before conducting this exercise.

Learning Objectives

- Identify the ingredients and source of the food we eat
- Examine the carbon footprint associated with the different food we eat

Exercise

Take printouts of *PDF 1* and share it with students. Ask them to think about the food they ate the day before. The components of a meal could include fruits, vegetables, lentils, dairy products, condiments, meat, oils, and more.

Reflect

After students draw up their list, divide them into groups and ask them to discuss the following questions. You can also encourage them to speak to people who work in the school canteen/mess to understand the source of the ingredients.

You can conduct a class discussion by asking students to share their answers to the following questions:

- How many local fruits and vegetables can you identify in your meals? Are any of them seasonal?
- Are there dairy and other animal products? Where are they produced?
- Are there processed foods? Can you check the packaging to see where they've been transported from?
- What changes in preferences can you make to the components of your three meals to reduce your footprint?

PDF 1

Name:		**Date:**	
	Breakfast	**Lunch**	**Dinner**
Local			

In-state			
Out of State			
Out of country			

2. Imagining our Future with Fossil Fuel and Energy

This exercise allows students to imagine two different futures of our planet, based on our energy use. This enables students to visualise and compare the two scenarios and, in the process, speculate upon the changes required to achieve a future with sustainable energy.

Class: 6 – 10
Discipline: Chemistry, Physics, Political Science, Environmental Studies
Prep time: 30 minutes
Exercise time: 1.5 Hours

<u>Background</u>

Fossil fuels are the primary sources of energy we use today. The large-scale use of these non-renewable forms of energy have contributed to climate change and global warming. Many

researchers are working on alternative forms of energy that can reduce our dependence on fossil fuels.

This article summarises the energy use in India in 2021:
https://www.iea.org/reports/india-energy-outlook-2021/energy-in-india-today

It is important to understand how different forms of energy are used, the impact they have on our planet, and the steps we can take to reduce the negative consequences of unchecked fossil fuel use.

Learning Objectives

- Hypothesise the potential futures of our planet based on different energy use
- Recognise the potential consequences of using different types of energy

Exercise

This exercise asks students to imagine two possible futures in the year 2100:

I. A future still heavily reliant on fossil fuels such as coal, petroleum, and natural gas.
II. A future where sustainable energy has entirely replaced non-renewable forms of energy. The most popular sources of sustainable energy are hydropower, solar, and wind energy.

To conduct this exercise, you can follow the steps below:

- Conduct a group discussion based on the two imagined futures where the students get to share their thoughts with each other.
- Split the class into two groups.
- Ask one group to imagine and discuss what the year 2100 would look like without sustainable energy. (20 mins)
- At the same time, ask the other group to imagine the year 2100 if sustainable energy had entirely been replaced by non-renewable energy. (20 mins)
- Ask the two groups to write or Illustrate their respective futures (20 mins).
- Conduct a discussion next, bringing the groups back together to compare their imagined futures based on the given pointers.

Here are some pointers for the students to consider while making their illustrations:

- Quality of air, food, water, soil

- Transportation and commuting
- The outlook of urban and rural spaces
- Forests or greenery
- The daily usage of technology
- Others (based on the suggestions of the class)

Reflect

You can bring some of the questions below into the discussion:

- Why is alternate energy being promoted?
- How bad is the energy crisis for us to push toward alternative energy?
- What are the implications of the energy crisis in your locality?
- How can we shift from unsustainable energy consumption practices when livelihoods are dependent on them?
- Does everyone equally benefit/suffer from the effects of using renewable/non-renewable energy?
- What changes would we have to make in our society to be able to achieve a future with sustainable energy by the year 2100?

3. Calculating the CO_2 Captured by Trees

This exercise teaches students to estimate the amount of carbon captured (or sequestered) by different trees. Trees play a crucial role in reducing the amount of CO_2 in the air, and learning to quantify this amount is important as we think of solutions to climate change issues. Depending on its species, age, location, wood density, each tree captures a different amount of CO_2, which can be observed through the exercise.

Class: 6 – 10
Discipline: Biology, Mathematics, Environmental Studies
Prep time: 1.5 – 2.5 Hours
Exercise time: 2 Hours

Background

Carbon dioxide, as a greenhouse gas, is responsible for trapping heat within the earth's atmosphere. However, with the increasing amounts of CO_2 in the air, caused primarily by human activity, the planet's overall temperature is rising, accelerating the effects of climate change.

One way to address the increase in atmospheric carbon dioxide is by removing the gas from the air and storing it. Through photosynthesis, trees sequester carbon naturally.

Learning Objectives

- Examine the role of trees in reducing atmospheric carbon dioxide
- Estimate the amount of carbon different types of trees sequester
- Recognise the interdependence between trees , water, and carbon in our ecosystems

Optional prep

To know more about this topic, you can listen to a lecture by hydro-ecologist Jagdish Krisnaswamy, who speaks about the complex and interdependent ecological systems around us, and shares the current scientific understanding of carbon's connection to rain, drought, and landslides. By explaining the process of photosynthesis and transpiration in plants, Krishnaswamy shows how replacing grasslands with trees might reduce the amount of water in the atmosphere.

Please feel free to access the lecture here: https://youtu.be/BtIKD_Qo3cg
This can be used as prep material or screened in the classroom prior to the exercise.

Materials required for exercise

- Calculator
- Measuring tape
- Paper/ Notebook
- Pen
- Some trees!

Exercise

Identify three trees within or close to your school campus. Carry the materials listed above and take your class to each of the three trees.

You can ask different students to help you measure each tree. You will have to measure the tree's diameter in inches (D) and its height in feet (H). Ask students to write down the diameter D and Height H of each tree, and then go back to the classroom to conduct the calculations as given in *PDF 2*.

Reflect

After students have calculated the total amount of carbin sequestered by each tree, you can conduct a discussion on the following questions:

- What is the importance of trees as carbon sinks in your locality?
- What kind of long-term effects would you anticipate experiencing personally if the trees in your town/city were completely removed?
- Is planting trees a viable solution to combating climate change?

PDF 2

After determining the diameter D and height H of three trees, you will have to calculate the following:

A. The total green weight of the tree
B. The dry weight of the tree
C. The weight of the carbon in the tree
D. The weight of the carbon dioxide sequestered by the tree

A. Calculate the total green weight of the tree

- Determine the green weight (or the tree's weight when it is alive) of the tree above the ground. Use the following formulae:
  - $W_{above\text{-}ground} = 0.25\ D^2\ H$ (for trees with D<11)
  - $W_{above\text{-}ground} = 0.15\ D^2\ H$ (for trees with D>11)

  $W_{above\text{-}ground}$ =

- Since the roots of a tree are approximately 20% of the tree's weight above ground, the total green weight of the tree by multiplying 1.2 with its above ground weight. The formula is:
  - $W_{total\ green\ weight} = 1.2 * W_{above\text{-}ground}$

$W_{total\ green\ weight}$ =

B. Calculate the dry weight of the tree

- Since the average tree is 72.5% dry matter and 27.5% moisture, multiply 72.5% by the total green weight of the tree. Use the formula:
  - $W_{dry\ weight} = 0.725 * W_{total\ green\ weight}$

$W_{dry\ weight}$ =

C. Calculate the weight of the carbon in the tree

- The carbon content of a tree is approximately 50% of the tree's total dry weight. So, multiply 50% by the total dry weight of the tree. Use the formula:
  - $W_{carbon} = 0.5 * W_{dry\ weight}$

W_{carbon} =

D. Calculate the weight of the carbon dioxide sequestered by the tree

- CO_2 has one molecule of carbon and two molecules of oxygen. The atomic weight of carbon is 12 (u) and of oxygen is 16 (u).
- The weight of the CO_2 in trees is determined by its ratio to carbon, which is, 44/12 = 3.67. So, to calculate Step 4, multiply 3.67 by the W_{carbon} of the tree. Use the formula:
  - $W_{carbon\text{-}dioxide} = 3.67 * W_{carbon}$

$W_{carbon\text{-}dioxide}$ =

For further information and an example of the calculations, follow the link:
https://www.ecomatcher.com/how-to-calculate-co2-sequestration/

4. Creating a Mini-Ecosystem

This exercise asks students to create a self-sustaining ecosystem in the form of a terrarium. It allows them to closely observe natural cycles present in the terrarium. This becomes a micro-level example of larger ecosystems which consist of many more actors.

Class: 6 – 10
Discipline: Biology, Chemistry, Environmental Studies
Prep time: 1.5 hour
Exercise time: 2 Hours

Background

Carbon connects different aspects of our lives (such as our lands and livelihoods) to a larger network of feedback loops in our environment. Understanding these complex relationships is key to identifying points of balance or imbalance in the feedback mechanisms around us. This exercise asks students to consider feedback mechanisms in our environment.

What is a feedback loop?

Feedback is when an action by a component of a system impacts another component in the system. A feedback loop is formed when the components of a system impact each other. There are two types of feedback loops, positive and negative. A positive feedback loop is when an action by a component enhances or amplifies changes and is likely to cause a system to be more unstable. A negative feedback loop is when an action by a component reduces changes and is likely to keep the system more stable. Some examples of feedback mechanisms in nature are the water cycle, nitrogen cycle, and carbon cycle.

Follow this link for more information on feedback mechanisms.

Learning Objectives

- Define feedback mechanisms in nature, and recognise their importance
- Prepare a terrarium to understand feedback mechanisms at a micro level

Exercise

In the following exercise, students will construct a terrarium. A terrarium is a sealed, transparent jar in which plants are grown. Successfully built terrariums contain self-sustaining ecosystems. Sealing the jar facilitates necessary feedback processes such as the carbon and water cycles. Since the jar is sealed, the atmosphere inside a terrarium mimics a tropical climate. Consequently, tropical plants such as ferns, air plants, orchids thrive in it.

Follow this link for more information on terrariums and the plants that could be used in them.

Materials required before exercise

- A glass jar or any clean and dry container

- A lid to seal the atmosphere within the jar
- Pebbles
- Soil
- Activated charcoal
- Pencils, chopsticks, little trowel, or long spoons
- Tropical plants such as ferns, air plants, orchids
- Moss (optional)

For additional information on terrariums, refer to the link:
https://www.kew.org/read-and-watch/how-to-make-terrarium

Making the terrarium

Follow the steps below to construct a terrarium. You can ask different students to volunteer during different parts of this exercise.

- Take the glass jar and ensure that it is dry before you begin constructing the terrarium.
- Add pebbles to form the base layer of the terrarium.
- Add the activated charcoal next. It helps in keeping the terrarium water fresh and prevents the growth of unwanted bacteria.
- Next, add soil to form the next layer. You'll only need a handful depending on the size of the jar.
- Use the pencil to dig holes in the soil, and place the plants in it. You can add multiple plants based on your preference. You could also add moss, as it helps regulate moisture content in the terrarium.
- If you're building a closed terrarium, place the lid onto the jar to seal the atmosphere.
- Ask the class to keenly observe the terrarium every day for a week.

Reflect

After one week of constructing the terrarium and observing it daily, engage in a group discussion with the class asking them to reflect upon the following questions:

- What do the plants in your terrarium need to grow and sustain on their own?
- Do the water, gases, and nutrients appear to be recycled within the terrarium's atmosphere?
- If the plant(s) in the terrarium continue to grow, what feedback mechanisms contribute to it?

- If the plant(s) die out, could you identify what might have caused the ecosystem to fail?
- How is the terrarium similar to the Earth's biosphere? How is it different?

5. Observing the Health of a Lake

This exercise focuses on analysing the quality of water in the locality. Lakes, ponds, or other small water bodies can be observed to determine the levels of pollutants in the water around us. It encourages students to keenly look at their surroundings, and make inferences based on their observations. Not only does this exercise enable students to get hands-on experience around issues with water, it also encourages them to think about citizen-led research projects.

Class: 8 – 10
Discipline: Geography, Environmental Studies, Chemistry, Biology
Prep time: 2 Hours
Exercise time: 2 – 3 Hours

Background

Water is a fast-depleting resource on our planet. Even within the last few decades, water levels have shrunk and water quality has deteriorated. The most common way people might encounter this change in water is through lakes around them. The colour, smell, and levels of water in lakes changes from season to season, and they are a good way to measure the health of the water in an area.

https://www.downtoearth.org.in/blog/urbanisation/how-do-india-s-policies-and-guidelines-look-at-urban-lakes--68662
This article talks about lakes in India, their history, and the current issues with lake health. It also defines urban lakes and points to the specific problems we are facing with them.

Learning Objectives

- Identify local water bodies and recognise their importance in our ecosystem
- List the factors that contribute to a lake's health

Introduction to the connected lecture

Focusing on the general public's interpretation of the science, technology, and research around climate change, V. Ramprasad speaks about citizen science as an important tool to involve

people in knowledge creation. Sharing his journey of researching lakes in Bengaluru, Ramprasad shows how widespread technology such as mobile apps can become critical tools for participatory research. In analysing the condition of water in Bengaluru's lakes, he helps us determine the factors that contribute to a water body's overall health.

Link to lecture: https://www.youtube.com/watch?v=ax950Ue-MTY
You can watch this lecture or screen it prior to the exercise.

Exercise

Before conducting the exercise, identify a pond or a lake that the students of your class could be taken to in your locality.

Make printouts of *PDF 3* and distribute them among students prior to the exercise. The students will have to fill in the details based on their individual observations of the water body.

Keeping the observable indicators of the Lake Health Index in mind, visit a lake or a pond in your locale and assess its quality based on its appearance to you. Please refer to *PDF 3* for examples of the observable indicators.

Ask the students to make notes on the quality of each observable indicator (as mentioned in *PDF 3*)

Fill in the table in *PDF 3* for reference.

Reflect

When back in the classroom, engage the students in a group discussion about their individual observations for each parameter. Note the various points down on the blackboard/ whiteboard as they speak so that they are able to see their observations collectively.

Having gone through all their observations for each parameter, ask for their opinions on the quality of the lake and identify the parameters that contribute to it being good or bad.

Additionally, make the students identify actions that could be taken to improve the quality of water in the pond/lake based on the parameters that negatively contribute to the quality.

PDF 3

Name of the lake:	**Date:**

Indicator	Remarks
What do you see around the lake? (agriculture/farming, apartments/society complexes, individual houses/layouts, industries, sewage treatment plants)	
What is the colour of the water? (black, brown, green, clear)	
What do you smell? (no smell, bad smell, pleasant smell)	
Are there any signs of garbage dumping?	
Can you see where the water enters (inlets) and exits (outlets) the lake? Are you able to observe and make a judgement on the quality of the water in either case?	
What birds do you see? (Refer to the lecture to find some examples of birds as indicators)	
Do you see any fisher folk? What kind of fish have they caught? Can you see any fish in the lake/pond?	
What plants do you see?	
Any additional indicators that you think are missing?	

6. Recognising the Carbon in Your Room

This activity encourages students to think about the materials used in the construction of their home/school. By contextualising construction material in their own lives, this exercise provides students a starting point to think about sustainability through the lens of development.

Class: 8 – 10

Discipline: Chemistry, Environmental Studies
Prep time: 1 Hour
Exercise time: 2 Hours

Background

https://www.thehindu.com/features/homes-and-gardens/sustainable-architecture-for-india/article3558934.ece

The article above discussed the need for sustainable architecture in India, while acknowledging the different social, economic, and cultural factors that must be considered in this process. Given that construction and buildings are all around us, it is crucial to think of the ways they affect our environment.

Learning Objectives

- Recognise common carbon-based materials in their surroundings
- Estimate the amount of carbon it takes to build their town/city
- Relate concepts of sustainability to their own environment

Exercise

Ask students to think about the classroom they use. Support them in listing the various materials that may have gone into producing this space.

You can print out *PDF 4* to assist students with the activity.

Here are some pointers you can invite students to consider while making the list:

- Think of the structure of the room. What kind of materials would have gone into making the outer structure of the room? Can you research where the materials might have been brought from?
- Do you see any use of metal within the room? For what have they been used? Could you research more about the types of metals that are used in a room?
- How many colours of paint are on the wall?
- How many electrical points do you see in the room? Ask an electrician or research online about the materials that go into putting them there.
- Think of the interior design of the room. What kind of furniture can you see in the room?

PDF 4

Components of the Room	**Materials used in its production**
The shape of the room	
Wall	
Windows	
Paint	
Windows	
Ceiling	
Floor	
Plumbing	
Electrical layout	
Furniture	
Fabric	
Other Technology	

Other components (Please specify)	
How would you design the space differently (both internally and externally) specifically keeping sustainability in mind?	

7. Tracking our Ecological Footprints

This exercise aims to enable the students to think about their footprints in terms of water, food, and energy consumption, and waste creation. Some of the questions would require the students to step out of their classrooms and converse with people so that they can collect information. Other questions would require them to research beyond their class material in their classroom syllabus for them to get some answers.

Class: 9 – 12
Discipline: Biology, Chemistry, Political Science, Environmental Studies
Prep time: 30 Minutes
Exercise time: 2 Hours

Background

Through the concept of ecological footprints, we are able to, with some certainty, determine quantitatively the impact of human activity on the earth. Though there are many ways to calculate individual carbon footprints, it is equally important to think about other ecological factors such as local context, infrastructure, and social systems. This exercise asks students to focus on all these factors, and encourages them to speak to members of their community to understand the challenges of sustainability in their locality.

Learning Objectives

- Outline the concept of footprints by looking at consumption patterns
- Relate footprints to student's lives by encouraging research into the local production and

sources of energy, water, food, and waste.
- Determine the practicality of 'sustainable' solutions and their effectiveness in reducing our footprints

Exercise

- Organise the students into four groups and assign a footprint type from *PDF 5* to each group to enable a group discussion.
- Distribute a printout of *PDF 5* to each group.
- Give the groups 30 minutes to discuss the pointers of their respective footprint type and ask them to list it out on a piece of paper.
- Encourage the groups to step out of the classroom to engage in conversation with people in the educational space to get the answers for the questions in the printout. They could alternatively also research the answers to the questions if they have access to the internet.
- Discuss the findings of each group and note them down on the whiteboard/blackboard.
- Discuss the groups' solutions in the respective local context.

PDF 5

Footprint	**Pointers**
Water footprint	● Can you look up the various sources of water for your town? ● Approximately how far does the water travel to reach you? ● Does the water come from higher ground? ● Calculate the carbon emission of transporting water to your location, if it approximately takes 2 units of energy to transport 100 litres of water across 100 kilometres?

Energy footprint	● Where do you think the energy for the electricity in your room comes from? ● Can you travel to your nearest electricity supplier to find more information? ● Can you find out more about the source of your electricity (nuclear power plant, hydropower plant, fossil-fuel reliant power plant, combination of multiple sources)? ● How does the distance of the source to your town/city affect the amount of emission while producing that energy? ● How do we reduce carbon emissions individually and collectively, when it comes to energy?
Food footprint	● Think of the food that you eat and whether it is locally produced or brought from outside state boundaries. What are the sources of grains, vegetables, fruits, and meat that you consume? ● Where do you normally buy your fruits and vegetables from? Are there any vendors close to your home that sell locally sourced vegetables and fruits?
Waste footprint	● Where in your neighbourhood do you throw your garbage? ● Do the garbage trucks come to pick your waste from there? ● Could you speak to the sanitation workers to find out more about what they do with the garbage they collect everyday from your locality? ● How far do they travel to collect garbage from your neighbourhood? ● Research online to see if there are STPs (sewage treatment plants) in your town.

8. Tracing Climate Change in the Sundarbans Island

This exercise encourages students to think about the consequences of land erosion in India. Students are asked to think of the people, land, wildlife that is affected by the disappearance of part of the Sundarbans Islands. It focuses on the ongoing, real-life implications of climate change, and contextualises the issue for students.

Class: 9 – 12

Discipline: Political Science, Economics, Environmental Studies
Prep time: 1.5 Hours
Exercise time: 1 – 2 Hour(s)

Background

The Sundarbans Island in West Bengal has dealt with rising sea levels since the 1980s. Heavy rainfall and the soil erosion in this area is leading to the disappearance of the Ghoramara island. This is an example of a landform that might vanish from the earth if we do not take measures to mitigate the effect of climate change here. Already, the people who inhabit this island are facing serious issues to their livelihoods and daily life. This assignment prompts students to think about the immediate consequences of climate change.

https://www.scmp.com/week-asia/health-environment/article/3134368/indias-ghoramara-island-shrinks-so-do-residents-hope
This article goes into detail and explains the disappearance of the Ghoramara island.

Learning Objectives

- Examine the effect of climate change on the Ghoramara islands.
- Design a flowchart to understand the consequences of disappearing landforms.

Introduction to the film Anthropocene Relooked

Anthropocene Relooked is a video essay examining the impacts of the anthropocene on the low-lying islands of the Ghoramara region in the Sundarban Delta complex. Tracing the repercussions of human actions, the film ponders upon the loss of land and culture in this region. Combining footage and interviews from the people of Ghoramara, the film focuses on the community's efforts to mitigate the social, economic, and cultural problems that arise with climate change.

Link to film: https://www.youtube.com/watch?v=ud7IJYJzsoY

This film can be screened in the classroom prior to the exercise.

Exercise

Begin by discussing the process and function of a flowchart. You can refer to this link to know

more about flowcharts:
https://www.med.unc.edu/neurosurgery/wp-content/uploads/sites/460/2018/10/Flow-chart-Process-Flow.pdf

After having gone through the film, *Anthropocene Relooked*, ask students to make a list of all the stakeholders mentioned in the film. Provide students with blank sheets of paper, and ask them to draw a flowchart that identifies the consequences of land erosion.

Ask students to keep in mind the communities, village bodies, unions, governmental and non-governmental organisations mentioned in the film. After making the flowchart, have a discussion based on the following points:

- What relationships can you see between the various stakeholders mentioned in your list?
- Is there a hierarchy? On what basis does the hierarchy exist?
- Do some stakeholders have more agency/power to influence outcomes over others?
- Is there a difference in the carbon footprint of the different stakeholders?
- Are the effects of climate change being felt differently in different regions?