Smithsonian | SCIENCE *for Global Goals*

INNOVATION!

How can we create new solutions for the changing climate?

SUSTAINABLE DEVELOPMENT GOALS

developed by
Smithsonian *Science Education Center*

in collaboration with
iap SCIENCE HEALTH POLICY
the interacademy partnership

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Dear Parents, Caregivers, and Educators,

Youth should have an integral role in conversations about how to create a shared, sustainable future. What needs to be part of a sustainable world? Are we hoping for a world where peaceful societies collaborate; a world where we live in balance with the environment of our planet; a world in which our economies fulfill our needs; a world that is fair to all? This Community Research Guide encourages young people to use science, technology, engineering, and math (STEM) to discover, understand, and act on the answers to these questions.

As youth around the globe engage with the activities in this guide, they will gain an understanding of the science that underlies global sustainability issues. They will be able to share their knowledge with their community, create tangible ways to help their community make informed decisions, and understand the best places to find additional information on these topics.

Throughout the guide, young people may find themselves asking many questions about people and our shared planet. You do not need to have the answers to any of these questions. The most important thing you can offer young people is the opportunity to question, investigate, think critically and systemically, synthesize, and act. Ask the young people around you how they are feeling and what they are thinking about as they learn this content.

I am immensely grateful to the experts who helped to develop this guide—the InterAcademy Partnership, a collaboration of 150 national academies of sciences, engineering, and medicine; our colleagues across the Smithsonian Institution; and the external subject matter experts who contributed to this guide—for their perspectives and technical support in ensuring the science in this guide is accurate. I also want to say a special thank you to the Smithsonian Science Education Center developers of this guide for their thoughtful contributions to the *Smithsonian Science for Global Goals* project.

Working together—scientists, researchers, parents, caregivers, educators, youth—we can make a better world for all. This guide is a step toward that grand collaboration.

Thank you for partnering with us to inspire our youth to build a better world.

Best,

Carol L. O'Donnell

Dr. Carol O'Donnell,
Douglas M. Lapp and
Anne B. Keiser Director
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Student Letter

Dear Student,

This is the last time you will be called a student in this Community Research Guide. Instead, you will take on a new role as an action researcher. Action researchers are interested in figuring out what to do to make their communities better. They use scientific investigations to help understand the natural world around them. They use social science investigations to help understand the people, cultures, and history of their communities. Then they use the information they gather to help solve problems in their own communities. This guide will help you learn more about this process. The most important thing to know is that you will control your own research and make your own decisions.

Think back to a time when you solved a problem. You first needed to know what you wanted—your goal. Then you needed to figure out what you had to do to achieve your goal. This guide is similar. You will think about goals you have for your local community, then figure out what you need to take action to help reach those goals.

You and your classmates will work as a team to think about information you already have about the place where you live. Then you will investigate your local community and how things work. Finally, your team will decide how to make things better. Together, you will put your decision into action. Sometimes making decisions about what to do is difficult. Don't worry, this guide will give you lots of support.

How to Use this Guide

This guide is designed to help you explore and think about problems in your community. The guide is here to help you. That means you can always change it.

Adapting the Guide

You will notice that in this guide there are often suggestions about different ways of sharing your ideas or doing investigations. This is because different people think and work best in different ways. For example, some people like to draw, some people like to talk out loud, and some people prefer to write to express their ideas. This guide has suggestions, but you can always change the method suggested. You can share your

ideas using discussions, acting, signing, telling stories, recording your voice, writing by hand, typing on a computer, drawing, or another way you choose. Think about the way you and your team learn best together. Including everyone on the team is important.

Safety Tips

This guide asks you to do and think about things that may seem unfamiliar. You will notice physical and emotional safety tips in the guide. These will help you stay safe and supported during the activities. Make sure you follow your teacher's directions about staying safe.

Guide Structure

There are eight tasks in this guide. Each task has three activities. The activities are called ***Discover***, ***Understand***, and ***Act***. In the ***Discover*** activities you will focus on thinking about information you and your team already know. In the ***Understand*** activities you will investigate to find out new information. In the ***Act*** activities you will put your existing and new knowledge into action by applying it and making decisions. Words that may be unfamiliar will be in **bold** the first time they are used. Then, at the end of the guide, a glossary lists the definitions of all these words.

Investigations

You are the one doing the research in this guide. This means often you will develop your own questions and determine the best way to answer them. Developing and answering questions is how scientists find out new information about the world around them. As an action researcher, you need to think like a scientist to discover what you need to know, investigate to find out more information, and think about the meaning of what you found out.

Keeping Organized

In this guide you will have some papers you will need to keep so you can look at them later. You may want to have a folder, notebook, or science journal to help you stay organized.

Teams

You will be working with other classmates as part of a research team. Your team will conduct investigations and make decisions together. When conducting research, there may be many things to figure out as a team. You will need to be creative. There will not always be a clear right and wrong answer. Sometimes the team might not agree. This is okay. Just make sure to respect your teammates. There is no one right answer to the problems faced by your community. There is just the right answer for you and your team.

Research Mentors

In this guide you will learn from the experiences and knowledge of research mentors. You can also find research mentors in your local community. Any expert willing to share their knowledge could be a research mentor. You could even be a research mentor for someone just learning about research or about the place you live.

What do you feel you are an expert in? Each person has knowledge. Experts sometimes gain their knowledge through study or academic research. Other times, experts gain their knowledge through their experiences, such as living in a specific place. Often, experts can have both types of knowledge!

Throughout this guide, your research mentors will share knowledge and experiences to help you understand topics more thoroughly. They may help you understand better ways to learn more information or share some of the information they have learned. The photos here are of the research mentors you will meet in this guide.

Getting Started

You will be thinking about complex problems. Sometimes this can feel difficult. Be patient. You will be guided to consider different parts of the problem. By the time you are making big decisions, you should have lots of information. Always remember, your work is important. Decisions you make can change your community. You are an important part of making your local and global communities better.

Thank you for working to make your community better.

The Smithsonian Science for Global Goals team

Smithsonian Science Education Center

Smithsonian Institution

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Find out More!

For additional resources, activities, and innovation examples, please visit the *Innovation!* StoryMap at https://s.si.edu/InnovationGuide.

Innovation Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 1: Why do we need innovation?					
Discover	Develop a personal *Identity Map* showing the different parts of who you are. Identify characteristics you have that help you be innovative. Learn about innovation at the Smithsonian.	• Paper • Pens or pencils		40 minutes	3
Understand	Identify how existing innovations help people solve problems related to your local climate. Act out problems and innovative solutions. Consider innovations necessary for a changing climate.	• Paper • Pens or pencils		30 minutes	9
Act	Learn about different perspectives and how they might motivate people to innovate. Use futures thinking to consider your goals for the future and relate them to the SDGs.	• Paper or poster • Pens, pencils, markers	*Identity Map*	45 minutes	13

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 2: How can we innovate?					
Discover	Create a sense of the chain of causation around climate change by first analyzing a climate problem, and then check your understanding with a card-sorting activity.	• Chairs (optional) • *Climate Change Story Cards*, printed and cut apart		45 minutes	21
Understand	Observe innovation in action and identify the different steps of the innovation process.	• 2 tables or desks • Small ball • Several pieces of paper • Connecting materials • Timer • Other building materials (optional) • Video recording device (optional) • Paper • Pen or pencil		30 minutes	30
Act	Create your *Climate Innovation Organizer* and define the problem at different parts of the climate change story.	• Paper • Pens or pencils	*Climate Change Story Cards*	25 minutes	34

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 3: How can we think of new ideas when innovating?					
Discover	Discuss trends and changes in social norms. Analyze different human behavior categories for shifts in norms over the past 100 years. Collect an oral history to gather data about these shifts.	• Paper • Pens or pencils • Audio or video recording device(optional)	*Climate Change Story Cards*	20 minutes + Oral history collection time	39
Understand	Explore ways communities innovate. Analyze oral histories for changing norms. Generate ideas to encourage behavior shifts.	• Any object around you • Small pieces of paper or index cards • Pens or pencils • Timer		55 minutes	46
Act	Add your generated ideas to your *Climate Innovation Organizer*. Choose one behavior you will change and decide how you will communicate this change with others.	• Paper • Pens or pencils • Timer	*Climate Innovation Organizer*	25 minutes	54
Task 4: How can we select solutions when innovating?					
Discover	Discuss the production of common items and how that relates to greenhouse gas (GHG) emissions. Determine criteria for selecting potential innovations to develop.	• Paper • Pens or pencils		35 minutes	61

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Understand	Assign a scale to your criteria and create an *Innovation Criteria Chart*. Research and analyze different innovations to reduce production of GHG emissions.	• Paper • Pens or pencils	*Team Criteria*	25 minutes + Research time	67
Act	Select the best innovation solution according to your criteria. Select solutions for other parts of the climate change story.	• Pens or pencils	*Innovation Criteria Chart* *Climate Innovation Organizer*	25 minutes	71
Task 5: How can we evaluate innovations?					
Discover	Use an active modeling activity to show the cyclical movement of carbon among Earth's spheres. Explore the natural cycle, the modern cycle, and the potential for sequestration to remove carbon from the atmosphere.	• The 4 sphere signs • About 60–80 small counters • 4 containers • At least 4 six-sided dice • *Rolling Instructions* cards, printed and cut apart • Timer		35 minutes	76
Understand	Use experimental design concepts to design experiments to better understand how to create a green wall innovation.	• Paper • Pens or pencils		35 minutes	87
Act	Create a prototype of your green wall innovation. Fill in your *Climate Innovation Organizer* with experiments and potential sketches of prototypes.	• Paper • Pens or pencils • Prototyping materials, such as cardboard and tape	*Climate Innovation Organizer*	20 minutes + Prototyping time	96

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 6: How can we test innovations in communities?					
Discover	Examine data and consider the risks of different climate challenges. Identify local climate data sets and creatively represent them.	• Sticky notes or small pieces of paper • Pens or pencils • Tape or rope (optional) • Art materials to represent data (optional)		40 minutes + Representing data time	102
Understand	Choose a climate innovation and design a field test.	• Paper • Pens or pencils • Online or physical maps (optional)	*Data representation*	35 minutes + Presentation creation time	109
Act	Get community feedback on your field test plan. Design field tests for innovations related to other parts of the climate change story.	• Paper • Pens or pencils	Field test presentation *Field test site map* *Climate Innovation Organizer*	25 minutes + Community presentation time	115
Task 7: How can we launch innovations?					
Discover	Analyze the impacts of climate change from four perspectives. Think about differences in the adaptations needed for different levels of warming. Think of ideas for adaptation innovations.	• Pens or pencils • Paper • Printed copy of *Impacts of Climate Change* chart (optional)		35 minutes	120
Understand	Take on different roles as your team prepares to launch your innovation. Create your launch plan and share it with your audience.	• Paper • Pens or pencils		45 minutes + Launch plan sharing time	126

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Act	Reflect on the process of preparing for launch. Create launch plans for other potential innovations.	• Paper • Pens or pencils	*Climate Innovation Organizer*	25 minutes	133
Task 8: How will we innovate?					
Discover	Find consensus on the innovation your team will develop to rewrite the climate change story. Start to create your *Innovation Plan* by going through steps 1 through 3 of the innovation process.	• Paper • Pens, pencils, or markers	*Climate Innovation Organizer* *Team Criteria*	35 minutes	137
Understand	Complete your *Innovation Plan* and put it into action.	• Paper • Pens or pencils • Innovation materials (optional)	*Innovation Plan*	30 minutes + Innovation time	142
Act	Reflect on your innovation, the process you learned, and how your innovation identity has changed.	• Paper • Pens or pencils	*Identity Map*	15 minutes	144

Innovation! How can we create new solutions for the changing climate?

This guide is about **innovation**. Innovation means solving a problem with a new idea or method. In this guide you will explore how you and your team can help solve problems related to climate change. The information shared about climate change in this guide is based on scientific facts and evidence. The climate change story shared here is the **consensus** of the vast majority of scientists. There are other people who have different perspectives on the causes and effects of climate change.

While using the guide, you will become an **action researcher**. You will identify and help solve problems in your **community**. A community is a group of people who have something in common, such as living in the same local area. Action researchers first ***discover*** their own knowledge and the knowledge within their communities. Then they investigate to ***understand*** problems. Finally, they ***act*** on what they have learned to improve their local and global communities.

You will create and keep several sheets of paper or digital documents to help you record and remember information. You may want to use a notebook or folder to help organize these sheets.

Remember: *In this guide you and your team are in charge. You can always change the instructions in the steps to make them work better for you and your team.*

Meet Your Research Mentor

Meet Dr. Mafini Dosso. Mafini (pronounced ma-FEE-nee) will be your research mentor for Task 1.

Mafini co-founded and leads OIITID, an innovation-enabling organization that helps unleash the potential of Africa's innovators. She lives in Abidjan, Côte d'Ivoire (West Africa). Mafini has a doctoral degree and focuses on the economics of innovation. She is committed to innovation for sustainability.

Mafini's Identity Map

- Values sustainable societies and economies
- Belongs to OIITID, French Tech Abidjan, and Dream VC
- The co-orchestrator and creative of the household
- Values impact, communities
- Values generosity, inclusivity, innovation for all
- Funny, kind, and curious
- 42 years old
- 172 cm tall with short black hair
- Belongs to ADSEN and ICBnF
- Belongs to Superwoman by AYANA
- Likes to joke, to design, to write, and to communicate
- Interested in industry, startups, research, and Africa
- Connected to Sevilla, France, Côte d'Ivoire, and Comoros
- Interested in innovation and digital for development

Before you begin Task 2, think quietly to yourself about Mafini's identity map.

- Are there things you have in common?
- Are there ways in which you are different?

Throughout this task Mafini will share ideas with you. These ideas might give your team new information or help you think of ways to investigate your community. Visit the *Innovation!* StoryMap to learn more about Mafini and the other research mentors you will learn from throughout the guide.

Task 1: Why do we need innovation?

In this task you will first ***discover*** how innovation relates to you and your identity. Next you will analyze to ***understand*** the role of innovation in solving past and future climate problems. Finally, you will ***act*** by exploring different **perspectives** and creating a vision of an innovative climate future.

Discover: *How am I innovative?*

Our different experiences, backgrounds, and ideas give each of us a unique identity. Your **identity** is what makes you you. Each of us can play a role in creating a better future for people and the planet. This activity will help you think about how the identity and experiences of your team can help develop new ideas and solve problems.

1. Take out a piece of paper and title it "Identity Map."
2. On the paper, write your name in the center of the page or draw a small picture of yourself.
3. Draw a circle around your name or picture.
4. Answer the question, "Who am I?" or, "What describes me?" The list below can give you some ideas to consider. You can also include things that are not on the list. You choose what you want to include to represent who you are.
   - Hobbies or things you like to do for fun
   - Physical traits (such as age, height, hair color)
   - Personality traits (such as loud, funny, thoughtful, kind)
   - Topics or subjects that interest you
   - Strengths, skills, and talents
   - Places or cultures you feel connected to
   - Values, beliefs, or goals that are important to you
   - Roles you have in your household (such as cousin or helper)
   - Groups you belong to (such as groups related to race, gender, ethnicity, or religion)

5. Write each answer on the page around your name. Draw a line between your name and each answer. Figure 1 is an example of a written *Identity Map*. You can put your answers at the end of each line.

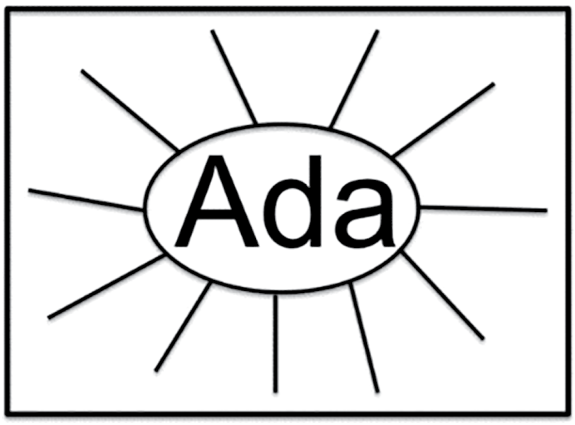


Figure 1: Example of a written Identity Map.

6. Read *Your Innovation Identity* and start to think about how you might be innovative.

Your Innovation Identity

In this guide you will be thinking about **innovation**. Some people think innovation is something only experts do, but that is not true. Innovation just means solving a problem with a new idea or method. An **innovator** can be anyone who solves a problem in a new way. Innovators often have characteristics such as **curiosity**, **creativity**, **flexibility**, **persistence**, and the ability to **collaborate**. Each of these characteristics can help individuals or groups innovate.

7. Turn to a partner, or with your team, discuss whether you already think of yourself as an innovator. Why or why not?
8. Read what research mentor Dr. Mafini Dosso says about how our experiences and identities can help us innovate. What parts of your identity or experiences do you think have helped develop your innovative characteristics?

Mafini says . . .

One major factor of innovation is creativity—thinking about things in a new way. For example, a pen might just be a pen, or it could be something to push a cup or put up your hair. A watch might just tell the time or it could be a phone or a health device. What matters is to be open to discovery and experimentation.

Collaboration and collective intelligence encourage innovation, as well. We share information and ideas between people and across places, we learn, we connect; and we do so even faster thanks to digital tools. We can have experiences that encourage our curiosity and expose us to new ways of doing things or novel approaches. Some cultures or economic situations might encourage flexibility or persistence. You might think people are just born innovative, but often it is the environment and experiences that help people become solvers and innovators.

9. Examine your *Identity Map* and think about the innovation characteristics shown in Figure 2. Which parts of your identity have contributed to your own curiosity, creativity, flexibility, persistence, and collaboration?
10. Draw the symbol for each innovation characteristic next to the related part of your identity. For example, maybe your *Identity Map* lists "many siblings" and being part of a large family has taught you to be flexible. You would draw the star symbol next to "many siblings" on your *Identity Map*. Do not worry if you are unable to find every innovation characteristic, just mark what you do notice. If one part of your identity is related to more than one innovation characteristic, draw all the related symbols next to it.

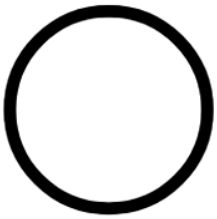
Innovation Characteristic	Innovation Characteristic Symbol
Curiosity: Wanting to know more Which parts of your identity encourage you to ask questions or make you want to learn more? Think about times you may have felt excited to find out more about something or think more deeply, even if it was not part of school. Put a triangle next to each part of your identity that relates to curiosity.	
Creativity: Coming up with new ideas Which parts of your identity help you think about things differently or come up with creative ideas or solutions? Think about times you created something, whether it was an object, an idea, or a way of bringing people together. Put a circle next to each part of your identity that relates to creativity.	
Flexibility: Adapting your thinking When have you taken risks or adapted your thinking to solve a problem? Think about new things you have tried or even small changes you have made to improve something. Put a star next to each part of your identity that relates to flexibility.	
Persistence: Continuing despite obstacles When have you kept trying despite challenges or difficulties? Think about times you have persisted even though something may have been hard or was not working the way you wanted it to. Put a square next to each part of your identity that relates to persistence.	
Collaboration: Working with others Which parts of your identity have helped you learn or work with others? Think about times you have had to collaborate with others, whether it was a sibling, a friend, or someone else in your community. Put a heart next to each part of your identity that relates to collaboration.	

Figure 2: Innovation characteristics and symbols.

11. Examine your *Identity Map*. Which innovation characteristics do you think are already areas of strength for you?
12. Read about SparkLab at the Smithsonian. How do you hope to develop your innovative identity?

At the Smithsonian

Everyone can be an innovator, but sometimes people don't how innovative they can be. People are invited to unlock their inner innovators at SparkLab in the Smithsonian National Museum of American History. SparkLab creates hands-on opportunities for adults, teens, and children to become inventors.

Within SparkLab, different stations invite guests to try to solve problems in new ways. Stations may range from creating a new recipe to designing a city block to finding a new way to pick fruit to producing music. At each station, guests can try out different ideas—sketching their thoughts and using materials to create them. As they try out their new inventions, guests can make small changes to make them work even better.

Figure 3: Activities from SparkLab.

SparkLab's approach emphasizes that anyone who solves problems (and that is everyone) is an inventor. Different people might use different processes or produce different items to solve a problem. These differences are good! They show us the incredible creativity we have as humans. History shows us the many ways inventors innovate. There is no wrong answer; just start by coming up with an idea, then make it better.

SparkLab staff follow this same process when developing SparkLab activities. They start with an idea and think of station possibilities. They consider which materials might help guests express their creativity when solving the problem. After designing the station and its materials, they create the station within SparkLab and then watch carefully. Which materials get used by guests? What breaks easily? Is anything confusing? There are always improvements to be made. The designers have to be flexible and think about what could change. Over and over they persist in improving stations to make them even more engaging to SparkLab guests.

Learn more about SparkLab by visiting the *Innovation!* StoryMap.

13. Form a team with the other learners around you. Teams can be as small as a few people and as big as your whole group. Innovations are not usually created by one person acting alone. Most often innovations are created by teams. This is why collaboration is so important in innovation. Teams can be useful because they allow people with similar strengths to work together. They can also help bring different strengths together.
14. Take your *Identity Map* and move around your learning space. Find another team member who has one of the same innovation characteristics as you. Share with each other about a part of your identity related to this innovation characteristic.
15. Next, find another team member who has a different innovation characteristic. Share with each other about a part of your identity related to your different strengths.

⚠ Emotional Safety Tip

Sharing your identity with someone else can help build trust between you and that person. But it can be hard to share your personal identity with someone else. Only share parts of your *Identity Map* that you feel comfortable talking about.

16. Quietly reflect on the different identities you found in your team, or discuss them as a team. Everyone is unique. As action researchers, you will work together, using each person's strengths, to contribute to innovative climate solutions. Consider:
    a. How can the different strengths of people on your team help you innovate better together?
    b. Which part of your innovator identity would you most like to develop while using this guide?
    c. Are there ways you think sharing what you don't know can also help the team?

Understand: *How is climate related to innovation?*

Human innovation helps meet the needs of people. The most basic needs include water, food, shelter, clothing, and a comfortable temperature. Throughout history, people have been challenged to meet their needs despite the conditions outside.

1. Turn to a partner and share what the weather is like outside today.
2. With your partner, read *Weather and Climate* and discuss the difference between today's weather and the climate of your area.

Weather and Climate

Weather and **climate** are related, but they refer to different aspects of Earth's atmosphere. Weather refers to the short-term conditions outside, like what's happening today or tomorrow. Weather includes things such as temperature, precipitation (rain or snow), wind speed, and cloudiness. When we talk about a sunny day or a rainy afternoon, we are talking about the weather.

Climate refers to the long-term patterns of weather in a specific place over a more extended period, like decades or centuries. It is the expected weather, on average. For instance, a place with hot and humid summers and cold winters has a different climate than a place that is warm all year round, even if one day they have the same type of weather. Weather is what we experience day to day, while climate is the long-term average of weather patterns in a particular area.

People have often innovated to solve problems related to the weather and climate of a place. You might notice climate innovations if you examine the housing, clothing, or daily habits of people in your area.

3. Create a three-column table with your partner like the one shown in Figure 4. Label the columns "Our Climate," "Problem," and "Innovation."

Our Climate	Problem	Innovation

Figure 4: Climate, Problem, Innovation table.

4. Write down the characteristics of the climate in your local area in the *Our Climate* column. Include information on the seasons you have and how your weather might change throughout the year. For example, you might write, "hot summers."
5. Work with your partner to think about any problems created by your climate that need to be solved so people can meet their basic needs. Write any problems you can think of in the *Problem* column. For example, if your climate is very wet, you might have a problem staying dry. Try to identify at least one problem related to each of the different parts of your climate.
6. Read what Mafini says about problems and innovation. What do you want to remember about how Mafini defines innovation?

Mafini says . . .

Innovation is the introduction of a new solution to a problem. Innovation can be the creation or improvement of a product, process, or system to help solve a problem. It can be technological, but it can also be non-technological (such as a new way of organizing things). It can be **incremental**, which means the change happens in small steps over time. It can be **radical**, which means the innovation is a dramatic change from what was there before. People have always innovated in different ways to solve their problems.

7. For each problem you listed in your *Problem* column, think about what you do or use to solve that problem. Write or draw your ideas in the *Innovation* column. For example, if you have trouble staying warm you might wear warm clothing or go inside an insulated, heated building to keep warm. Warm clothing, heating, insulation, the building, and even the behavior of going inside are all innovations that people created.
8. With your partner, pick one of the problems and related innovations you listed.
9. As a pair, you will act out the problem and innovation without speaking, while the rest of the team guesses what you are doing. One person should act out the problem. The other person should act out the innovation. For example, maybe one partner acts out the climate problem of being cold and the other partner acts out the innovation of wearing a coat.
10. Pick one pair to start. Whoever guesses the problem and innovation they are acting out will be the next pair to act out their problem and innovation.
11. Keep acting out problems and innovations until every pair has had a chance.
12. Discuss as a team:
    a. Are there things you hadn't previously thought of as an innovation?
    b. Were there any situations where the same problem was solved by different innovations?
    c. How do you think life for people might have been different before each innovation?
13. Read *Climate Change Problems* and consider the major problems created by a changing climate in your area.

Climate Change Problems

People have always innovated to meet our basic needs while living in different climates. There are some natural climate variations every year, and over the course of thousands of years the global climate changes very slowly.[1]

However, we currently live in a time of rapid **climate change**.[2] Climate change is changes in the patterns of temperature and precipitation on Earth. In Task 2 you will explore more about the causes of this rapid climate change. For right now, you will think about any problems caused by a changing climate in your area.

Communities across the globe often face problems related to climate-related events, such as the ones shown in Figure 5. In many cases, these climate-related events are becoming more frequent or severe because of climate change. Some events are sudden, such as **typhoons** (also called hurricanes or cyclones), severe storms, floods, and **wildfires**. Other events are slower, such as heat waves, **droughts**, melting glaciers, coastal erosion, and **sea level rise**.[3]

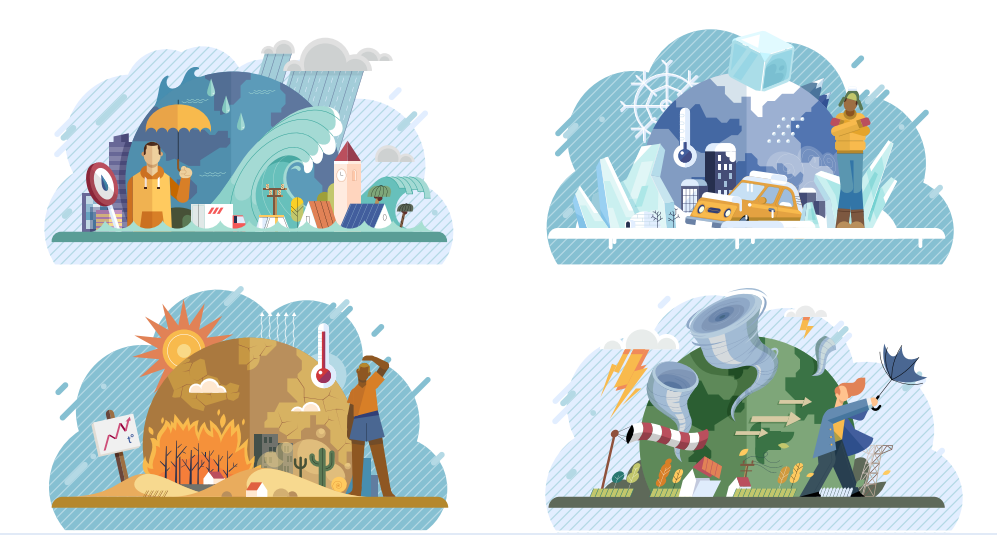


Figure 5: Climate-related events.

⚠ Emotional Safety Tip

Thinking about problems related to climate-related events might feel stressful. However, recognizing the problems we face can help us find ways to solve them. You are not the only innovator working on this. Scientists, engineers, and others around the world are also working hard to solve climate-related problems.

14. Add a new row in your *Climate, Problem, Innovation* table. This row will show future climate, problems, and innovations.
15. In the *Our Climate* column, write down how you believe the climate in your area is changing or will change in the future due to climate change.
16. In the *Problem* column, write down any new or different problems that might happen in your area related to climate change. These could include things you have seen in the news, heard from others, or faced yourself. For example, maybe your area is experiencing more severe floods, wildfires, or heat waves. For right now, do not worry if you are unsure whether a change is caused by climate change. Just do your best. You will learn more about the specifics of the climate change problem in Task 2.
17. Discuss as a team, what new innovations do you think the changing climate requires? If you can think of any, write them down now in the *Innovation* column.

Act: *How can we innovate for a sustainable future?*

Innovations can be newly invented objects, but innovations can also be new methods or ways of doing things. People can have different motivations or reasons for innovating. In this activity you will think about the reasons people might want to innovate for a better climate future.

1. Examine your *Identity Map* from the Discover activity. Is there anything from your identity that makes you interested in innovating for a better future?
2. Read *The Four Perspectives*. Which perspectives do you often use when thinking about the problems related to the changing climate?

The Four Perspectives

Climate can affect communities in different ways, and people may focus on different effects, depending on their perspective. A perspective is the way we think about the world around us. People with different motivations may be using different perspectives. In this guide you will use four different perspectives to help build a broader understanding about situations or problems.

- **Social** is about the interaction of people in a community. This perspective focuses on the health, education, cultural and community ties, and well-being of people.
- **Economic** is about money, income, and use of wealth. This perspective focuses on economic growth, including making sure people have jobs and enough money.
- **Environmental** is about the natural world. This perspective focuses on protecting living things, natural systems, and Earth itself.
- **Ethical** means that something is fair. This perspective focuses on doing what is right and having a community where everyone and everything is treated fairly.

3. Break into four groups and assign each group one perspective—social, environmental, economic, or ethical.
4. With your group, think about the motivations to innovate from your assigned perspective. Use the questions listed under your assigned perspective in the *Climate Innovation Motivations* box to help you start thinking. You can use the current and future problems you wrote on your *Climate, Problem, Innovation* table to get you started.

Climate Innovation Motivations

An **innovation motivation** is your why, the reason you create an innovation. Sometimes motivation comes from concerns about something, such as worrying about the **impacts** of climate change. Other times motivation comes from hopes for a better future.

Social

Consider the climate change problems you wrote in your *Problem* column. How could those problems affect the health, education, cultural and community ties, and well-being of people? What are the social hopes people have for the future? For example, are people motivated by:

- People's health or safety?
- Shared spaces, such as schools or hospitals?
- The ways people interact with one another or maintain cultural ties?

Environmental

Consider the climate change problems you wrote in your *Problem* column. How could those problems affect the Earth and its natural systems? What are the environmental hopes people have for the future? For example, are people motivated by:

- The continued health and well-being of other living things besides people?
- Changes in ecosystems or habitats?
- Sustainable relationships with **natural resources**, such as land and water?

Economic

Consider the climate change problems you wrote in your *Problem* column. How could those problems affect money, income, and use of wealth? What are the economic hopes people have for the future? For example, are people motivated by:

- Economic damages caused by increasing natural disasters?
- Property damage or increasing insurance costs?
- Changes to businesses, trade, or job markets?

Ethical

Consider the climate change problems you wrote in your *Problem* column. How could those problems affect fairness and justice? What are the ethical hopes people have for the future? For example, are people motivated by:

- Problems that challenge one group more than another?
- Making sure all voices are heard?
- Creating solutions that benefit everyone?

5. With your group, take out a piece of paper and label it with your assigned perspective and the word "Motivation."
6. Use the paper to create a poster to show the hopes and concerns related to your assigned perspective that might drive people to innovate. You can draw, use pictures, or create a digital poster. If you prefer, you can also use methods such as creating an infographic, a short film, or another method to communicate your information.

7. Place the four posters from the four perspective groups around the room.
8. Move around the room and examine each poster.
9. Come back together as a team and discuss:
    a. What climate innovation motivations had you not thought about before?
    b. Why do you think it is important to consider all four perspectives when thinking about the problems related to climate change and the innovations people need?
10. Come back together with your perspective group and read *The Sustainable Development Goals*.

The Sustainable Development Goals

Balancing perspectives on what is important and how to solve problems is complex. However, since we all share the same planet, it is important for us to work together to find a future that is **sustainable**. Sustainable means an approach that balances different perspectives and can keep working for a long time. We need a future that is sustainable for people and our planet. A sustainable future will require collaboration between many people.

One example of how people around the world are collaborating to work toward common goals is a group of global goals called the **Sustainable Development Goals**, or SDGs.[4] The SDGs are shown in Figure 6. They are global goals for the future designed by people across the world[5] and the countries of the United Nations.[6] The United Nations, also called the UN, is a global organization designed to help governments and people around the world collaborate.

You may notice that only SDG 13 is about taking action on the climate. But really all of the SDGs are linked to problems related to climate change. Now you will be thinking more about these connections.

Figure 6: United Nations Sustainable Development Goals.

11. With your perspectives group, examine the climate innovation motivations you listed on your poster.
    a. How do each of the motivations you listed relate to the SDGs shown in Figure 6? For example, if you listed flooding of schools in your area as a concern, that might relate to SDG 4, SDG 11, and SDG 13.
    b. Beside each innovation motivation, write or draw the SDG numbers or symbols that relate to that problem. Try to identify as many connections as possible.
12. Tape your four posters from step 6 to the edge of a blank piece of paper, as shown in Figure 7.

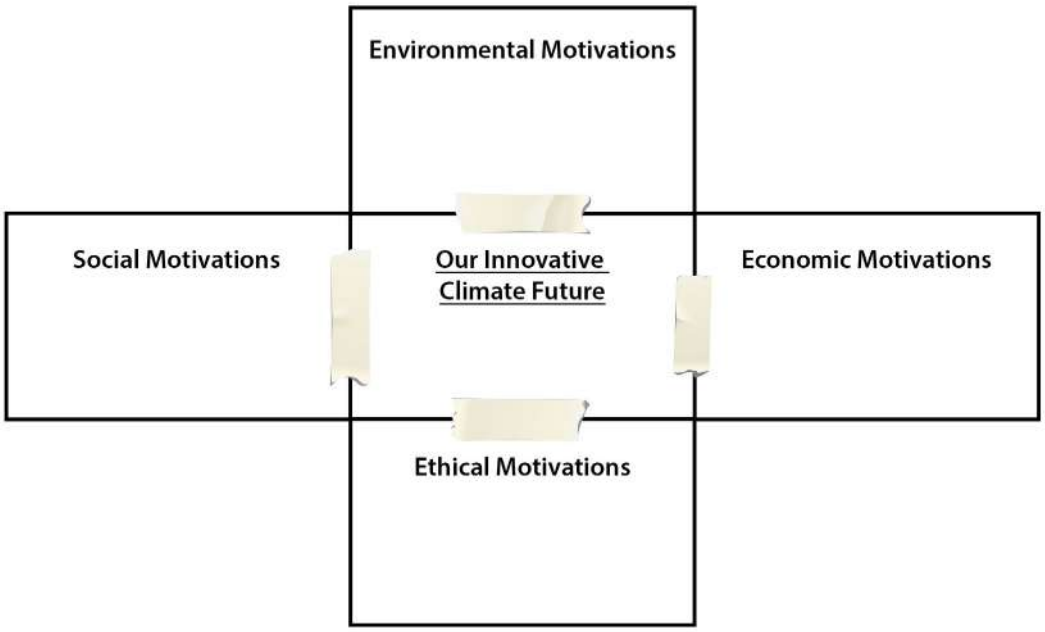


Figure 7: Example of an Our Innovative Climate Future document with four perspective posters attached.

13. Title the blank paper "Our Innovative Climate Future." Your team will now collaborate to envision a positive climate future.
14. Imagine quietly to yourself:
    a. What would life be like if the problems you identified on your poster or the problems shown through the SDGs were solved in a sustainable way?
    b. Pick one problem represented that is important to you.
    c. Think of an image that represents an innovation to help solve that problem. Do not worry whether you think that solution is likely. Right now it is time to dream.
    d. Create that image either by drawing, painting, using a digital tool, or finding a photo that shows your idea.
15. Have each team member add their image to the *Our Innovative Climate Future* paper.
16. After everyone's images are added, examine the *Our Innovative Climate Future* together. Discuss:
    a. What makes you feel hopeful?
    b. How do you think innovation will play a role in achieving those hopes?

17. Read Mafini's thoughts about the role innovation will play in achieving a better future. What do you think is exciting about innovating for the future?

Mafini says . . .

Innovation is everywhere and everyone can innovate. Innovation shapes our present and it paves the way toward possible futures. Innovation contributes to solving our daily and long-term challenges in domains such as learning, mobility, health, food, poverty, energy, production, business, trade, defense, employment, justice, and the environment. Innovators drive impact within and beyond borders by tackling specific or common challenges faced by people, communities, economies, and our planet.

Find out More!

For additional resources, activities, and innovation examples, please visit the *Innovation!* StoryMap at https://s.si.edu/InnovationGuide.

Meet Your Research Mentor

Meet Dr. Peter Desmond. Peter (pronounced PEE-ter) will be your research mentor for Task 2.

Peter is an assistant professor in sustainable development at Hamad Bin Khalifa University in Qatar and a research group leader at RWTH Aachen University in Germany. Peter's work focuses on the interface between water infrastructure, climate resilience, and sustainable technology adoption in rapidly developing urban environments.

Peter's Identity Map

- Places that shaped me: Ireland, Switzerland, and Qatar
- Faculty at Hamad Bin Khalifa University
- Member of the Royal Dublin Society in Ireland
- Uses photography to see shape, space, and meaning
- Believes education is one of our greatest tools for change
- Believes science and the arts are partners in understanding
- Believes that education can cultivate empathy
- Is drawn to experiences outside his formal work
- Enjoys the arts, visual narrative, and architecture
- Researches sustainable development
- Works on water systems, climate adaptation, and design
- My sense of home lives in shared values and relationships

Before you begin Task 2, think quietly to yourself about Peter's identity map.

- Are there things you have in common?
- Are there ways in which you are different?

Throughout this task Peter will share ideas with you. These ideas might give your team new information or help you think of ways to investigate your community.

Task 2: How can we innovate?

Innovations can help solve many different problems. As you learned in Task 1, throughout history humans have been innovating to solve problems related to the climate, from keeping warm by building fires to using umbrellas to keep dry. In this guide you will learn about the process of innovation to help solve the problem of climate change.

In this task you will first ***discover*** more about the problem and causes of climate change. Then you will investigate to ***understand*** more about the process of innovation. Finally, you will ***act*** by defining more about the climate change problem in your community.

Discover: *What is causing climate problems?*

To solve a problem, you usually need to understand it. The problem of climate change is **complex**. This means there are many different parts that relate to one another in complicated ways. There are multiple factors causing climate change. There are multiple consequences of climate change. This also means there can be many different solutions.

In this activity you will be examining climate-related problems and analyzing the causes of those problems. After this analysis you will be prepared to share the story of climate change. Scientists study many factors that can influence climate, and you will explore some of the scientific explanations behind climate change problems.

1. As a team, pick one problem related to climate change that you think affects the people in your community. For example, you might choose property damage from extreme storms or wildfires, health challenges due to increasing heat waves, or flooding or drought affecting agricultural lands.[7] You may want to use one of the problems you identified in Task 1.
2. As a team, read *Telling the Whole Story Instructions* and do the activity.

Telling the Whole Story Instructions

When you think about a problem such as climate change, there are often immediate causes for some of the related community problems. For example, a hurricane might cause people to be injured. The hurricane is the immediate cause of the injury. But what are the causes of the hurricane?

Thinking beyond immediate causes can help you make sure you don't miss part of what is causing the problem. This activity is about understanding the whole story of the problems related to climate change and what is causing them. You may not know about all the causes and effects of this problem yet. That is okay. Just do your best and you will have a chance to correct any mistakes you made later.

a. Put five chairs together, or if it is difficult to move around, you can do this activity from where you are already sitting or standing.
b. Choose one person and have them sit in the first chair in the line. This person says, "The problem is . . ." and then states the problem your team has selected. For example, "The problem is many people have lost their homes."
c. As a team, discuss why you think this problem is happening. For example, many people may have lost their homes because they were burned by a wildfire. This is the cause or the reason for the problem.
d. Choose one person to sit next to the first person and tell the story, starting with the problem and then sharing the cause. For example:
    - Person 1: "The problem is many people have lost their homes."
    - Person 2: "They lost their homes because of wildfires."
e. As a team, discuss why the cause presented by Person 2 is happening. For example, perhaps wildfires are becoming more common because there are frequent droughts. Sometimes there may be multiple reasons for a problem. For this activity, try to choose a reason related to the climate and climate change.

f. Choose a third person to sit next to the first two, and then tell the entire story in order, starting with Person 1, then going to Person 2, and ending with Person 3. Using the previous example, Person 3 might say, "One reason the wildfires happened was because of increasing drought."
g. Continue asking the reason for problems, adding people to the line, and building the story until you feel you have gotten the whole story. Keep adding more chairs to the line, if you need to.

3. Come back together as a team and discuss:
   a. What are some of the causes of climate change problems?
   b. A **root cause** is an underlying reason for a problem. What do you think are some of the root causes of climate change problems?
4. As a team, follow the instructions in *Analyzing the Climate Change Story*.

Analyzing the Climate Change Story

You will now use a card-sorting activity to analyze the story of the relationship between people and climate change. Stories can be imaginary or they can be based on facts and evidence. This story of climate change is based on facts and evidence. If you want to understand more about the evidence, you can read about the scientific evidence in the documents listed at the end of each task in the endnotes (linked to the little numbers found throughout this guide). It is important to think critically about the whole story, what is causing changes, and what are the effects of those changes.

In the climate change story, there may be a few words that you are unfamiliar with. These words will help you understand the whole story.

- **Atmosphere** means the mixture of gases that surround Earth.
- **Greenhouse gases (GHG)** are gases, such as carbon dioxide and methane, that trap heat and cause atmosphere to warm.
- **Emissions** are things released into the atmosphere.

Getting Ready

Print and cut apart the *Climate Change Story Cards* in Figure 9. Separate the blue cards and white cards. Separately shuffle both sets of cards. The blue cards show major parts of the climate change story, including root causes, intermediate causes, and impacts. The white cards show details or aspects related to those parts of the story.

Make a Choice

There are two ways to complete this activity. Choose the one that works best for your team.

- If you have a smaller group or cannot move around, you can sort the cards on a tabletop. Use the *Tabletop Sorting* instructions.
- If you have a larger group or want to move around, you can sort the cards through movement. Use the *Movement Sorting* instructions.

Tabletop Sorting

Spread the five blue cards representing the parts of the climate change story face up across the top of the table. As a group, decide on the order you think these cards should go in. You can use the ideas from your *Telling the Whole Story* activity to help you think about the order.

Next, make a pile with the shuffled white cards and take turns picking from the pile. After you pick a white card, sort it by placing it near the blue card that you think it relates to. Figure 8 shows an example. If other members of your team disagree, try to discuss and reach consensus. Consensus is a balanced decision that works for everyone in the group.

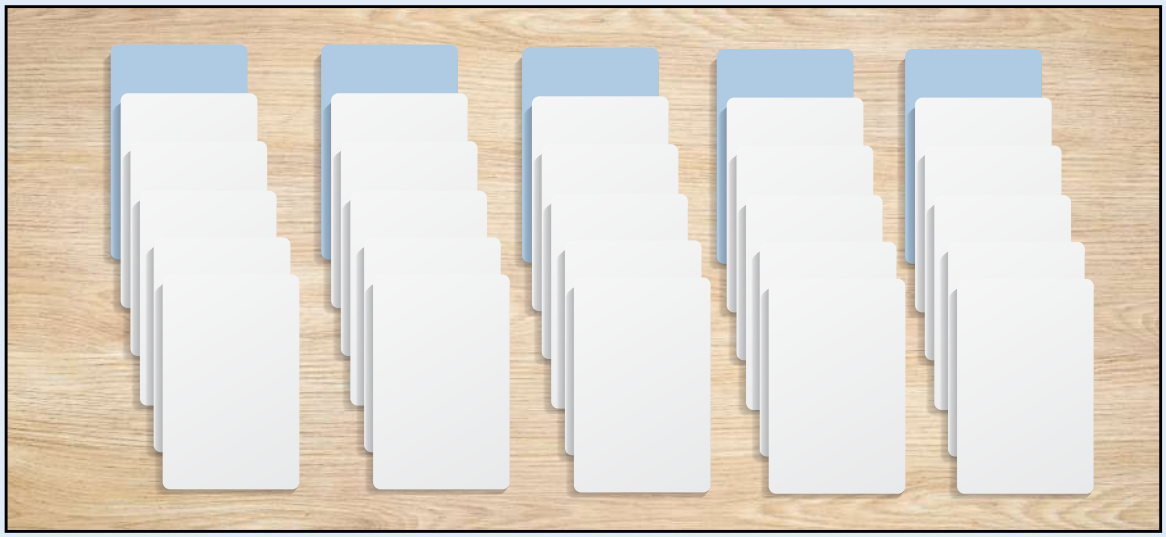


Figure 8: Example of a tabletop sorting setup.

Movement Sorting

Give five members of your team the five blue cards representing the climate change story parts and have them read their cards aloud. As a group, decide on the order you think these cards should go in. You can use the ideas from your *Telling the Whole Story* activity to help you think about the order. Move the people with the blue cards to different areas of your learning space.

Distribute the shuffled white cards to other team members. If there are more cards than team members, have team members start with one card and come back for more. If there are more team members than cards, you can pair two team members with one card.

Take your white card and move around to the different climate change story part areas. Try to match your white card with one of the blue card categories. When you arrive, find consensus with the team member holding the blue card about whether your white card should be sorted into that blue card part of the climate change story. Move around until all the cards have been sorted.

Check Your Answers

When you have finished grouping and ordering, you can use the groupings shown in Figure 9 to check your answers about which white cards go with which blue cards.

5. Check your answers.
   a. Are your white cards sorted into the same blue card categories as shown in Figure 9?
   b. Do you disagree with any of the ways the cards in Figure 9 are sorted? That is okay. People sometimes think about things differently. The important thing is to understand all the parts of the climate change story, from human behaviors to impacts on living things, including humans.

Human Behaviors[8]	People choose to use motorized transportation.	People make choices about the type of food they eat and how to produce that food.	People's habits create waste.
People choose the type and amount of products they use.	People choose to use electricity.	People choose to heat and cool buildings.	People make choices about whether to build on land, use it for agriculture, or leave it wild.

Producing Emissions[9]	Power plants generate electricity by burning coal, oil, and natural gas. This releases carbon dioxide, methane and other GHG.	Industrial production processes, such as cement production, release carbon dioxide and other GHG.	Landfills produce methane and other GHG.
Buildings are heated and cooled by burning natural gas and petroleum, releasing carbon dioxide, methane, and other GHG.	Vehicles such as cars, trucks, and planes burn gasoline and diesel fuel, releasing carbon dioxide and other GHG.	Livestock farming and other agricultural practices release methane and other GHG.	Deforestation releases carbon stored in trees and soil, releasing carbon dioxide and other GHG.

Figure 9: Climate Change Story Cards. (continued)

Changes to the Atmosphere[10]	Atmospheric carbon dioxide has increased 51% (from pre-1750 to 2023).[11]	Atmospheric GHG have increased. These gases absorb and radiate heat energy, warming the global temperature.	Natural removal of atmospheric carbon dioxide is limited by deforestation and other land use changes.[12]
Atmospheric warming: 2024 was the warmest year on record, 1.46°C (2.63°F) higher than pre-industrial times.[13]	Atmospheric methane has increased 165% (from pre-1750 to 2023).[14]	The annual rate of increase in atmospheric carbon dioxide over the past 60 years is over 100 times faster than previous natural increases.[15]	The surface ocean has absorbed around one-quarter of all human-created carbon dioxide emissions.[16]
Changes to the Climate[17]	More hot days and more heat waves	More extreme precipitation events, drought in some areas, flooding in others	More wildfires due to drought
Ocean acidification (changes in ocean chemistry due to increasing dissolved carbon dioxide from the atmosphere)	More frequent and severe storms, including hurricanes and typhoons	Decreased snowpack and ice coverage, and melting permafrost	Sea level rise due to melting ice and thermal expansion (increase in water volume due to heat)

Figure 9: (continued)

Impacts on Communities[18]	Health threats from heat-related illnesses and increased spread of some diseases	Threats to food systems because of increased heat, flooding, and drought	Threat of decreased access to clean water due to changes in precipitation
Threats to marine life and fishing economies from ocean acidification	Threats to health, life, and property because of disasters such as storms, floods, and wildfires	Threat of biodiversity loss and migration due to climatic changes and potential collapse of ecosystem food webs	Threats to human property, cultures, and communities as sea levels rise

Figure 9: (continued)

6. Discuss as a team:
   a. Are there missing parts or other aspects you would want to add to these climate change story parts?
   b. How do the climate change story parts and the related aspects connect to what you discussed during the *Telling the Whole Story* activity?
   c. Is there anything you would you want to change about the way you originally told the story of climate change in the *Telling the Whole Story* activity?
7. Read how research mentor Dr. Peter Desmond describes the climate change story. Does his description add any important information to your understanding of the climate change story?

Peter says . . .

Climate change is the story of how our behaviors—how we produce energy, grow food, and build cities—translate into greenhouse gas emissions that alter the composition of our atmosphere. These atmospheric shifts disrupt climate systems, intensifying heat waves, sea level rise, and extreme weather events. The result is a cascading impact on communities, ecosystems, and economies across the globe.

8. Follow the instructions to *Represent Your Climate Change Story*.

Represent Your Climate Change Story

You will follow and innovate on the climate change story throughout this guide. As a reminder, the parts of that story are:

Human Behaviors → Producing Emissions → Changes to the Atmosphere → Changes to the Climate → Impacts on Communities

Figure 10: Parts of the climate change story.

Now you will create a representation to help you remember the different parts of the story.

a. **Decide on the size of your groups.** You can do this activity as a whole team or break into five smaller groups. If you break into five smaller groups, assign each group one part of the climate change story (the blue cards).
b. **Choose what is most important.** For each part, think about the aspects of that part of the climate change story that are most related to your community and are important to you. These can be aspects that were part of your *Analyzing the Climate Change Story* activity or other aspects that you thought of yourself.
c. **Decide how you want to represent the climate change story**. If you create a visual representation, title it "Climate Change Story." There are many possible ways to represent the story, for example, you could:
   - Create one poster for each part
   - Create a comic showing the progression between parts
   - Create a picture book showing the parts
   - Write a poem with five parts
   - Create a short film or animation
   - Create a play or musical number
   - Come up with another idea that works for your team

9. Share your *Climate Change Story* with each other and with others around you. If it is a visual story, post it in your learning space. As you think about the story, consider how it could be different.
   a. What changes or innovations for each part could make the story different?

Understand: *How can we innovate to solve problems?*

The process of innovation can help support people who want to create new approaches or ideas. Although each problem is unique, the innovation process is a predictable way to move from identifying a problem to putting a solution into practice. In the Discover activity you explored the many aspects of the problem of climate change. In this activity you will learn more about the process of innovation and how it can help you solve problems.

1. Turn to a partner and discuss the steps you can think of that are often used to solve a problem. Don't worry if you don't think you know all the steps. This activity will help you learn more.
2. Follow the instructions in *Observing Innovation in Action* to innovate and observe more about the process of innovation.

Observing Innovation in Action

Setup and Materials

Move two desks or tables around 30 centimeters (12 inches) apart.

Gather your materials. You will need:

(For Innovators)

- Two tables or desks
- A small ball such as a marble, bouncy ball, or table tennis (ping pong) ball
- Several pieces of paper
- Timer
- Connecting materials such as rubber bands, tape, paper clips, or staples (optional)
- Other building materials such as popsicle sticks, toothpicks, or cardboard (optional)
- A video recording device such as a camera or smartphone (optional)

(For Observers)

- Something to take notes on, such as paper and pencil, a whiteboard, or a computer

Innovators and Observers

In this activity there are two roles: innovators and observers. The innovators will be trying to solve a problem. The observers will observe the process of innovation and take notes.

Make a Choice

You can either make a video or film recording or you can divide your team into two groups, one for each role.

If you make a recording, your team will first record yourselves completing the instructions for innovators. Then you will watch the recording to complete the instructions for observers.

If you do not have access to a recording device, divide your team into two groups: innovators and observers. Follow the instructions for either observers or innovators, depending on the group you are in. Have observers read both sets of instructions first. Then give the innovators the innovator instructions to read. After completing the activity, you can switch roles if you have time.

Innovator Instructions

The problem you are trying to solve is: How to get the ball from one table or desk to the other without carrying, throwing, or bouncing it.

- As a group, you have seven minutes to find the best way to build a bridge between the two tables or desks.
- You can use any materials available.
- You can try as many solutions as you want. You can also modify a solution to make it better.
- At the end of seven minutes, you will demonstrate your solution to the observers. Or, if you are recording, you will watch your recording.
- Start the timer now and, if you are recording, start your recording.

Observer Instructions

From the time the innovators get their instructions, observe them closely. Or, if you are watching a recording, observe the recording. Make notes about what you notice people are doing to try to solve the problem. Pay particular attention to whether you observe any of the following parts of the innovation process.

- Defining or trying to understand the problem of moving the ball from one table to another
- Coming up with a variety of ideas
- Choosing an idea and creating a design
- Experimenting or making a model or sample to test whether it works, and then improving it
- Putting the solution onto the tables or desks and changing it according to what they learn
- Using the solution and monitoring to make sure it continues to work

3. Discuss the innovation process as a team.
   a. First think about the innovators. Share what you felt went well and what they would want to improve in the future while innovating.
   b. Next think about the observers. Did you notice different steps or stages of the innovation process? Were there any steps or stages that were missed but could have been helpful?
4. As a team, examine Figure 11, which shows a graphic of the innovation process. Do you recognize anything the innovators did as they tried to solve their problem?

Figure 11: Graphic showing the process of innovation.

5. Read *The Process of Innovation* and discuss as a team why you think following a process might be helpful when innovating.

The Process of Innovation

Sometimes it might seem as if problems are solved through brilliant ideas that come out of nowhere. But that is rarely the case. Innovation often builds on the knowledge and ideas of others and on previous attempts to innovate. In this guide, we will break down innovation into six main steps.

1. **Define the problem:** Decide on the problem you are trying to solve. Then work to understand the problem by gathering more information on what is already known about the problem, the causes of the problem, and its impacts.
2. **Generate ideas:** Come up with a variety of different ideas that might help solve the problem. These ideas might be totally new or could be small changes to existing approaches.
3. **Select a solution:** Choose the best idea to move forward with, based on what you know about the problem. This might not be the final solution, but it is the most promising one based on what you currently know.
4. **Experiment and prototype:** Conduct experiments and use results to help you create a **prototype**. A prototype is an early model or sample of a product. Test the prototype, review results, and revise it to be more efficient and effective, based on those tests.
5. **Field test:** Test the solution in real-world contexts. Pay close attention to the results of this trial and then **iterate** or improve the design based on those results.
6. **Launch and monitor:** Finalize and **launch** or share your innovation widely. Continue to monitor the effects and respond to any areas for improvement.

6. Create a graphic for your team to remind yourselves about the process of innovation. Title it "Innovation Process." Examine Figure 11 for inspiration. Think together as a team:
   a. What pictures or drawings would help you remember the process?
   b. Do you think the process should be shown as a line, a circle, a pyramid, or another shape?
   c. What colors do you think you should use?

7. Post your *Innovation Process* in your learning space to help you remember the six steps of the innovation process.
8. Peter leads a team of innovators. Read what he says about the innovation process. Why does he think it is important?

Peter says . . .

Innovation without process is improvisation. In the face of climate change, we don't have the luxury of trial and error. A structured innovation process is essential—it creates the pathway for turning ideas into actionable solutions, for aligning science with community needs, and for scaling what works. It is the process that transforms innovation from a concept into climate resilience on the ground.

Act: *How will we be innovators in our community?*

You have learned about the problem of climate change. You have also learned about the process of innovation and how it helps solve problems. Throughout this guide you will be using the process of innovation to think about the problem of climate change.

1. Take out a big piece of paper, use a class board, or open a digital document. You will now create your team's *Climate Innovation Organizer* that you will use throughout the guide. Be sure to create the organizer in a place where your team can continue to refer to it and add to it as you use the guide.
2. Create six columns and seven rows for your *Climate Innovation Organizer*.
3. Title the columns with the parts of the climate change story you learned about in the Discover activity.
4. Title the first blank row "1. Define the Problem." The rows will show different stages in the innovation process. Figure 12 shows an example. Leave the additional five rows blank for now.

	Human Behaviors	Producing Emissions	Changes to the Atmosphere	Changes to the Climate	Impacts on Communities
1. Define the Problem	Group 1	Group 2	Group 3	Group 4	Group 5

Figure 12: Climate Innovation Organizer.

5. Divide your team into five groups and assign each group one part of the climate change story: Human Behaviors, Producing Emissions, Changes to the Atmosphere, Changes to the Climate, or Impacts on Communities. Figure 12 shows where each group will write their answers.
6. Read *Defining Climate Change Problems* and follow the instructions.

Defining Climate Change Problems

Define the Problem

Define the problem: Decide on the problem you are trying to solve. Then work to understand the problem by gathering more information on what is already known about the problem, the causes of the problem, and its impacts.

As a group, you will now explore how defining the problem relates to your part of the climate change story.

a. Take out the *Climate Change Story Cards* from the Discover activity. Use the white cards related to your part of the climate change story.
b. Decide which of the aspects listed on the white cards are important to include when you are trying to understand problems related to your climate change story part. You can also add additional aspects of the problem, if you want.

c. Based on these aspects, create a one- to three-sentence summary defining the problem of your climate change story part. Add this summary in the appropriate column in the *Defining the Problem* row of your *Climate Innovation Organizer*.

d. Discuss as a group what other information you would want to have about this problem before trying to solve it. This might include information related to the four perspectives, such as:

- Social: Information about human systems and behaviors related problems you listed
- Environmental: Information about natural processes related to problems you listed
- Economic: Information about money and costs related to the problems you listed
- Ethical: Information about how problems you listed might affect people differently

e. Think about where you might be able get this information. For example:

- Places: You might be able to find some of this information through government or organization websites, in scientific articles, the library, or other places. Be as specific as possible when you are listing places where you might find information.
- People: There are many people who might have the information you want.
    - Natural scientists, such as people studying living things, the atmosphere, the weather, and other Earth-wide systems
    - Social scientists, such as people who study history, human behavior, communication, and the way societies work
    - Community members, such as people working in local organizations, environmental groups, people who have lived in your community for a long time, and community leaders
    - Or others, you know your community best!

7. Have each group present what they listed in their *Define the Problem* summary and then share a few examples of other information they would like to have and some ideas about the best sources of that information.
8. Discuss as a team: You have just taken the first step toward defining a problem.
    a. Why do you think defining the problem is an important first step of innovation?
    b. What issues do you think might come up if you skipped this step?
9. Think about the problems your group and other groups listed. Which one would you be most interested in trying to innovate to help solve? Why?
10. Turn to a partner and share your answer. Listen carefully as your partner shares their answer. In this guide you will be exploring different parts of the climate change story and different steps in the innovation process. At the end of the guide you will have a chance to pick one problem and work on an innovation based on everything you have learned.
11. Keep your *Climate Innovation Organizer*. You will use it throughout this guide.
12. Read Peter's ideas about how defining the problem is the first step in solving it. What does he share that you want to remember?

Peter says . . .

The first step in solving any problem is understanding it. Defining the problem clearly is what anchors innovation; it ensures we're solving the right challenge, not just the most obvious one. When it comes to climate change, the issues are deeply interconnected, so clarity at the start is essential for impact later. What I want young people to remember is this: Innovation isn't just about inventing new things—it's about asking the right questions, listening deeply, and designing with purpose. That's how we build a future that's not just sustainable, but resilient and just.

Find out More!

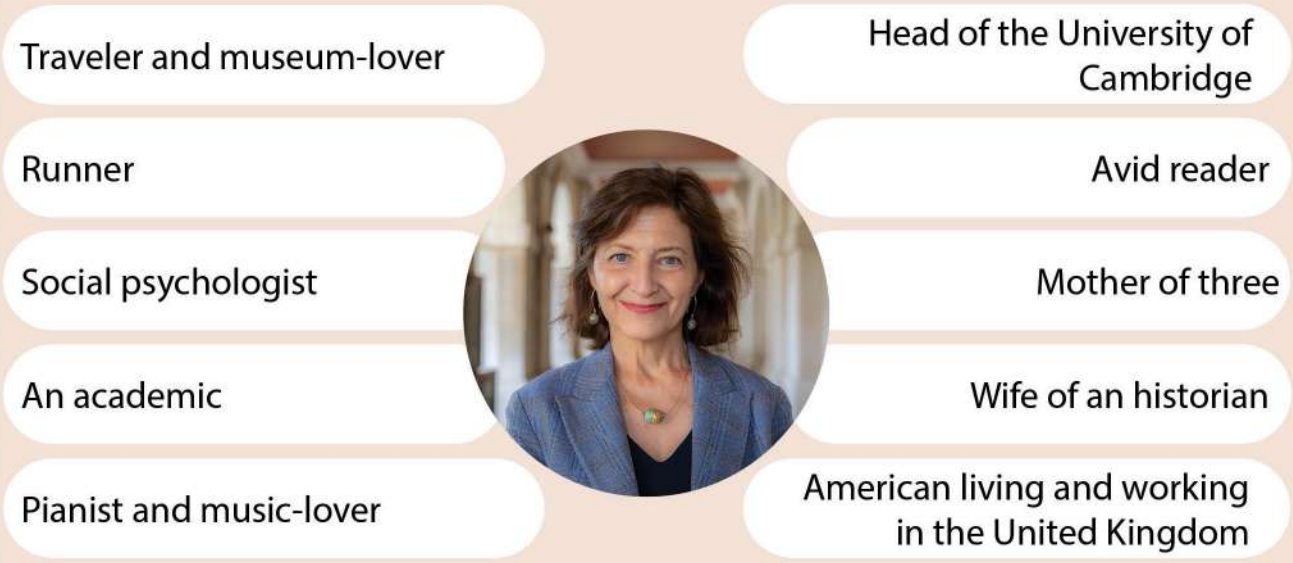
For additional resources, activities, and innovation examples, please visit the *Innovation!* StoryMap at https://s.si.edu/InnovationGuide.

Meet Your Research Mentor

Meet Dr. Deborah (Debbie) Prentice. Debbie (pronounced DEH-bee) will be your research mentor for Task 3.

Debbie is the vice chancellor of Cambridge University in the United Kingdom and a professor of social psychology. She studies **social norms** and how they affect human behaviors and experience. Debbie believes that understanding social norms provides a key to unlocking widespread behavior change.

Debbie's Identity Map



Before you begin Task 3, think quietly to yourself about Debbie's identity map.

- Are there things you have in common?
- Are there ways in which you are different?

Throughout this task Debbie will share ideas with you. These ideas might give your team new information or help you think of ways to investigate your community.

Task 3: How can we think of new ideas when innovating?

The climate change story starts with human behaviors and activities.[19] People's habits, lifestyles, and the ways we are currently meeting our needs are causing our global climate to change rapidly. In this task you will ***discover*** more about this change over time. Then you will generate ideas to help you ***understand*** the second step in the innovation process (shown in Figure 13). There are many innovative ideas that can help us respond to these changes.

Figure 13: This graphic of the innovation process highlights Step 2: Generate Ideas.

*Finally, you will **act*** by becoming a **trendsetter** for more climate-friendly behaviors. A trendsetter is someone who starts or helps popularize a new way of doing things.

Discover: *How have human behaviors changed over time?*

Lifestyles have changed a lot. In the past, people did things and used resources differently. For example, if you think back 150 years, no one had electricity in their home. Even today, people in different places and different situations often have very different daily habits or ways they meet their needs. Many groups experience **trends** or shifts in popular behaviors or fashions. Sometimes these shifts last just a few months or years. Other times, the shifts can last a long time. Sometimes shifts can help the planet; other times they can hurt it.

1. Turn to a partner and discuss the way you have seen trends change during your lifetime. For example, think about changes in what people wear, what they eat, how they communicate, the technology they use, and what they do with their time.

a. What are a few things that are popular or trendy now?
b. Can you remember other trends from three years ago? Five years ago? Longer?
c. Which current trends do you think will last only a short time and which do you think will last longer?

2. As a team, come together and share some of the trends you have experienced that you think will be most long-lasting. Discuss:
   a. Which trends are associated more with a specific group—such as people of a particular age or place?
   b. Which trends are affecting the whole planet—such as using social media?
   c. Which trends do you think have increased or decreased the amount of resources we use?
3. Read what research mentor Dr. Deborah Prentice explains about trends and social norms. Social norms are ideas or ways of behaving that are generally acceptable in a particular place. What do you think are some of the social norms around resource use in your community?

Debbie says . . .

A trend is something that you notice changing—usually increasing over time. A social norm is a trend that sticks. Social norms are the characteristic behaviors, attitudes, and beliefs you notice in a particular group or community. They are the things that everybody seems to do, the things that everybody knows, the things that everybody cares about. Whether you are aware of it or not, you are probably noticing regularities in what other people think, feel, and do all the time. These regularities are social norms.

4. Divide your team into two groups. One group will focus on the current time and the other group will focus on 100 years ago.
5. Remember the *Human Behaviors* from the *Climate Change Story Cards* in Task 2. The related categories are listed here. For each category, have a person from the 100 years ago group share what the common human norms and behaviors were in that category 100 years ago. Then have a person from the current time group do the same for today's

norms and behaviors. For example, for transportation methods: 100 years ago, it might have been more normal to cross an ocean using a ship; currently, it might be more normal to use a plane. You can use words, acting, drawing, or pictures to share your idea. If you are not sure of the answers, just do your best.

a. Transportation methods
b. Electricity use
c. Consumption of products, and shifts to synthetic products such as plastics
d. Food habits and production
e. Heating and cooling buildings
f. Amount of waste produced
g. Land use, such as how much land is built up, how much is used for agriculture, and how much is left wild

6. Discuss as a team, over the last 100 years have social norms changed? Has that led to different behaviors or habits? For example, are there social norm changes that might be related to behaviors that change the amount of greenhouse gases (GHG) produced?
7. Read *Human Behaviors and Climate Change*. You can also break into seven groups and have each group read one section, then come together as a team and share what each group has learned. Did you expect how human behaviors might be contributing to GHG emissions and climate change? Are there any surprises?

Human Behaviors and Climate Change

Sometimes it can be hard to know which behaviors might be related to increased production of greenhouse gases (GHG) and climate change. Even small behavior changes can add up over time, when many people are involved. Use these descriptions to discover more about the link between human lifestyles and GHG production.

Transportation Methods

More than one billion passenger cars are registered around the world.[20] Currently, most vehicles, including many motorcycles, cars, trucks, and airplanes, use gasoline (petrol) or diesel for power, although there are increasing

numbers of electric vehicles.[21] Gasoline (petrol) and diesel are usually created from petroleum (oil), a fossil fuel. Gasoline and diesel produce GHG when burned to create power.

Electricity Use

Globally, 60% of electricity[22] is produced using fossil fuels, which generate GHG. Between 1965 and 2023, global electricity use per person increased by 64%.[23] We use electricity to charge phones and computers, run appliances, provide light, and many other things at home. In addition, electricity is used to produce many of the items we buy.

Consumption, and Shifts to Synthetic Products

People are not just using more electricity. They are consuming more of other products as well.[24] This includes food, clothing, cars, appliances, furniture, construction materials, and beauty products. Producing each item uses natural resources and often also requires energy. In addition, the production of many items, such as plastics and cement, may give off GHG.[25]

Food Habits and Production

What people eat and how that food is produced is changing. Globally, 26% of GHG production is associated with food.[26] Producing certain foods, including meat and dairy,[27] often produces a lot of GHG. The global rise in meat consumption[28] contributes to the rising GHG levels. In addition, farming practices such as overuse of fertilizer and improper manure storage can increase GHG emissions, especially potent GHG gases such as nitrous oxide and methane.[29]

Heating and Cooling Buildings

Around 15% of global carbon emissions come from heating and cooling buildings.[30] As the world's population increases and global temperatures rise, the need to make spaces comfortable for people will likely also increase. Adjusting the need for heating and cooling could involve adjusting expectations about what temperature a living space needs to be kept at, and could also include innovations to building design to make them more naturally

cool or warm. More efficient heating and cooling technologies and technologies that use **renewable energy**, such as **geothermal energy**, can also help regulate temperatures in some places.

Amount of Waste

Each time we throw something away, we also waste the energy and natural resources used to create that item. Increases in consumption lead to increases in waste. Reusing or repurposing items can help reduce the GHG produced when new items are produced. Beyond this, waste itself can also create GHG. In a landfill, waste that comes from things that were once living, such as food, produces the potent greenhouse gas methane.[31] However, if food is composted instead, it can reduce methane emissions and produce new soil. Globally, the average person creates 0.74 kilograms of waste each day, with an average of 44% of that being green or **food waste.**[32]

Land Use

Natural areas, such as forests, are often **carbon sinks.**[33] Carbon sinks are environments or living things that store carbon. Areas such as forests, **mangroves**, wetlands, and soils can store a lot of carbon. Carbon dioxide and other GHG can enter the atmosphere when these areas are disturbed, such as by plowing the soil. GHG can also enter the atmosphere when vegetation is removed, such as by removing trees (**deforestation**). Between 1960 and 2019, land use changes affected almost one-third of the land area on Earth.[34] Growing cities, deforestation, and agricultural expansion all contributed to these changes.

8. Discuss with a partner: How could you learn more about how social norms and human behaviors have changed over time? For example, are there people or places in your community that might help you understand these changes?
9. Have each team member follow the *Oral History Instructions* to understand more about how social norms and behaviors change in your community.

Oral History Instructions

When you talk to people and record information about their past, it is called an **oral history**. Oral histories create a record of what people or communities were like in the past.

If you did not personally experience a change, sometimes you may not even know that things were different. When thinking about how to change human behaviors to reduce the problem of climate change, it can be helpful to talk to someone about changes they have noticed in what is normal or what are the behaviors happening frequently around them. This can help you consider how people may have lived more or less sustainably in the past.

Choosing Your Questions

Ask people to focus on the changes they have witnessed to habits and behaviors in your community. You may want to prompt them by asking about the human behaviors you have been discussing related to:

- Transportation methods
- Electricity use
- Consumption of products and shifts to more synthetic products
- Food production
- Heating and cooling buildings
- Amount of waste
- Land use

What changes has this person noticed and what do they think caused those changes?

Choosing People to Talk to

a. Try to have each team member record one oral history.
b. Think about who might know the most about how your community has changed. For example, it might be people who are part of **Indigenous** groups, older people who have lived in the community a long time, a local historian, people who build new things or tear things down, or leaders who make decisions. (Indigenous means a group of people or other living things that are native to a place and have not migrated from elsewhere.)

c. If possible, include people with a variety of experiences, backgrounds, and perspectives. If you have limited time, it is okay to talk to family members or people you know. Just remember there may be perspectives in your community you are missing by making this choice.

Ways to Record an Oral History

a. You can talk to people in person, over the phone, or using the Internet.
b. You can use audio or video to record an oral history. Or you can write or draw to make a record of the ideas that are shared with you.

Tips for Collecting an Oral History

a. Make sure you ask permission to record a person's answers.
b. Ask permission to share the oral history with the rest of your team, class, or other people in the community. People might be more willing to talk if their oral history is anonymous. Anonymous means you don't include their name.
c. If it feels like someone didn't answer your question, don't be afraid to ask the question again in a different way.
d. Let the person you are talking to answer the questions in the way they want. Be patient. Listen carefully. Understand that they might give answers that you didn't ask for.

Safety Tips for Talking to People

⚠ Physical Safety Tip

Take a partner or adult with you to record an oral history if it is with someone you don't know well. You might want to suggest recording the oral history in a quiet public place. Talk to your teacher for guidelines. They will know what is safest in your community.

⚠ Emotional Safety Tip

It can be hard to talk to other people in the community. You may feel shy or nervous. Someone may tell you they don't want to talk. That's okay! It doesn't have anything to do with you. It just means they don't want to share. You can show them respect by thanking them and moving on to another community member.

10. Come back together as a team and share what you learned from your oral histories. As a team, discuss:
    a. Remember what you learned from the *Human Behaviors and Climate Change* box. Do you think the way people lived in the past produced more or fewer GHG emissions?
    b. What are the major lessons you think people today should learn from the way people lived in the past?
    c. How can we use knowledge of the past to help us generate ideas for innovations we would like to have in the future?
11. By yourself or with a partner, think of one example of a behavior or practice from the past that you think should be brought back as a new norm.

Understand: *What are some ideas of ways to change people's behaviors?*

Innovations sometimes cause changes that are positive for people and the planet. Other times they can cause changes that are negative. Sometimes they have some positive and some negative impacts.

Our current lifestyles and habits may be contributing to the climate problem. But how we live is often a choice. You can probably think of many different choices we could make both individually and collectively. This activity will help you generate ideas about how to innovate in a positive way to shift to more sustainable behavior choices.

1. Pick up any object around you and turn to a partner. Together try to think of as many different uses for the object as you can in one minute. Bad or even silly ideas are fine. Sometimes it is useful to think about ways familiar things could be used differently. There are often many ways to solve a problem. It is important to think about a variety of different ways before making decisions. In this activity you will be thinking about ways to rethink familiar patterns and systems.
2. With your partner, think about a change you have noticed in your community. It could be a new event, a new building, a new technology, or a change in habits. What caused this change?
3. With your partner, read *At the Smithsonian* and consider where in your community you have noticed places of innovation.

At the Smithsonian

What makes communities welcome new ways of doing or thinking? The Museum on Main Street (MoMS), a Smithsonian program that specifically engages small towns, has been collaborating with communities across the United States to answer this question. The traveling Smithsonian exhibition, *Spark! Places of Innovation*, has been installed in libraries, community centers, and schools. The exhibit prompts communities to consider what it takes for a community to be innovative. Almost anywhere and anyone can be innovative. All it takes to start is an idea—a spark!

Figure 14: Spark! features stories from more than 30 rural communities across the nation that reveal the dynamic relationship between place and creativity.

As they have supported communities to tell their stories of innovation, the staff at MoMS have noticed some common characteristics. Innovative communities have creative thinkers and leaders. Innovative communities have a free flow of ideas and a spirit of collaboration. These communities understand that risk is necessary and innovation requires the persistence to fail and try again.

Inspired by *Places of Invention,* an exhibition developed by the Smithsonian's Lemelson Center for the Study of Invention and Innovation, *Spark!* shares examples of many types of community innovation. One type, **social innovation**, is when people in a community reimagine the way they connect with and support one another. For example, in Bethel, Vermont, innovation was based on community responses to questions about the changes they wanted. In Coopersville, Michigan, creating new social events developed a stronger sense of community spirit. In Hillsboro, Illinois, the city council focused on using local resources to help the local economy. In big ways and small, communities can engage in social innovation.

There are other types of innovation as well. **Artistic innovation** can provide creative expressions that encourage individuals and communities think about things differently. **Technological innovation** can help create new products or processes. **Behavioral innovations** encourage people to make different choices. And communities can draw upon their heritage and past to identify and support new ways forward. For every community, telling the stories of innovation can help inspire others to innovate as well.

4. With your partner or team, discuss one type of innovation you have noticed in your community.
    a. What do you think you could do to help encourage innovation in your community?
    b. What are some ideas you have about innovations you would like to encourage in your community?
5. As a team, think back to the oral histories you collected in the Discover activity.
    a. What do you think caused the changes people told you about?
    b. How do the changes you learned about relate to different types of innovations?
    c. In what way do the changes you noticed represent opportunities to generate new ideas for future innovations?
6. Read what Debbie says about what changes social norms. What ideas do you have for how you might help change social norms?

Debbie says . . .

To change the norm of a group, what you need to do is change the visible properties of the group, change what everybody is doing and saying. That's what norm-changing strategies are about—making different behaviors visible. Anything that makes a behavior more observable helps create it as a social norm. The more present a behavior is, the more it will start to seem like a social norm for a group. The great thing about norms is that as a group member you have a lot of **agency**. The norms are created by the group, and you are a part of that—which means you can change them. I think there is a lot of power in that.

7. As a team, continue to analyze your oral histories for evidence of previous innovations and changing norms. There are many ideas that can lead to these changes. For each change you notice, discuss with your team whether you think it was related to:
    a. Technological innovation, such as when a new product or process is engineered to help solve a problem. This also might include making a technology more affordable.
    b. Behavioral innovation, such as when habits, rules, information, or cultures change to encourage people to make different choices.
    c. Both technological and behavioral innovations, such as when there is a new technology and an information campaign.
8. Think quietly to yourself about a time when you changed your behavior. Maybe you broke a bad habit, maybe you started doing an activity you now love, or maybe you just changed what had been a daily pattern. What made you change your behavior?
9. Keeping this behavior change in mind, examine the following list. There are many reasons people change their behaviors. Rank this list from 1 (most important) to 4 (least important) in making you change your behavior.
    a. New rules made it easier to behave in the new way or harder to behave in the old way.
    b. Other people you know or admire were behaving in the new way.

c. You learned more information that made you want to change your behavior.

d. The new behavior became exciting or more attractive because of the design of a product or system.

10. Turn to a partner and share your rankings. Are your rankings the same? Discuss why you might want to use several different approaches to encourage people to change their behavior.

11. With your partner, read *Behavior Shifts*. As you have learned, there are different types of innovations. Some ways to change the climate change story need new technologies. Others just need people to make different choices. You will learn more about technology innovation in Task 4. Right now, you will think about behavior shifts that do not require new technologies.

Behavior Shifts

One way to innovate and change behavior is by making different choices. For example, you could innovate by making the choice to reduce the number of clothes you buy. Examine this list to learn more about behavior shifts related to the climate that you could consider.[35]

To reduce GHG production, people could learn more about:

- **Transportation methods:** Use less motorized transportation and shift away from vehicles that use gasoline or diesel.
- **Electricity use:** Use less electricity and shift electricity production away from fossil fuels.
- **Consumption of products and shifts to more synthetic products:** Reduce the amount they consume and shift away from products that require a lot of energy to produce or generate GHG during production.
- **Food production:** Reduce the amount of GHG-intensive foods they eat and shift away from farming practices that produce GHG.
- **Heating and cooling buildings:** Reduce the need for heating and cooling or shift away from heating or cooling their houses in a way that produces a lot of GHG.
- **Amount of waste:** Limit waste and shift away from placing food waste into landfills.
- **Land use:** Limit disturbing natural areas, especially forests, and shift toward increasing the amount of space dedicated to creating carbon sinks.

12. Think quietly to yourself, which behavior shift do you think would be easiest for you? If someone was encouraging you to make this shift, what would help you do it? You can use your behavior change rankings from step 9 to help you think.
13. Read Debbie's thoughts on behavioral **interventions**. An intervention is an action taken to improve a situation. One type of innovation is to take action to encourage people to behave more sustainably.

Debbie says . . .

There are a lot of behavioral interventions. Many are **nudge** interventions that simply make it easier to do the desired thing. For example, people generally won't just carry things around in their hand that they don't want—they will toss them in the nearest bin. So, the best way to get people to recycle is to put brightly colored recycling bins in strategic locations. You are not changing people. You are modifying the environment to change their behavior. You can also communicate to have people to reflect on what they want. Most people are concerned about the effect of their actions on the next generation, for example. How do you help them think about that part of their identity when they are making decisions?

14. Read *Idea Flurry* and follow the instructions. You and your team will be working together to generate ideas about how to encourage behavior shifts.

Idea Flurry

This activity will help you generate a lot of ideas about innovations to shift current human behaviors. A flurry of ideas is when many ideas get generated in a short period of time. Sometimes when people are thinking of ideas, they limit themselves because they try to only think of good ideas. In this activity you want quantity over quality. You will be trying to come up with as many ideas as possible. For the moment, do not worry whether your ideas are good or even possible.

In this activity you will be thinking about four different types of innovations to encourage behavior shifts.

- **Design:** The design of something can make it easy or exciting to use. Design can be an important element of starting trends.
- **Communication:** If people do not understand the purpose of shifting a behavior, they may not want to change. Communication plays an important role in sharing information and raising awareness about the reason to shift behaviors.
- **Nudge:** A nudge is something in the surrounding environment that makes it a little easier to behave in ways you want to encourage. This might mean moving an object you want someone to use to a place where it is easy to reach. It might mean a phone notification to remind someone of something. Nudges can also mean making behaviors you want to discourage a little less convenient.
- **Model:** People are sometimes reluctant to do something they have never seen anyone else do. People often change behaviors when someone they know or admire uses the new behavior. This is how trends are often started.

Gather Your Materials

You will need:

- Index cards, sticky notes, or small pieces of paper
- Pens or pencils
- A timer

Play Idea Flurry

a. Form a group of two to eight people, and sit around a table or desk.
b. Assign one person the role of timekeeper.
c. Give each person 12 pieces of paper or index cards and something to write with.
d. Label three cards "Design," three cards "Communication," three cards "Nudge," and three cards "Model."
e. As a group, pick one change from the *Behavior Shifts* box and read the description to remind everyone about the types of behaviors that might help reduce GHG. Your job is to generate ideas about how to encourage this behavior shift.

f. Think of an image or item to represent the behavior shift you want to encourage. For example, maybe you want to encourage people to ride a bike rather than drive a car. If you can, use a picture of the item to help you concentrate. For example, you could place a picture of a bike on the table.
g. Have the timekeeper start a five-minute timer.
h. Use each of your cards write or draw one innovation idea in the category listed on the card (such as a communication or a nudge) to encourage the behavior shift. Try to fill in as many cards as possible out of your 12. Here are some questions to get you started.

   - **Design:** Examine the item your group chose. Is there a way you could redesign it so it would be more exciting, attractive, or easy to use? In the bike example, you might change the color of the bike so it is more attractive or make it more comfortable to ride.
   - **Communication:** How could communication help you shift behaviors? For example, maybe you could start a social media campaign about places to bike safely.
   - **Nudge:** How could you make the environment encourage the behavior? For example, if you create a bike-sharing program would that encourage people to use bikes? Or maybe if it is inconvenient to park a car, that would discourage people from using cars.
   - **Model:** How can others help encourage this behavior? For example, maybe if a group of people at school started biking, it would encourage other students. Or maybe if a celebrity or local leader talked about biking or biked themselves, it would encourage people.

i. As you finish writing an idea on each card, throw it into the middle of the table. Try to write as many ideas as you can think of in five minutes. Remember, they do not need to be good ideas, just any ideas you can think of.
j. If you have another idea that is not part of one of these innovation types, write down that idea now.
k. If you have time, generate ideas for other behaviors you would like to encourage.

15. Place all the cards face up in a place where everyone on your team can examine them. This might be along a long table or on the wall.
16. Move around and read the ideas listed by your teammates. On at least five cards, try to add a small improvement to make the idea even better. For example, if someone's idea was, "Tell people about why they should use less electricity," maybe you would want to add details about which people or which communication method you might use to reach them.
17. Come back together as a team and discuss:
    a. Were there any ideas that many different people thought of independently?
    b. Why do you think it is important to generate a lot of different ideas?
    c. Why do you think you should try to improve ideas after you think of them?
    d. Did any silly ideas turn into good ones, after some suggested improvements?

Act: *How can we become climate-friendly trendsetters?*

You have learned about the problem of climate change. You have also learned about the process of innovation and how it helps solve problems. Throughout this guide you will be using the process of innovation to think about the problem of climate change. One approach to innovation is to model behaviors. In fact, you can become a climate-friendly trendsetter.

1. As a team, discuss your favorite innovation ideas that you remember from the *Idea Flurry* from your group or others. Choose a few ideas you would like to remember.
2. Take out your *Climate Innovation Organizer* and label the next blank row "2. Generate Ideas."
3. Write down the ideas you want to remember in the *Human Behaviors* column in your new *Generate Ideas* row. Figure 15 shows a blue box where you should write your ideas.

	Human Behaviors	Producing Emissions	Changes to the Atmosphere	Changes to the Climate	Impacts on Communities
1. Define the Problem					
2. Generate Ideas					

Figure 15: Climate Innovation Organizer with the Generate Ideas row in the Human Behaviors column highlighted.

4. Turn to a partner and discuss:
   a. Which innovations do you think could start a trend that could change the impact people have on the climate?
   b. What trends do you think these innovations could create?
5. Read *Become a Trendsetter* and follow the instructions.

Become a Trendsetter

What is one trend you wish would happen that would change human behaviors to become more climate-friendly?

You may underestimate the way your actions can help shift social norms. Whether it is your friends, your family, or even just people you pass on the street, other people notice and are influenced by your habits and behaviors.

Pick a Trend

Divide your team into groups of two. As a pair, choose one trend you would like to start so that it becomes a social norm. It does not need to be a huge innovation—just one small habit you can change.

Share Accountability

Choose how often you and your partner will check in with each other. Will you come back together after an hour, a day, a week, or another period of time to keep encouraging each other to stick to the new habit?

Communicate with Others

Create a way to share your new habit with others. Trends start by one person shifting their behavior. Trends become norms when many people decide to shift their behavior more permanently.

Think together:

- Who would you like to share your new habit with? For example, your friends, your family, others in your community?
- How will you share your new habit? For example, in conversations, on social media, or just modeling the new habit around others?
- How will you explain your why? If people ask you, what will you tell them about why you have started this new habit? For example, maybe you want to tell them about changes in human lifestyles or the way those changes relate to climate change.

Join in

As you start your new habit, also pay attention to your teammates, who are starting their own trends. Do you notice what those new trends are? If you do, tell your teammates you have figured out their trend and think about joining in.

Try to notice as many of your teammates' trends as possible. If your teammates notice your trend, tell them about your why and perhaps they will join you.

6. Break into four groups and assign each group one of the remaining parts of the climate change story from the *Climate Innovation Organizer*: Producing Emissions, Changes to the Atmosphere, Changes to the Climate, or Impacts on Communities.
7. Read *Generating Ideas to Help Solve Climate Change Problems* and follow the instructions with your group.

Generating Ideas to Help Solve Climate Change Problems

Generate Ideas

Generate ideas: Come up with a variety of different ideas that might help solve the problem. These ideas might be totally new or could be small changes to existing approaches.

Review what you wrote in the *Define the Problem* row in the *Climate Innovation Organizer* to help you remember your part of the climate change story.

a. Pick a way to help generate ideas about your problem. For example, you could use the *Idea Flurry* instructions to help you, but you could also:
   - Go around your group and quickly share ideas out loud
   - Draw six boxes and try to draw a different idea in each
   - Do a silent brainstorm, writing down as many ideas as possible without stopping
   - Use another method that works well for your group

b. Set a timer for five minutes and generate as many ideas as possible.

Write down a few of your favorite ideas under your climate change story part column in the *Climate Innovation Organizer in the Generate Ideas* row. Figure 16 shows an example of where each group will record their ideas.

	Human Behaviors	Producing Emissions	Changes to the Atmosphere	Changes to the Climate	Impacts on Communities
1. Define the Problem					
2. Generate Ideas		Group 1	Group 2	Group 3	Group 4

Figure 16: A sample Climate Innovation Organizer showing where the different groups should write their ideas.

8. As a team, think about the climate change story you have been learning about. Discuss:
   a. How could innovation change the human behaviors part of the story?
   b. What effect do you think that change would have on the rest of the story?
9. Keep your *Climate Innovation Organizer*. You will use it throughout the guide.
10. Read what Debbie says about changing behavior. What beliefs about the climate or environment do you have that you wonder whether others think are important? Turn to a partner and share something you think is true and that you would like to act on.

Debbie says . . .

Changing behaviors is about more than just giving people information. You need to tackle social norms. Maybe I believe the world is on the wrong path related to the environment. If I don't see other people acting like they think so too, it makes it very hard for me to act on my belief. It also makes me feel anxious and alone. You may assume you are the only one who feels the way you do, even if everybody else actually feels the same way!

This is why there is so much power in showing new behaviors and starting to shift social norms. For example, you can make your private thoughts and feelings visible. You can give and share the results of surveys on what people say they feel. You can lead a discussion group where people talk together about what is important to them. All of these approaches give other people a way to express beliefs they have and permission to do so. They create a sense of connection and allow people to understand that others might have similar concerns and worries.

All it takes is people coming together and starting to talk, and they often realize, "Actually, we are all on the same page with this." The heroism you need is just to be willing to step up and say, "Here's what I feel, does anybody else feel that way too?"

Find out More!

For additional resources, activities, and innovation examples, please visit the *Innovation!* StoryMap at https://s.si.edu/InnovationGuide.

Meet Your Research Mentor

Meet Dr. Thinus Booysen. Thinus (pronounced TEE-niss) will be your research mentor for Task 4.

Thinus is an engineer and tenured professor at Stellenbosch University in South Africa. He is passionate about using smart technology and **data** to improve access to transportation, energy, and water, especially in communities facing real-world challenges in developing countries.

Thinus's Identity Map

Has a deep love for teaching

Professor of engineering

Child of Mama Africa

Deep-seated awareness of injustice and inequity

Supported and loved by a gracious wife

Grew up privileged during apartheid South Africa

Participated in a variant of the Scouts, called Land Service

Believes in the developmental potential of quality education

Focuses on sustainable transport, energy, and water

Co-habitant of our beautiful planet Earth

Child of a passionate schoolteacher

Has two wonderful daughters

Experienced the fight for freedom as a teenager

Has a deep appreciation of nature and our custodianship of it

Before you begin Task 4, think quietly to yourself about Thinus's identity map.

- Are there things you have in common?
- Are there ways in which you are different?

Throughout this task Thinus will share ideas with you. These ideas might give your team new information or help you think of ways to investigate your community.

Task 4: How can we select solutions when innovating?

Remember, emissions are things released into the atmosphere. Emissions include greenhouse gases such as carbon dioxide and methane. These gases trap heat in the atmosphere. Many processes that produce things such as electricity, transportation, and manufacturing also produce greenhouse gas (GHG) emissions.

The good news is that because there are many processes, there are also many possible ways to reduce the GHG emitted through those processes. Scientists, engineers, and even you can study how to reduce the emissions created by these processes. As innovators, you will make choices about where to focus your time and effort.

In this task you will ***discover*** more about the processes that are producing GHG emissions and the **criteria** you could use to make your choices. Then you will gather data to ***understand*** more about potential innovation approaches and their relative strengths. This will help you learn how to use criteria to select a solution, the third step in the innovation process (shown in Figure 17).

Figure 17: The innovation process, highlighting Step 3: Select a Solution.

Finally, you will ***act*** by applying your criteria to solutions to determine which one you think might be the most promising.

Discover: *Where do greenhouse gas emissions come from?*

In Task 3 you thought about behavior changes people could make to reduce GHG emissions. This might mean changing how much or which items they use. In this task you will think about innovations to change the way things are produced—for example,

changing the technologies used in electricity generation, transportation, manufacturing, food production, and other areas. To compare this task with the previous one, maybe in Task 3 you thought about reducing the amount of electricity you use. In Task 4 you might consider innovations to make electricity generation produce less GHG emissions.

1. By yourself, pick one thing you have used today. You might choose an electronic device, furniture, a building, **infrastructure** (such as roads, bridges, and sidewalks), transportation, food, heat, air conditioning, or other products (anything you might buy or use).
2. Turn to a partner and discuss anything you know about the production process behind this thing. For example, was it produced in a factory? Does it use other things that also have to be produced, such as electricity? How does it reach the place where you used it? If you are not sure, just do your best.
3. As a pair, examine Figure 18 and discuss:
    a. What do you notice about different categories of greenhouse gas emissions? Does anything surprise you?
    b. In step 2 you thought about the production of a thing and how it reaches you. Which categories in this figure do you think might be part of that process?
    c. Innovation could potentially improve each part of the production process to reduce GHG emissions. What do you wonder about how people pick which innovation to pursue?

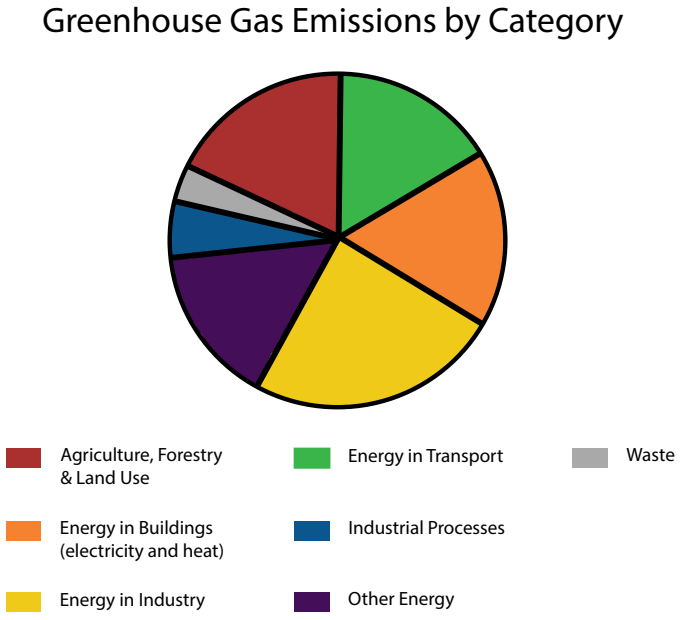


Figure 18: Greenhouse gas emissions by category[36].

4. With your partner, examine the categories in Figure 18. For each, can you think of an innovation that might reduce GHG emissions? For example, one of the things that produces a lot of GHG emissions is burning fossil fuels to power transportation. Are there innovations that might reduce these emissions by using an alternative to fossil fuels? It does not matter if your innovation does not currently exist; just think about innovative ways to reduce emissions. Don't worry if you are not sure, just do your best.
5. Read *Determining Criteria: How to Judge* and follow the instructions by yourself or with a partner.

Determining Criteria: How to Judge

There are many possible innovations. Innovations might range from wind energy to bioplastics to green roofs to electric vehicles, and there are so many more. Innovations often require investing creativity, time, effort, and resources. This means you should pick your potential solution carefully. Although many innovations might be useful, how will you decide which one to focus on?

Before investing in a potential innovation, determine the criteria you want to use. Criteria are the standards you use to judge or decide something. For instance, if you want to buy a piece of clothing that is affordable and comfortable, then the criteria you are using to judge possible clothing purchases are whether they are affordable and comfortable. Different people might choose different criteria. Often criteria are things that can be counted or measured.

Now you will create a list of the criteria you want to use to judge innovations to reduce GHG emissions. First think about what categories you want to use to judge potential innovations.

a. By yourself, with a partner, or in a small group, take out a piece of paper and title it "Innovation Criteria."
b. Start by listing "GHG reduction." If you are trying to reduce emissions, this is an important criterion.
c. Write down any other criteria you think are important. What do you think you want to consider when making decisions about innovations?

d. If you are having trouble coming up with criteria, you may want to consider some of the following possibilities. Criteria are often used by engineers and scientists. Here is a list of criteria you might consider.

- **Costs:** How much does the innovation cost to produce or implement?
- **Feasibility:** Do people currently have the knowledge needed to create this innovation?
- **Usability:** Can people easily use this innovation?
- **Integration:** Does the innovation work within existing factories or machines?
- **Market demand:** Would there be a demand for this innovation? Are there other innovations already available that would compete with it?
- **Locally appropriate:** Is this an innovation that would be appropriate in your local area?
- **Possible for youth:** Is this something that a young person could contribute to developing?
- **Co-benefit:** Does this innovation provide another extra benefit, for example does it save water or make communities more pleasant?
- **Unintended consequences:** Are there any environmental or social harms that might be created by accident when implementing this innovation?

e. Examine your list of criteria and underline the six you would personally want to use to help you choose which innovation to develop.

You will be working together to find consensus as a team on the most important criteria. Consensus is not competing to win or lose. Coming to consensus means working together to find a balanced decision that works for everyone.

6. Take your criteria list and find a partner or another group. Examine your lists together and circle any criteria you have all underlined. Write those criteria on the bottom of one piece of paper.
7. Next, discuss the criteria you chose that were different. Listen closely to others' opinions and share your own thoughts about why the criteria you chose are most important.

8. Together with your partner, pick the additional criteria that you two together think are most important. Write down a total of six criteria. This is not about picking your ideas. It is about picking the best ideas. You can use these phrases to help you have a useful conversation.
   - I agree/disagree because . . .
   - I'd like to go back to what you said about . . .
   - I noticed that . . .
   - Couldn't it also be that . . .?
   - Can you explain why you think that?
9. As a team, slowly build consensus on a list of six criteria (including GHG reduction). If you are having trouble agreeing on the final set of criteria, you can try these ideas.
   a. List the good things and bad things about using each criterion. Discuss as a team.
   b. Build a sense of group opinion. Each person can vote for six criteria and you will use the criteria with the most votes.
   c. Find a slow consensus. Find a new partner and, as a pair, find consensus on which criteria are most important. Then, in a group of two pairs (four team members), you can find consensus. Then, in a group of four pairs (eight team members), you can find consensus. Keep adding together groups until you have found a team consensus.
10. Once you have your list of criteria, write them down and title the list "Team Criteria."
11. As a team, decide on the type of data you will use to assess each criterion. For example, if you are thinking about cost criteria, you might use the amount of money it costs to produce the item as the data you will use to assess that criterion. List the data you chose next to each criterion.
12. Discuss as a team: If you are making decisions about which innovation to choose, why would it be important to use the same list of criteria when comparing the possibilities?
13. Read what research mentor Dr. Thinus Booysen's says. Part of Thinus's research focuses on electric vehicles in sub-Saharan Africa. He shares some of the things he thinks about when working on electrification innovations. What criteria do you notice? Do they relate to the criteria list your team created?

Thinus says . . .

It's important to realize that sub-Saharan Africa is only a very small contributor of global GHG emissions. However, pollution from **vehicle tailpipe emissions** really affects people's health as well as the climate. To think about ways to innovate in this system, first you should understand the system.

In Africa the transportation system is largely **informal** and vehicles are owned by a large number of private operators. Most "public" transportation is privately owned minibuses or motorbikes taking on paying passengers. Routes are unscheduled, meaning there are no set arrival and departure times. The routes themselves also vary. Drivers decide where they want to drive or pick up passengers. A lot of vehicles are 20 years old or more, which means you can literally see the tailpipe emissions from the tailpipe as you drive around.

There are some complications to consider when selecting solutions for electric mobility in the region. For example, people use minibuses, but there are no electric minibuses available. So we had to take petrol and diesel minibuses and convert them to electric. It is cheaper to convert vehicles rather than buy new ones. This reduces the cost to change to electric for individual minibus owners. This also helps reduce waste, and the climate change impact of converting a vehicle is substantially less than manufacturing a vehicle. Converting vehicles also helps build local skills related to electric mobility.

We also must think about charging. If drivers take different routes every day, how do you determine where to put charging stations? Then there is the charging time. How long does it take? Could you just swap a full battery for an empty one? How far can people get on a single charge?

Finally, you might also consider the impact on the electricity network. The region has very fragile electric grids. What can be done if there is not enough electricity or it is being produced in a way that creates a lot of GHG emissions? Fortunately, the region has abundant sunshine, so solar power is an option.

Understand: *How can we choose innovations to reduce GHG emissions?*

There are many possible ways to innovate to solve a problem. You can use criteria to help make decisions about which potential innovations are the most worthy of investing time, energy, effort, and resources.

1. Have each team member or pair use a piece of paper to create an *Innovation Criteria Chart* like the one in Figure 19. Fill in the blank spaces with the *Team Criteria* you chose. If you prefer, you can also just list your criteria and assign a score to each one.

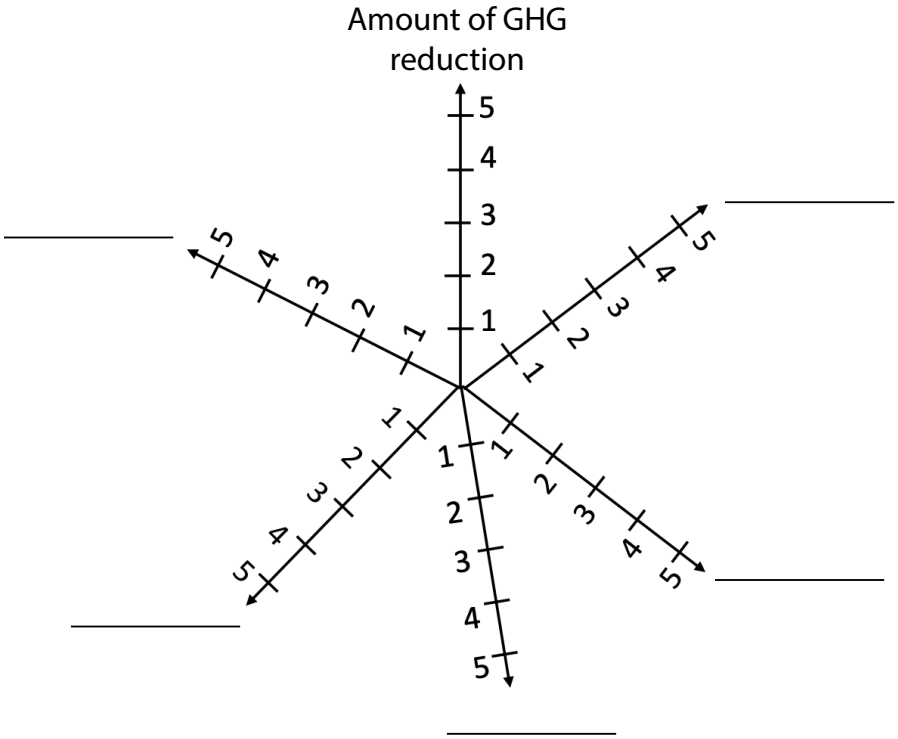


Figure 19: Example of an Innovation Criteria Chart.

2. Read *Using Data to Make Decisions,* and as a team, follow the instructions to identify the type of data you will use and set the range for your criteria.

Using Data to Make Decisions

As individuals or pairs, you will be researching innovations and using the data you find to create an *Innovation Criteria Chart*. Then you will compare the different charts to select the innovation that is best, according to your criteria.

Identifying the Type of Data

a. Next to each of your criteria on your *Team Criteria* list, write the specific type of data that will help you assess the criterion. For example, for the criterion "GHG reduction" you might write "tons of GHG" or "tons of carbon dioxide." For the criterion "Costs" you might write "amount of money to produce."
b. For items that do not have specific data sets, you can write something more general. For example, "number of extra benefits," or, "how locally appropriate something is on a scale of 1 to 5." If you are unsure about the best data, just do your best.

Setting the Range

When you examine the *Innovation Criteria Chart,* you will notice each criterion ranges from very bad (1) to very good (5). Everyone should use the same range to assess each criterion for the innovations they are researching. By using the same range and the same criteria, you can compare charts later in the activity.

a. As a team, decide how this range might represent the data you chose for each criterion. Write the range next to the data on your *Team Criteria* list.

For example, if the criterion was about whether it might be possible for a young person to contribute to this innovation, you might decide on the following range.

- 1 means no possibility of youth contribution
- 2 means it would be very hard for youth to contribute
- 3 means youth could contribute in a limited way
- 4 means youth could contribute if they were committed
- 5 means it would be easy for youth to contribute

Another example uses more measurable data. If you were ranking GHG reduction, you might choose to assess potential yearly GHG reduction for the innovation, in metric tons. You can to assign the numbers to different data ranges in many ways. Here is one possibility.

- 1 means equal to less than 1,000 metric tons
- 2 means 1,000 to 5,000 metric tons
- 3 means 5,000 to 50,000 metric tons
- 4 means 50,000 to 500,000 metric tons
- 5 means more than 500,000 metric tons

3. Read Thinus's ideas about why it is important to use data when making decisions about innovations. How would you explain this idea to someone else?

Thinus says . . .

It has been said that data is the gold of the information age in which we live. Reliable and accurate data supports good decision-making. This could help us transition to cleaner energy use. It can also help ensure a fair transition.

However, when data is used, a lot of trust is put in that data. This means we must be careful to make sure the data is accurate and actually represents the population it is supposed to represent. It is important to set up the data-gathering to prevent any form of misrepresentation. Good data can lead to good decisions. Bad, misrepresentative, or inaccurate data often results in bad decisions.

4. Choose one potential technology innovation to research that reduces GHG emissions. Individually, you will conduct research on an innovation of your choice to assess its score for each criterion you listed. This will work best if everyone chooses a different innovation. If doing this individually isn't the right choice for your team, you can work in pairs or small groups. If you have a technology that already interests you, pick that innovation. If not, you can use this list of many GHG-reduction innovations for different categories to help you pick an innovation to research.
    a. Transportation: electric vehicles; biofuels; hydrogen fuel cells; autonomous or connected vehicles
    b. Electricity: energy efficiency in light bulbs and appliances; renewable power generation such as wind or solar; battery storage; smart grid or microgrid
    c. Products: designing products for reuse or easy recycling; changing to biomaterials, such as bioplastic or mycelium; energy efficiency in manufacturing; carbon-negative concrete
    d. Food: plant-based food alternatives; vertical or rooftop farming; precision agriculture; reducing supply chain food waste

e. Heating and cooling: high-efficiency heat pumps; insulation and air sealing; passive heating, cooling, and natural ventilation; cool or green roofs

f. Waste: artificial intelligence to sort waste; waste-to-energy technology; landfill gas capture; composting

g. Land use: reforestation; urban greening through parks or green walls; agroforestry, integrating trees into agricultural land; regenerative agriculture practices such as biochar

5. Write the innovation you are researching across the top of your *Innovation Criteria Chart*. Each person or small group should have their own chart.
6. Read *Researching Your Innovation* and follow the instructions.

Researching Your innovation

You will be conducting research to understand more about the innovation you have chosen.

Where to Research

You can choose one or more of these places to conduct research.

- Online: For recent innovations, information on the Internet may be the most current. Web searches can help you identify recent data about your innovation.
- Community: If you know scientists, researchers, engineers, or others involved with your innovation, you can ask them questions about it to get more information.
- *Innovation!* StoryMap: This website has links to articles and data related to the innovations listed in this task.

How to Research

Pay attention to where the data comes from. Reliable data often comes from government websites, international organizations, or experts. Different sources may provide data for different criteria. For example, social media is not always a good source of scientific data, but it can provide important perspectives from your community. For technology-related criteria, try to use data from technical experts or organizations.

Analyze the Data

Use what you have learned to assign a value of 1 to 5 for each criterion, based on the range you agreed upon for your *Team Criteria*. On your *Innovation Criteria Chart,* place a dot along the line showing the value you assigned. Then connect the dots. This creates the chart for your innovation. Keep this *Innovation Criteria Chart*. You will need it in the Act activity.

Act: *What would we select as the best idea to reduce emissions?*

Making choices is part of making progress. No one has all the information they might want or even need. But we can use the information we have to make the best decision we can. The ability to compare different innovations based on the same criteria can help us make more informed decisions.

1. Have each team member place their *Innovation Criteria Chart* on a wall or anywhere it can be easily examined.
2. Move around your space examining every *Innovation Criteria Chart*.
3. Based on the *Innovation Criteria Chart*, which innovations would you be interested in working on?
4. Discuss as a team:
    a. Based on the criteria you previously decided, which innovations do you think are the most promising?
    b. Now that you have completed your research, are there other criteria you would choose to add to your list?
5. As a team, choose the innovation you would like to work on.
6. Take out your *Climate Innovation Organizer* and label the next blank row "3. Select a Solution."
7. Write down your selected innovation in the *Producing Emissions* column on that row. Figure 20 shows a blue box where you should write your ideas.

	Human Behaviors	Producing Emissions	Changes to the Atmosphere	Changes to the Climate	Impacts on Communities
1. Define the Problem					
2. Generate ideas					
3. Select a solution					

Figure 20: Climate Innovation Organizer with a box highlighted for Select a Solution in the Producing Emissions column.

8. As a team, think about what you have been learning about GHG emissions. Discuss:
   a. How could innovation change GHG emissions in your local area?
   b. How could innovation change GHG globally?
   c. What effect do you think that change would have on the rest of the climate change story?
9. Divide your team into four groups and assign each group one of the remaining parts of the climate change story from the *Climate Innovation Organizer*: *Human Behaviors, Changes to the Atmosphere, Changes to the Climate, or Impacts on Communities*.
10. Read *Selecting Ideas to Help Solve Climate Change Problems* and follow the instructions with your group.

Selecting Ideas to Help Solve Climate Change Problems

Select a Solution

Select a solution: Choose the best idea to move forward with, based on what you know about the problem. This might not be the final solution, but it is the most promising one based on what you currently know.

a. Examine the *Generate Ideas* line for your part of the climate change story in the *Climate Innovation Organizer*.
b. Come up with a set of criteria you want to use to pick one idea. You can use the set of criteria you just created, or substitute other criteria if you think they are more appropriate.
c. Use what you know to select the idea you think is best, based on your criteria. Or, if you have time, you can do some additional research to help you decide.
d. Write down the idea you selected under your climate change story part column in the *Climate Innovation Organizer*. Do not worry if you are uncertain, just do your best. This will not be a final decision; it will just help you continue to explore the innovation process. If you need support in where to write your ideas, you can visit the *Innovation!* StoryMap.

11. Keep your *Climate Innovation Organizer*. You will use it throughout the rest of the guide.

12. Read Thinus's thoughts on why innovation related to climate is important. What do you want to remember?

Thinus says . . .

A lot of the damage done to our habitat—the climate included—is a direct consequence of well-intentioned innovation by engineers and scientists, in their drive to make our individual lives longer and more convenient. However, the focus has now turned to sustaining the life expectancy of all of humanity and nature. To reverse our impact on the environment requires innovative ways of fighting climate change and other factors negatively affecting our environment. It is important to be aware that different regions have different challenges and require different solutions. We must take care to find innovative solutions that bring not only a more sustainable future, but one that is just and equitable.

Find out More!

For additional resources, activities, and innovation examples, please visit the *Innovation!* StoryMap at https://s.si.edu/InnovationGuide.

Meet Your Research Mentor

Meet Dr. Jayaprakash (Jaya) Saththasivam. Jaya (pronounced JAH-yah) will be your research mentor for Task 5.

Jaya is a senior scientist specializing in wastewater treatment and reuse, dedicated to developing innovative technologies that sustainably integrate water recycling into green infrastructure. He is inspired by harnessing nature-based and innovative engineering solutions to protect water ecosystems, advance resource circularity, and secure equitable access to clean water.

Jaya's Identity Map

- Multilingual: English, Bahasa Melayu, and Tamil
- Values equity, sustainability, and science for the public good
- Enjoys problem-solving and mentoring
- Husband and father to two wonderful sons
- Family-centred
- Passionate about Taekwondo
- Asian male
- Quiet but loud
- Avid Ferrari Formula 1 fan
- Inspired by nature-based solutions
- Interested in deep learning applications
- A Malaysian currently living in Qatar
- Has worked in Malaysia, Singapore, and Saudi Arabia
- Researcher specializing in wastewater treatment and reuse

Before you begin Task 5, think quietly to yourself about Jaya's identity map.

- Are there things you have in common?
- Are there ways in which you are different?

Throughout this task Jaya will share ideas with you. These ideas might give your team new information or help you think of ways to investigate your community.

Task 5: How can we evaluate innovations?

Carbon is one of the most abundant elements in the universe. It is essential for life on Earth. All living things on Earth are carbon-based. Changes in where Earth's carbon is stored is part of the climate change story. Scientists and engineers are working on new innovations to help store carbon.

In this task you will ***discover*** more about the way carbon cycles around Earth and how innovations can add or remove carbon from the atmosphere. Then you will develop experiments and analyze data to ***understand*** ways to make an innovation more effective. You will use this to help you prototype. Experiment and Prototype is the fourth step in the innovation process (shown in Figure 21).

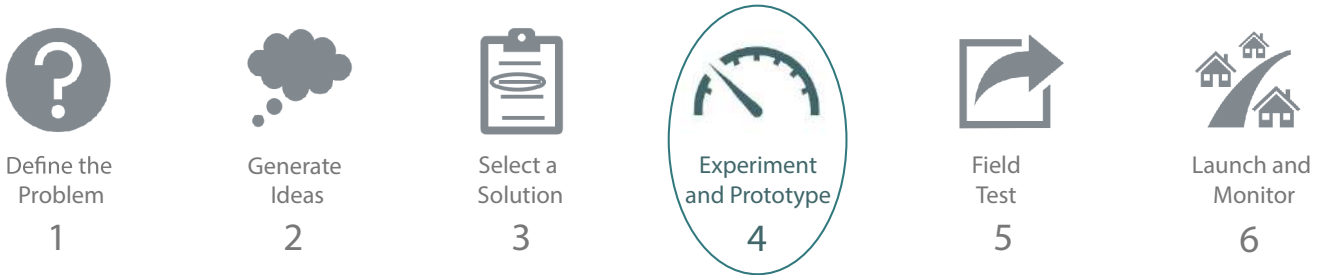


Figure 21: The innovation process, highlighting Step 4: Experiment and Prototype.

Finally, you will ***act*** by using the results of your experiments to improve your innovation.

Discover: *How are greenhouse gases removed from the atmosphere?*

On Earth, carbon naturally moves between organisms, the ocean, the land, and the air. This movement is called the **carbon cycle**. Some past innovations have changed the natural carbon cycle by adding additional carbon to the air. One possibility of future innovation for the climate change story is to help remove this additional carbon.

1. With a partner, count how many of the following items you think contain carbon.
    a. Diamonds, elephants, the exhaust coming out of cars, marble, ferns, seashells, pencil "lead," sugar, the breath coming out of your body, coal, bacteria, protein, soil, the ocean, humans

2. Share your answer with the rest of your team.
3. The answer is that everything on the list contains carbon. Carbon is part of every living thing and many non-living things on Earth. Does this answer surprise you? As a team, discuss:
    a. Some of the items listed are made only of carbon, for example, diamonds and pencil "lead," also known as graphite.
    b. Some items are made partly of carbon. For example, among other things, your breath contains carbon dioxide, which is made of carbon and oxygen. Living things contain many molecules, some which contain carbon and some of which don't.
    c. Can you think of any other examples of carbon on Earth? If you can't, don't worry. You will be learning more about the forms of carbon and the carbon cycle during this task.
4. With a partner or your team, read *Earth's Spheres*.

Earth's Spheres

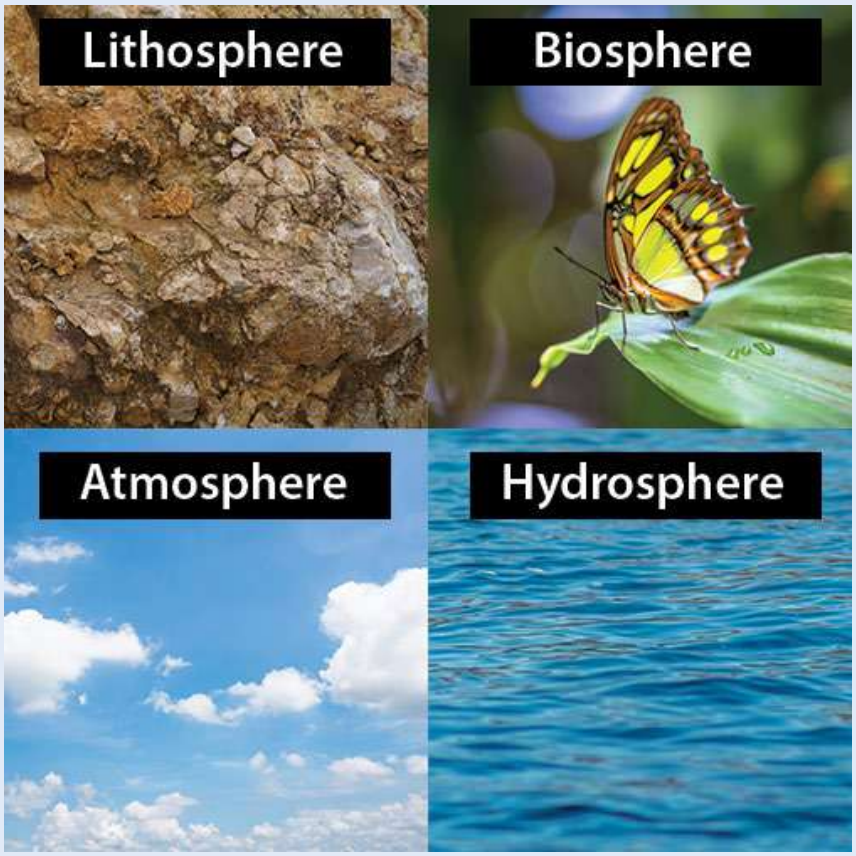


Figure 22: These photos represent Earth's four spheres: lithosphere, biosphere, hydrosphere, and atmosphere.

- The **lithosphere** is Earth's land. Sometimes it's called Earth's crust. It includes soil, dirt, and rocks.
- The **biosphere** is all living things on Earth. It includes animals, plants, and microscopic organisms, such as bacteria.
- The **hydrosphere** is all of Earth's water, whether it is liquid, ice, or in the air. It includes the ocean, lakes, water vapor, glaciers, and groundwater.
- The **atmosphere** is the mixture of gases that surround Earth. It creates a protective bubble between Earth's surface and outer space. The atmosphere contains nitrogen, oxygen, and other gases, including greenhouse gases (GHG).

5. Divide your team and your learning area into four parts. Each part will represent one of the spheres of Earth. Figure 22 shows these four spheres.
6. With your sphere group, create and decorate a sign to represent your sphere of Earth.
7. As a sphere group, take one minute to discuss ways you relate to the sphere you are representing. If this part of Earth changed, how might you be affected? For example, maybe you thought about how changes to the atmosphere might affect the air you breathe.
8. Write or draw a picture on your sign to represent your ideas about this relationship.
9. Go to the area that represents the next sphere and discuss your relationship with that sphere for one minute. Write or draw your ideas on the sign that's there.
10. Continue rotating until you are back in the sphere where you started.
11. Discuss as a sphere group, what do you think naturally moves among Earth's spheres?
12. With your sphere group, read *Getting Ready: Modeling the Carbon Cycle,* and follow the instructions to set up your model.

Getting Ready: Modeling the Carbon Cycle

Carbon is one thing that moves between Earth's different spheres. You and your team will now model how the carbon cycle naturally moves carbon between the lithosphere, hydrosphere, biosphere, and atmosphere.

Gather Your Materials

Each team will need:

- The four sphere signs
- A pile (approximately 60 to 80) small counters: Counters can be items such as small pebbles, dried beans, small building blocks, or beads, to represent carbon. The number does not need to be exact.
- Four containers (one for each sphere) to hold the carbon counters
- At least four six-sided dice (or another way to randomly pick a number between one and six, such as an online random number generator)
- The *Rolling Instructions Cards* found in Figure 24, printed and cut apart
- Timer

Get Ready

The counters represent the amount of carbon found in a specific sphere.

- Give each sphere group a container and have them place their sphere sign on or next to it.
- If your sphere group is the atmosphere, hydrosphere, or biosphere, count the people in your group. Double that number and place that many carbon counters in your container. For example, if there are four people in your group, place eight carbon counters in your container.
- If you are in the lithosphere, place the remainder of the available carbon counters in your container.

Place the die and the *Rolling Instructions Card* for your sphere next to your container. Figure 23 shows an example. If you have many people participating in the activity, you may want to add two or more dice to each sphere to minimize wait times.

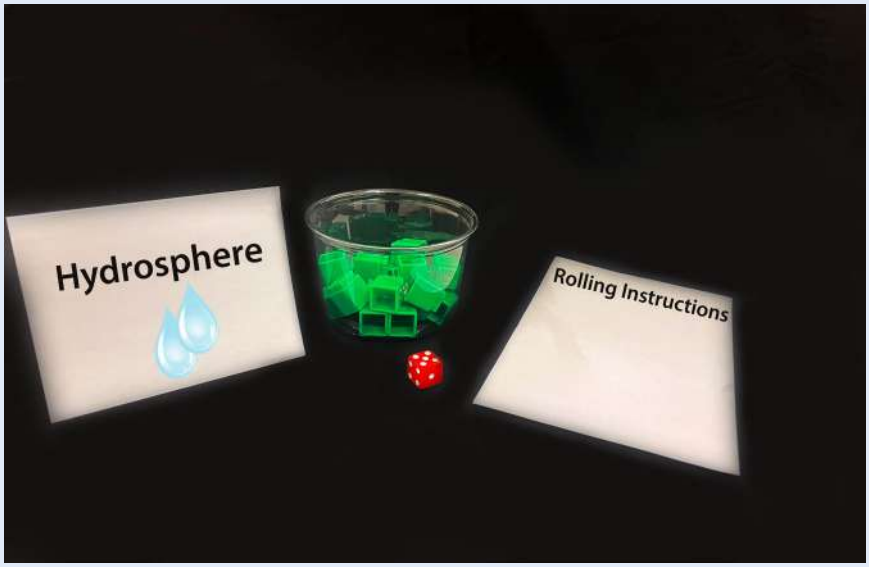


Figure 23: Example of a hydrosphere as one of the four spheres for the Modeling the Carbon Cycle setup.

Lithosphere Rolling Instructions

Carbon in the lithosphere includes soil, rocks such as limestone and chalk, and fossil fuels such as petroleum (oil), coal, and natural gas.

1: Carbon remains in the ground! **Stay in the lithosphere.**
2: Carbon remains in the ground! **Stay in the lithosphere.**
3: Water erodes rocks, moving carbon from rocks into rivers and the ocean! **Move to the hydrosphere.**
4: Carbon remains in the ground! **Stay in the lithosphere.**
5: Carbon remains in the ground! **Stay in the lithosphere.**
6: Volcanic eruption! **Move to the atmosphere**.

Figure 24: Rolling Instructions Cards. (continued)

Biosphere Rolling Instructions

Carbon in the biosphere is part of all living things. This includes plants, animals, and microscopic organisms such as bacteria, and all the living things on land, in fresh water, and in the ocean.

1: Living things die and become soil or sediment! **Move to the lithosphere.**
2: Decomposition produces carbon dioxide! **Move to the atmosphere.**
3: Carbon is stored in a long-living plant, such as a tree. **Stay in the biosphere.**
4: Living things breathe out carbon dioxide! **Move to the atmosphere.**
5: Carbon is used again by another living thing. **Stay in the biosphere.**
6: Fire releases carbon dioxide! **Move to the atmosphere.**

Hydrosphere Rolling Instructions

Carbon dioxide dissolves into fresh water and the ocean, eventually changing into carbonic acid, bicarbonate, and carbonate.

1: Carbon dioxide remains dissolved in the ocean! **Stay in the hydrosphere.**
2: Carbon dioxide is absorbed by a water plant during photosynthesis. **Move to the biosphere.**
3: Carbon remains dissolved in the ocean! **Stay in the hydrosphere.**
4: Carbon (in the form of carbonate) is used to build marine organism shells. **Move to the biosphere.**
5: Dissolved carbon dioxide becomes part of shells, which later sink to become sediment at the bottom of the ocean! **Move to the lithosphere**.
6: Carbon dioxide remains dissolved in freshwater! **Stay in the hydrosphere.**

Atmosphere Rolling Instructions

Carbon in the atmosphere is mostly found in the form of carbon dioxide, but also includes methane and other gases.

1: Over time, methane breaks down into carbon dioxide! **Stay in the atmosphere.**
2: Carbon dioxide is absorbed during photosynthesis! **Move to the biosphere.**
3: Carbon dioxide remains in gas form! **Stay in the atmosphere.**
4: Carbon dioxide dissolves into water! **Move to the hydrosphere.**
5: Carbon dioxide is absorbed during photosynthesis! **Move to the biosphere.**
6: Carbon dioxide dissolves into water! **Move to the hydrosphere.**

Figure 24: (continued)

13. Read the *Modeling the Carbon Cycle Instructions* and follow the directions.

Modeling the Carbon Cycle Instructions

Get Ready and Model

a. Within your sphere group, read your *Rolling Instructions Card* out loud so everyone is familiar with the different types of carbon in your sphere and how carbon stays in or cycles out of your sphere.
b. Write down the number of carbon counters in your container on the bottom of the *Rolling Instructions Card*.
c. Set a timer for five minutes.
d. Within each group, make a line to help you take turns. On your turn:
    - Roll the die and follow the instructions on the *Rolling Instructions Card* for the number you rolled.
    - If the *Rolling Instructions* tell you to stay in your sphere, go to the back of the line.
    - If the *Rolling Instructions* tell you to move to another sphere, pick up one carbon counter and move to the new sphere. When you arrive, place the carbon counter in the container and go to the back of the line for that sphere.

Analyze and Discuss

After five minutes, count the carbon counters in the container that's in the sphere where you finish. Write down the number on the *Rolling Instructions Card* and compare it to the starting number. Share both numbers with the other spheres.

As a team, discuss:

- How did the number of carbon counters in the different spheres at the beginning compare to the number at the end?
- The carbon might not be evenly distributed at the end of the model. Were there times during the activity when the carbon stored in the atmosphere, hydrosphere, and biosphere were more or less even?
- Why do you think the model showed more carbon in the lithosphere than in the other spheres?

This activity is just a model, which means it might have some limitations. For example, the lithosphere holds 99% of Earth's carbon, but held a lower percentage in this model. Also, it is possible that the levels of carbon did not remain at the starting level as you moved around while you were modeling the carbon cycle. Although the model may not have remained balanced, the natural carbon cycle is balanced among the spheres.

14. Think with your team about Earth's carbon cycle.
    a. How do you think this model shows the cycling of Earth's carbon?
    b. In the natural cycling of Earth's carbon, do you think the amount in different spheres changes a lot, or does it remain at about the same level even though carbon is being added and taken away?
15. Turn to a partner and discuss, based on what you know.
    a. Based on what you already know about GHG emissions, what do you think are things people are doing that may change the natural carbon cycle on Earth?
    b. If you think people are adding additional carbon, where do you think it is coming from?
16. Read *Modeling Changes to the Carbon Cycle* and follow the instructions.

Modeling Changes to the Carbon Cycle

Get Ready and Model

Get ready to model the carbon cycle again. However, before you do, replace the *Lithosphere Rolling Instructions Card* with the *Modern Lithosphere Rolling Instructions Card* in Figure 25. These new instructions show how carbon cycling out of the lithosphere has changed since the **Industrial Revolution**.

During and after the Industrial Revolution, people started burning a lot of fossil fuels for energy, using innovations such as the combustion engine. This moved carbon from the lithosphere to the atmosphere at a much more rapid rate.

For some of the *Modern Lithosphere Rolling Instructions* you will now be moving two carbon counters at a time. This helps model the faster rate of carbon cycling from the lithosphere to the atmosphere that is caused by burning fossil fuels. There are also other processes that move carbon from the lithosphere to the atmosphere, such as cement production.

a. Go back to your initial sphere groups.
b. Reset the carbon counters in each container, just as you did for the first model.
c. If you are in the lithosphere group, write down the number of carbon counters in your container on the new *Modern Lithosphere Rolling Instructions Card*.
d. Roll the dice and model the carbon cycle as you did before.

Analyze and Discuss

After five minutes, count the carbon counters in the container that's in the sphere where you finish. Write down the number on your *Rolling Instructions Card* and compare it to the previous numbers.

As a team, discuss:

a. Is your sphere's number of carbon counters more or less than the first model? Share your answer with the other spheres.
b. Did the amount of carbon in the different spheres change?
c. What do you think caused that change?
d. How does this model relate to the climate change story you have been exploring?

In most cases, you should have been left with more carbon in the atmosphere and perhaps more in the hydrosphere and biosphere.

a. More carbon in the atmosphere warms the planet.[37]
b. More carbon in the hydrosphere creates something called ocean acidification, which changes the chemistry of the ocean.[38]
c. More carbon in the biosphere can mean more living things,[39] but these living things need space to live and grow.

Models are not always perfect. The numbers in this model are not exact. It is meant to show the mechanism that moves an increasing amount of carbon out of the lithosphere. Are there ways you would change this model to show how more and more carbon is building up in the atmosphere?

Modern Lithosphere Rolling Instructions

Carbon in the lithosphere includes soil, rocks such as limestone and chalk, and fossil fuels such as petroleum (oil), coal, and natural gas.

1: Carbon from fossil fuels is burned! **Move 2 carbons to the atmosphere.**

2: Carbon remains in the ground! **Stay in the lithosphere.**

3: Water erodes rocks, moving carbon from rocks into rivers and ocean! **Move to the hydrosphere.**

4: Carbon remains in the ground! **Stay in the lithosphere.**

5: Carbon from fossil fuels is burned! **Move 2 carbons to the atmosphere.**

6: Volcanic eruption! **Move to the atmosphere.**

Figure 25: Modern Lithosphere Rolling Instructions Card.

17. Think to yourself or with a partner: You just modeled the problem of rising carbon in the atmosphere due to Industrial Revolution innovations that started using fossil fuels for energy. Do you think there are innovations that could help rebalance the carbon cycle?
18. Read *Modeling a Rebalanced Carbon Cycle* and follow the instructions.

Modeling a Rebalanced Carbon Cycle

In Tasks 3 and 4 you focused on innovations that would change human behaviors and technologies to reduce or stop GHG emissions. If you think about that in relation to this model, this type of innovation would mean replacing the *Modern Lithosphere Rolling Instructions Card* with the original instructions. This change would keep carbon in the lithosphere and out of the atmosphere. This is a very important part of slowing climate change.

However, there are other ways to innovate in the climate story. In this activity you will be considering how to remove carbon from the atmosphere once it is already there. This process is called **sequestration**. Sequestration removes carbon from the atmosphere and stores it in another sphere. There are a number of possible ways to sequester carbon, and this is an area where many people are innovating.[40]

In this activity you will model two different ways to sequester carbon.

- One way is by using machines. This method captures carbon dioxide from fossil fuels as they are burned. This carbon dioxide is then usually placed underground in the lithosphere.
- Another way is based on the natural cycle of carbon. Carbon dioxide is naturally captured through **photosynthesis**. Increasing green areas, planting trees, and protecting existing forests all sequester carbon in the biosphere.

Get Ready and Model

Get ready to model the carbon cycle again.

Keep using the *Modern Lithosphere Rolling Instructions Card*. Replace the *Atmosphere Rolling Instructions Card* with the *Innovations in the Atmosphere Rolling Instructions Card* in Figure 26.

a. Go back to your initial groups.
b. Reset the carbon counters in each container just as you did at the very beginning.
c. If you are in the atmosphere group, write down the number of carbon counters in your container on your new *Innovations in the Atmosphere Rolling Instructions Card*.
d. Model the carbon cycle as you did before.

Analyze and Discuss

Count the carbon counters in the container found in the sphere where you finish. Write down the number next to the others on your *Rolling Instructions Card*. How do the numbers compare? Share your answer with the other spheres.

As a team, discuss:

- Were you able to completely or partially rebalance the carbon cycle?
- What was the role of innovation in rebalancing it?
- Are there things you think would be simple or complicated about trying to sequester carbon to rebalance the atmosphere?

Innovations to sequester carbon might be a very important part of fighting climate change. However, it is hard for sequestration to stop climate change by itself.

- What other things in the model would you want to change to rebalance the carbon cycle back to its natural cycle?

Innovations in the Atmosphere Rolling Instructions

Carbon in the atmosphere is mostly found in the form of carbon dioxide, but also includes methane and other gases.

1: Machines capture the carbon dioxide and move it to deep into the Earth! **Move to the lithosphere.**
2: Carbon dioxide is absorbed during photosynthesis! **Move to the biosphere.**
3: Carbon dioxide remains in gas form! **Stay in the atmosphere.**
4: Additional areas are protected or created to allow for increased photosynthesis and carbon storage in living things! **Move to the biosphere.**
5: Carbon dioxide is absorbed during photosynthesis! **Move to the biosphere.**
6: Carbon dioxide dissolves into water! **Move to the hydrosphere.**

Figure 26: Innovations in the Atmosphere Rolling Instructions.

Understand: *How can we test different innovations?*

Designing an innovation takes time and often requires many small adjustments. Gathering data about different parts of the innovation through experiments can help you make these adjustments. This data can then be used to make a prototype of the innovation to test more thoroughly.

1. Turn to a partner and discuss: A prototype is an early model of an innovation, used to test and improve the design. Why do you think you might want to conduct experiments before designing a prototype?
2. Read *The Green Wall Innovation* and think about the different types of information you would want to have before you prototype.

The Green Wall Innovation

One of the ways to sequester carbon is to increase the amount of carbon stored by plants. But space can be an issue. **Green walls** are one innovation to help solve this problem. Green walls add walls of plants to the walls of buildings.

Figure 27: A building with a green wall.

Green walls can have lots of benefits. The plants can pull carbon dioxide out of the atmosphere and store it in the biosphere. But there are co-benefits as well. Plants can produce oxygen. The roots provide filtration, creating a natural method to clean slightly dirty water, called **graywater**. And plants can help regulate temperature, often providing a cooling effect on buildings and the surrounding area.

What additional information do you think you might need before creating a prototype? For example:

- **Plant selection:** Which plants might grow best in a location?
- **Watering method:** Which watering method would use the least amount of water to keep the plants healthy?
- **Structure design:** How would plants be arranged within the structure?
- **Cooling effect:** Plants can help make an area cooler. Do some plants provide more cooling than others?

There may be many other things you would want to know as well. For example:

- The best amount of sunlight or soil type for the plants you choose
- Plants that might be significant or useful to your community
- The amount of carbon sequestered by different plants

Additional ideas are great. Innovation includes thinking about and gathering information as part of creating your innovation. Considering the information you need and identifying any gaps in your knowledge is very important.

3. As a team, divide up into four **experiment** groups and assign each group one part to experiment on before creating a green wall prototype. The four parts are: plant selection, watering method, structure design, and cooling effect.
4. Read *Designing a Green Wall Experiment* and follow the instructions with your group to design an experiment to gather more information.

Designing a Green Wall Experiment

You will be able to build a better prototype if you first gather information about the different parts of the innovation. The best way to do this is through experiments. You may have designed experiments before. Experiments are a way of finding out the effect of a certain change on an outcome.

Follow these steps with your group.

a. Get out a piece of paper and title it "Green Wall Experimental Design:" then write the part your group is experimenting on. For example: "Green Wall Experimental Design: Structure Design"
b. Create a table like the one shown in Figure 28.

Green Wall Experimental Design: _____

Question	What are we trying to find out?	
Independent Variable	What factor will we change?	
Dependent Variable	What do we want to measure?	
Hypothesis	What do we think the effect will be?	
Procedure	What will be the steps of the experiment?	

Figure 28: Green Wall Experimental Design table.

c. In the *Question* row write down what you want to find out related to the part you are investigating. For example, maybe you want to write, "What is the best structure to hold plants on a green wall?"
d. In the *Independent Variable* row write down the factor you will be changing. The changing factor means the thing you will do differently for the experiment. For example, you might change the watering methods of the plants.
e. In the *Dependent Variable* row write down what you want to measure. For example, if you are trying to find out the cooling effect, how might you measure that? Perhaps you might measure the temperature next to the plants.
f. In the *Hypothesis* row write down your best guess about what the result of your experiment will be. Do you think changing the *Independent Variable* will affect the *Dependent Variable*? For example, do you think the plant species will affect the plant height?
g. In the *Procedure* row write down the steps of your experiment. Use as much detail as possible about how you would set up the experiment and when you would take your measurements.

Procedure Tips

- Imagine you have a whole laboratory that you can use for your **procedure**. Would you want to have rows of plants under grow lights that simulate the sunlight? Would you want to have constant watering or water once a day? You can design the experiment any way you would like.
- Make sure that only one thing is changing at a time. For example, if you are investigating the plants with the most cooling effect, you would only change the type of plants. Although your experiment would have different types of plants, you would treat them all the same way. This might mean giving each plant the same amount of sunlight and water. Changing just one thing at a time helps you understand which change is causing the effect. If you change many things at once, you don't know which one is causing the effect.

5. Share your group's experimental design with your whole team. Discuss together:
    a. Should some of these experiments be done before others, or is it okay to do them all at once?
    b. How could these experiments help you build a better prototype?
6. Read what research mentor Dr. Jayaprakash Saththasivam has been working on with the team of researchers at Hamad Bin Khalifa University (HBKU) in Qatar. How could Jaya's work help you with your innovation?

Jaya says . . .

In 2024, our HBKU team, together with research collaborators, developed a prototype green wall system. This is a living vertical structure that supports urban greening and treats graywater for reuse. We tested different plants and materials in the lab to see which ones could survive Qatar's hot and dry climate while removing pollutants from the water. Then we built a pilot-scale green wall at Qatar Foundation's student housing to see how it performs outdoors. The wall used recycled water from showers and sinks to grow plants, helping save fresh water and cool the surrounding area. This project is important because it shows how nature and science can work together to solve water and climate problems in desert environments like Qatar.

7. With your group, examine the following four boxes and find the experiment that is most similar to the one you designed. Read about the results of the HBKU researchers. For example, if your experimental design was on plant selection, go to the *Plant Selection Experiment Results*. As a group, answer the questions at the end of the box.

Plant Selection Experiment Results

The research team at HBKU tried to determine which plant species grows best on a green wall. Three species were tested: basil, pothos, and fern. The plants were grown and measured over a four-week period to determine which one grows the tallest. All plants were grown under identical conditions, with the same amount of water, light, and soil. Figure 29 shows the results of this experiment.

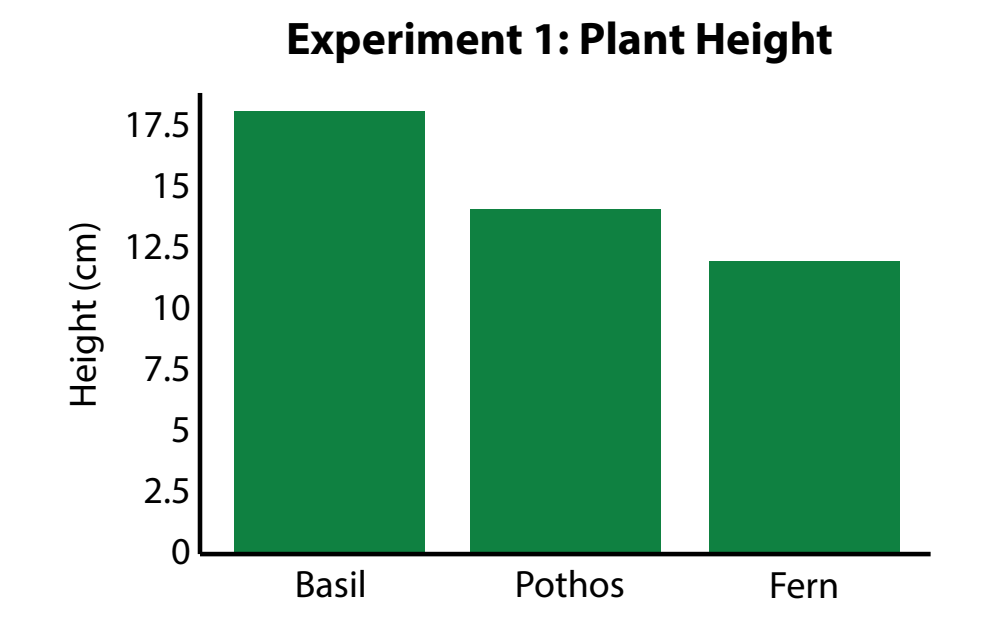


Figure 29: Effect of plant species on plant height. [41]

With your group, discuss:

a. What do you notice about the results from the HBKU experiment?
b. What conclusions do you think you could draw from the data shown in Figure 29?
c. What do you wonder about how this data could help you design a prototype? Is there anything else you would want to know? For example, is plant height the most important thing to measure for a green wall, or should you consider measuring something like leaf coverage?

Watering Method Experiment Results

The research team at HBKU aimed to identify the most water-efficient irrigation method for green wall systems. Three watering methods were tested: **drip irrigation**, **misting**, and hand-watering. All plants were grown under identical conditions with the same amount of light and soil over a four-week period. Plants were scored on their visual health, and researchers measured the amount of water that was necessary per day to maintain plant health.

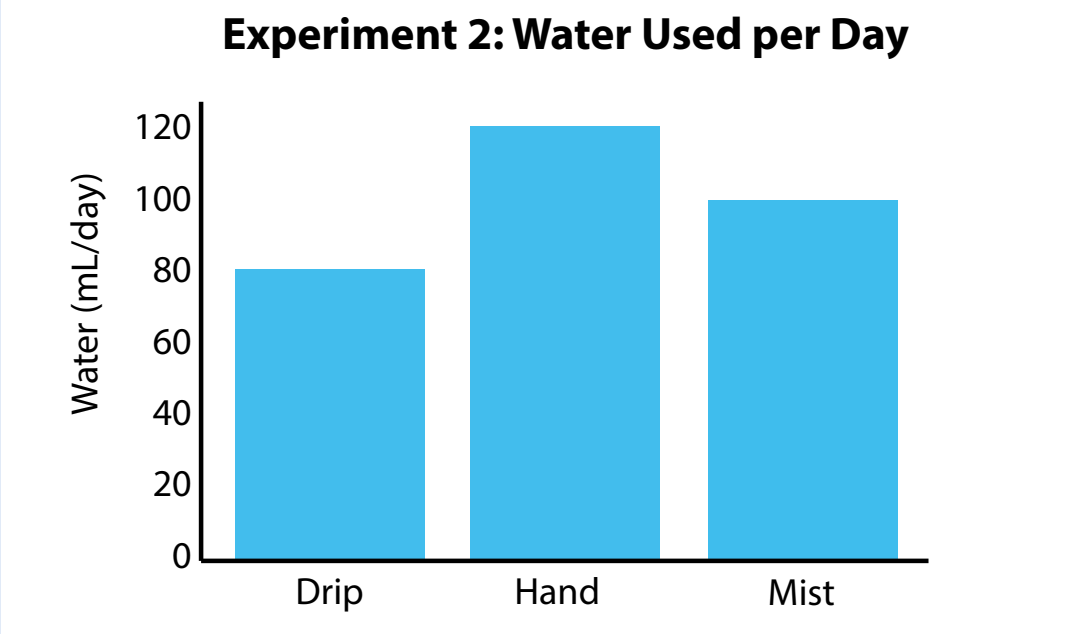


Figure 30: Effect of watering method on how much water is needed to maintain plant health.[42]

With your group, discuss:

a. What do you notice about the results from the HBKU experiment?
b. What conclusions do you think you could draw from the data shown in Figure 30?
c. What do you wonder about how this data could help you design a prototype? Is there other data you would want?

Structure Design Experiment Results

The research team at HBKU evaluated which structure design best supports plant survival. Researchers used three design patterns: grid, staggered, or zigzag. For each design pattern they kept 12 plants under identical conditions with the same amount of water and soil. Researchers recorded the number of plants that remained healthy after four weeks.

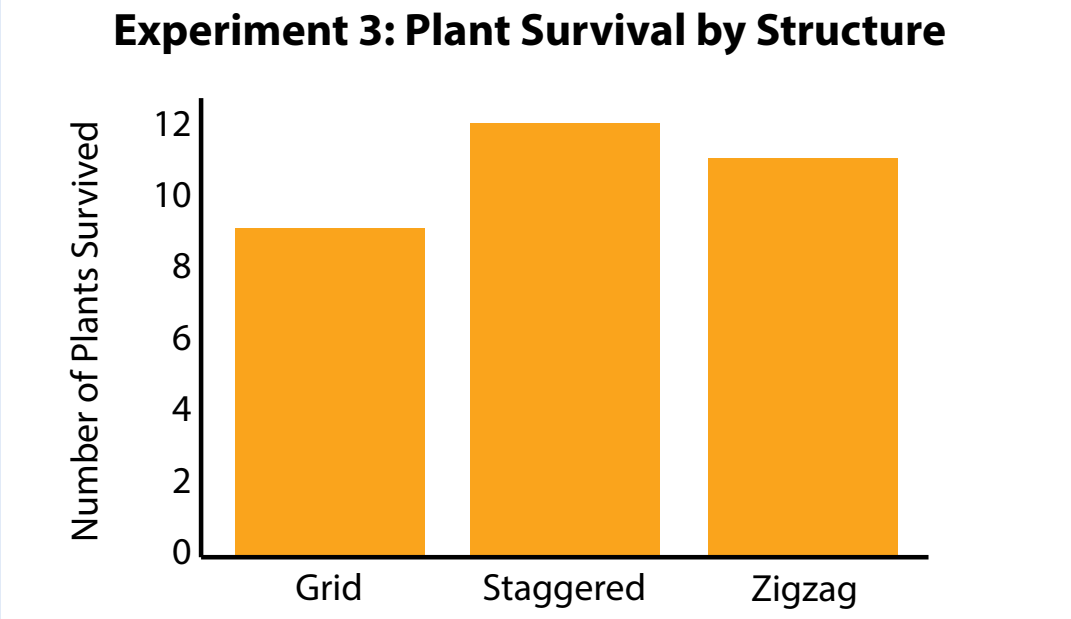


Figure 31: The effect of structure design on plant survival.[43]

With your group, discuss:

a. What do you notice about the results from the HBKU experiment?
b. What conclusions do you think you could draw from the data shown in Figure 31?
c. What do you wonder about how this data could help you design a prototype? Is there other data you would want?

Cooling Effect Experiment Results

The research team at HBKU assessed which plant type provides the greatest cooling effect when used in a green wall. Researchers used three types of plants: fern, ivy, and succulent. Plants were kept under identical conditions with the same amount of light, water, and soil for a four-week period. Researchers measured the temperature drop on the wall surface behind each plant at midday, the hottest part of the day.

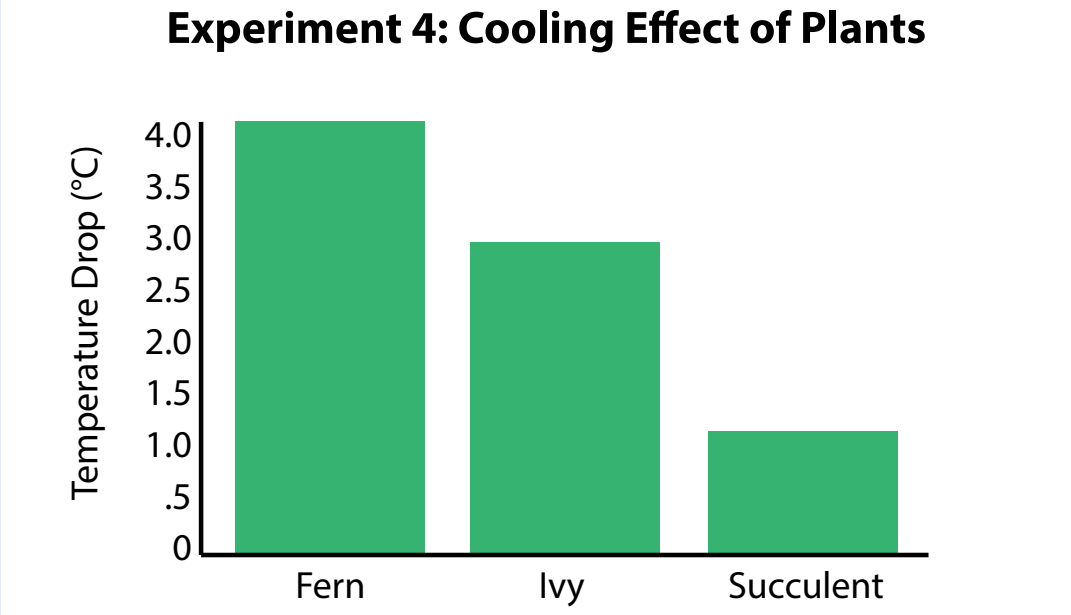


Figure 32: Effect of plant species on temperature drop.[44]

With your group, discuss:

a. What do you notice about the results from the HBKU experiment?
b. What conclusions do you think you could draw from the data shown in Figure 32? Which species cooled the wall the most?
c. What do you wonder about how this data could help you design a prototype? Is there other data you would want?

8. As a group, share the results you examined with the rest of your team. Be sure to identify the ways you would want to use these results to help you design your prototype.

Act: *How would we want to improve sequestration innovations?*

Experimenting and prototyping is all about figuring out how to create the innovation that works the best. The time has come to prototype, to help you move forward with your innovation.

1. Read *Creating a Prototype*, and design and create a team green wall prototype.

Creating a Prototype

A prototype is an early model of a product that's used to test and improve it before making the final version. You will now design and create a prototype.

Design

Use what you learned in the Understand activity to help you create a plan for the design of your green wall prototype. Be as specific as possible, including materials, structure, and location. You can:

- Draw what your prototype would look like and add details to the drawing using colors or words.
- Or you can write a detailed description of your prototype.

Modify to Make It Local

Which experiments from the Understand activity might have different results if they were done in your area? For example, is your climate different from Qatar's, so different plants would grow well in your community?

- Together, create a list of which experiments you would need to conduct to create the best prototype for your local area.

- Are there other things you would want to think about for your local area? For example, would it be important to have food plants as part of the green wall?
- Modify your prototype design to make it work best for your local area.

Create

Construct a basic model of your design idea. This model will help you understand how your design will work in the real world.

- This model can be made from any materials you have available, such as cardboard or fabric. This model does not have to work right now, it is just to help you understand how your design could work. You could also use plant pots to help you build this prototype.
- Think about how you can repurpose materials, such as water bottles or paper, that are typically thrown away.
- Make any final adjustments you need before finalizing your design.

2. Discuss as a team:
    a. What important things do you think you could learn by prototyping? If you want to learn more about HBKU's green wall prototype, you can visit the *Innovation!* StoryMap.
    b. Prototyping is **iterative**, which means it's a process that is repeated, so you should plan to make changes after you create your prototype. What types of changes do you think you might want to make after you create your first prototype?
3. Take out your *Climate Innovation Organizer* and write "4. Experiment and Prototype" on the next blank row.

4. Record your prototype design in the *Changes to the Atmosphere* column on the new *Experiment and Prototype* line. Figure 33 shows a blue box where you should write your ideas.

	Human Behaviors	Producing Emissions	Changes to the Atmosphere	Changes to the Climate	Impacts on Communities
1. Define the Problem					
2. Generate ideas					
3. Select a solution					
4. Experiment and Prototype					

Figure 33: Climate Innovation Organizer with the Experiment and Prototype row in the Changes to the Atmosphere column highlighted.

a. Break into four groups and assign each group one of the remaining parts of the climate change story from the *Climate Innovation Organizer*: Human Behaviors, Producing Emissions, Changes to the Climate, or Impacts on Communities.
b. Read *Experiment and Prototype to Help Solve Climate Change Problems* and follow the instructions with your group.

Experiment and Prototype to Help Solve Climate Change Problems

Experiment and Prototype

Experiment and prototype: Conduct experiments and use results to help you create a prototype. Test the prototype, review results, and revise it to be more efficient and effective, based on those tests.

Examine the *Experiment and Prototype* line for your part of the climate change story in your *Climate Innovation Organizer*.

a. Examine the solution you listed on the *Select a Solution* row.
b. Think about one experiment you would need to do to create a prototype of that solution.
c. Write down a short description of the experiment you would want to do under your part's column in the *Climate Innovation Organizer*. Do not worry if you are uncertain, just do your best. This will not be a final decision; it will just help you continue to explore the innovation process. If you need support in where to write your ideas, you can visit the *Innovation!* StoryMap.
d. Sketch the prototype you would want to build.

5. As a team, think about sequestration innovations to reduce GHG in the atmosphere. You have been thinking about green walls; this is one of many sequestration solutions based on nature. There are also solutions based on machines. If you are interested, you can find out more about some of these solutions by visiting the *Innovation!* StoryMap. Discuss:
   a. What do you personally find most interesting about the innovations to reduce atmospheric GHG?
   b. Why do you think prototyping might be especially important for these types of innovations?
   c. What effect do you think changing the amount of GHG in the atmosphere would have on the rest of the climate change story?
6. Keep your *Climate Innovation Organizer*. You will use it throughout this guide.
7. Read Jaya's thoughts on why prototyping and innovation are important. What do you want to remember?

Jaya says . . .

Experiments and prototypes help us find and fix problems early, so the final design works well when we build it for real. At HBKU, lab trials and a pilot green wall showed which plants and materials work best in Qatar's intense heat, saving time and money. Innovation like this turns graywater into a helpful resource, while green walls cool buildings and make cities more beautiful. These living walls also reduce water use and pollution, helping fight climate change in smart and practical ways. Sharing these successes inspires others to try new ideas that protect our planet.

Find out More!

For additional resources, activities, and innovation examples, please visit the *Innovation!* StoryMap at https://s.si.edu/InnovationGuide.

Meet Your Research Mentor

Meet Dr. Aduwati Sali. Aduwati (pronounced ah-doo-WAH-tee) will be your research mentor for Task 6.

Aduwati is from Penang and is a director at the Institute for Mathematical Research and a professor at the Faculty of Engineering in the Universiti Putra Malaysia. She embraces technology for the well-being of people, from the sea to the forest to the sky. She truly believes youth play a critical role for the future and admires them for their creativity and boldness.

Aduwati's Identity Map

Before you begin Task 6, think quietly to yourself about Aduwati's identity map.

- Are there things you have in common?
- Are there ways in which you are different?

Throughout this task Aduwati will share ideas with you. These ideas might give your team new information or help you think of ways to investigate your community.

Task 6: How can we test innovations in communities?

In this task you will ***discover*** more about how the climate is changing in your local area. Then you will assess your local community to ***understand*** how to create a **field test**. A field test is an opportunity to apply an innovation to a real-world setting and continue improving it to make it work as well as possible. This is the fifth step in the innovation process (shown in Figure 34).

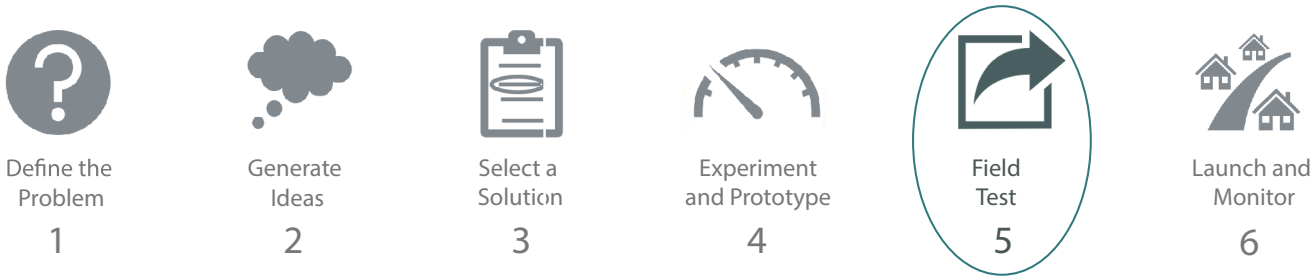


Figure 34: The innovation process, highlighting Step 5: Field Test.

Finally, you will ***act*** by exploring how to use community **feedback** to iterate on your field test and make your innovation better.

Discover: *How is our area's climate changing?*

The global climate is changing.[45] Global climate change affects local areas in different ways.[46] Some places are having periods that are hotter or colder than in the past. Some places are experiencing flooding or sea level rise. Other places are experiencing drought. Some places are having stronger storms, such as hurricanes and typhoons. Other places are experiencing more wildfires. Many places face more than one of these challenges. No matter what the climate experience in your place, innovation can help you adapt and prepare.

1. Remember the problems related to the changing climate that you thought about in Task 1. Which problems do you feel are most significant in your area?

2. Examine the data shown in Figure 35 and, with your team, discuss the graph.
   a. What do you notice about the data being shown on the graph?
   b. What do you think might be a reason for some of the **data trends** you notice on the graph? A data trend is the general direction or pattern of change in the data over time.
   c. What do you wonder about what the graph would be like if it just included data from your local area?

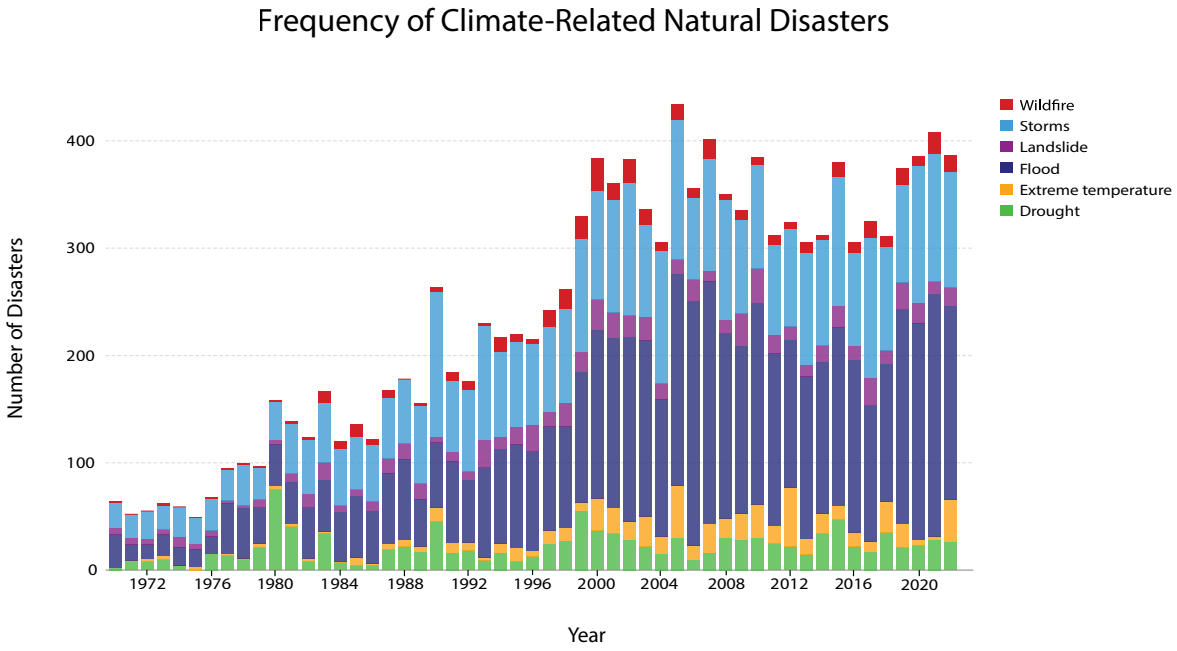


Figure 35: Global frequency of climate-related natural disasters from 1970 to 2022.[47]

⚠ Emotional Safety Tip

Exploring data about natural disasters can be scary, but it can help us understand and prepare for them. Scientists and others around the world are also working hard to understand and prepare for natural disasters. It is okay to pause or take a break if you feel upset.

3. Read *Global to Local Climate Change* and follow the instructions with your team.

Global to Local Climate Change

The global climate is changing,[48] and different areas are experiencing different **climate challenges** as a result of those changes.[49] A climate challenge is a climate-related event that causes problems for people and ecosystems. You are probably aware of some of the climate challenges in your area.

Start by thinking about your local area's **risk** of experiencing a climate challenge. Risk is the likelihood of experiencing something that is negative. For example, if your area has frequent heat waves, it probably has a high risk of extreme heat. However, if your area is very far from the ocean, it probably has a low risk of hurricanes.

a. Give each member of your team seven sticky notes or small pieces of paper.
b. On each note, write down one of these climate challenges: "**extreme heat**," "**flooding**," "drought," "**storms**" (including **hurricanes**, **typhoons**, and **thunderstorms**), "sea level rise," and "wildfires." (If you are unfamiliar with any of these words, they are all defined in the glossary.)
c. You should have one additional note. If you have another climate challenge that concerns you, write it on that note.
d. Draw a line on a class board or on a sheet of paper with an arrow at each end, as in Figure 36. Label one end of the line "Low Risk" and the other end "High Risk." Or use tape, rope, or your imagination to create a line running across your classroom and choose one side of the room to be *Low Risk* and the other to be *High Risk*. Figure 36 shows an example.

Figure 36: Low Risk to High Risk line.

e. Place each of your sticky notes along the line, at the spot you think represents the risk your area has of experiencing that climate challenge. For example, if your area is likely to experience extreme heat, place that sticky note toward the high-risk side of the line. If your area is unlikely to experience a wildfire, place that sticky note toward the low-risk side of the line.

⚠ Emotional Safety Tip

It can be difficult to think about changes to your local climate. It is okay to feel sad, angry, frustrated, or upset. Climate change is not your personal responsibility, but you can become part of efforts to make things better.

You may be thinking that you also care about climate challenges that are a high risk in other areas. That is very thoughtful of you. We all should be concerned about other people and places. However, for this activity you will just be thinking about how changes to the global climate affect your local area.

4. As a team, examine the climate challenges you placed along the line. Discuss:
   a. Are there some climate challenges everyone agrees are a high risk in your local area?
   b. Are there some climate challenges everyone agrees are a low risk in your local area?
   c. How do you think you could find out more about how climate challenges are affecting your local area?
5. Your research mentor Professor Dr. Aduwati Sali works on innovations for a wetland ecosystem called **peatland**. What climate challenge related to peatlands is Aduwati working on? What are the risks related to this challenge?

Aduwati says . . .

The climate challenge I work on is peatland wildfires. In the area of Southeast Asia where I live, these fires create a haze in the air almost every year between July and September. These fires create thick smoke that causes poor air quality, which creates health and economic problems. Peatland forests are slightly different than many other forests. The forest soil stores a lot of carbon. When it is dry, the soil itself can catch fire. It burns underneath, inside the soil. You cannot see the flames, just smoke. It is hard to put out the fire because it is so smoky and underground.

6. Divide your team into groups of four to six people and assign each group a climate challenge that many people think is a high risk for your local area.
7. With your group, follow the instructions for *Finding Local Climate Data*.

Finding Local Climate Data

Climate challenges such as **natural disasters** have always affected people. Natural disasters are natural events that cause harm to people and the environment. Climate change is increasing the challenges many communities are facing.[50] Around the world, challenges related to the climate are becoming more intense, more frequent, and occurring in new locations. Researchers use data, which are pieces of factual information, to help them think about the risk of future climate challenges.

Identify Types of Data

With your group, discuss what types of data could help you understand whether a climate challenge is posing a risk to your community.

For example, data on daily, monthly, or annual temperatures might help you understand the risk of extreme heat or cold. Data on precipitation might help you understand the risk of flooding or drought. Data on storms might help you to understand storm intensity. This data might include wind speed or the height of **storm surge**, which is the level of the ocean where a storm occurs. Data on areas affected by wildfires might help you understand how widespread that problem is.

Choose a Data Time Period

Try to find data that spans many years. You will want to use recent data, but you also need historical data. This will enable you to notice data trends.

- Longer data sets help you understand change over time. You may want to use something called a **baseline**. A baseline is a starting point used for comparisons.

- Climate scientists often use 1850 to 1900 as a pre-industrial baseline, though other baselines (like 20th-century averages) are also sometimes used for comparison. If you can find a baseline to compare your current local climate data to, it might be helpful. For example, if you can find the average local temperature or precipitation between 1901 and 2000, you can compare that to more recent years.

Find Your Data

Use online, library, or other resources to search for data.

- Try to find a set of data that is as local as possible. That means, if you can, try to get data for your town, district, county, or other local area, rather than data for your whole country or region.
- One of the best places to get climate data is online from a government meteorology department or other organizations that collect and share climate data. The *Innovation!* StoryMap also has links to data you can use.
- If you cannot go online, your local library may have some climate data, such as the data contained in almanacs.

8. With your group, discuss the meaning of the data you collected.
    a. What patterns or trends do you notice in the data?
    b. What do you think those patterns or trends mean?
    c. What do you still wonder about your local climate?
9. With your group or by yourself, create a way to communicate the data you found. Follow the instructions and ideas in *Creative Data Representation*.

Creative Data Representation

Humans have been gathering and sharing data for a long time. People are often quite good at noticing patterns or trends in data. But not everyone notices patterns in the same way. For example, some people are very good at noticing patterns in numbers. Others are good at noticing patterns in sounds. Others might be good at noticing patterns in textures. Others might be good at noticing patterns in colors or shapes.

Representing data in different ways can ensure many people can understand the data trends. You will now design a way to creatively communicate the local climate data you found.

Choose the Data You Will Use

Think about what you want others to understand about the local climate data you collected. For example, do you want people to understand recent changes? Changes over the last 100 years? Are there specific changes, such as changes to precipitation or temperature, you want to share? Choose the data type and time period you will communicate.

Choose a Way to Represent Your Data

Data can be represented in many different ways. Think about each of the ways listed here and choose the way that works best for you and your group. For more information on each way of representing data, you can visit the *Innovation!* StoryMap.

- Charts and graphs: You can represent data using bar graphs, line graphs, pie charts, maps, scatterplots, or other methods.
- Visual representation: You can represent data with shapes, symbols, or colors. People use many different methods for visual representation, including drawing, painting, embroidery, and digital tools.
- Three-dimensional representation: You can represent data with objects or things you can touch. People can use different objects, different heights, or textures to represent data.
- Sound representation: You can represent data with different sounds. People can use different pitches, volumes, or sounds to represent data.
- Other representation: Just because it is not listed here does not mean there is not another way to represent data. There are many ways to communicate information.

Create Your Key

Create a list to show what the parts of your data representation mean. There are many ways to do this. These are just a few examples. You could:

- Represent temperature data by assigning different colors to show different temperature ranges.
- Represent rainfall data by assigning different heights of blocks to show different amounts of rainfall.
- Represent the intensity of storm systems using different volumes in a piece of music.

Create Your Data Representation

Use your choice of data, representation method, and your key to create your data representation.

10. Have each group share their data representations.
11. After examining the data representations, discuss as a team:
    a. Does the data make you reevaluate any of your answers on whether your area has a low risk or high risk for specific climate challenges? If so, change where your sticky notes are placed along your *Low Risk/High Risk* line.
    b. Do you think the risks your community faced would have been different in the past? Based on the data, how have those risks changed?
12. Keep your data representation. You will need it when you create a presentation in the next activity.

Understand: *How do we test innovations within communities?*

Each local area is different, and so is the community that lives there. Something may work well in a laboratory but not work well when used in a community setting. That's why field tests are so important. A field test allows you to use an innovation in the environment where it will be placed. This enables you to identify any problems or unintended consequences and fix them.

1. As a team or with a partner, discuss:
    a. How might a laboratory setting be different than a community setting?
    b. Can you think of a situation where an innovation would work well in a laboratory but face unanticipated problems when used out in the community?
    c. What kind of problems do you think you could you learn about by testing something in the environment where it will be used?
2. Read about Aduwati's teams' innovation. Why do you think it would be important to field test the IoT system?

Aduwati says . . .

The innovation my team is working on is using monitoring and **machine learning** to manage peatland fires. This is an **Internet-of-Things (IoT)** system. It consists of sensors that can help monitor the ground, especially the soil in terms of groundwater level, soil humidity, and soil temperature. Then we correlate with data collected from sensors in a local weather station. We use machine learning, which is a type of artificial intelligence (AI) technology, to determine the risk of fires. If the risk is high, we can use fire suppression techniques, like pumping water into the area from a nearby canal.

We first build a prototype in the laboratory at Universiti Putra Malaysia. This allows us to gather data and test whether the sensors would work. Then we bring the system and place it in the real environment in the peatland forests. In the lab, it's a very controlled environment. You can anticipate what might happen. But when you put things into the field, all sorts of unanticipated things can happen.

3. Come together with your climate challenge group from the Discover activity. Remember the climate challenges you found data about.
4. Choose one innovation related to your climate challenge. Figure 37 shows examples of two choices of potential innovations to help adapt to specific climate challenges. Or you can choose another innovation related to your climate challenge. Visit the *Innovation!* StoryMap to learn more about these innovations.

Climate Challenge	Innovation Choice 1	Innovation Choice 2
Extreme heat	Adding shade	Adding green walls and roofs
Extreme cold	Insulating buildings	Planting trees as a windbreak
Flooding	Flood barriers	Rain gardens
Drought	Collecting rainwater	Planting drought-resistant plants
Storms	Reinforced roofs	Restoring mangroves
Sea level rise	Sea walls	Restoring coastal wetlands
Wildfires	Wildfire sensors	Create low-vegetation buffer zones

Figure 37: List of climate challenges and innovation choices.

5. Describe your innovation in a few sentences. If you can, find or draw a picture of this innovation as an example. Record this information on a piece of paper or as part of a digital slide show. You will use it when you create a presentation at the end of this activity.
6. Discuss with your group: How could a field test help show that your innovation could help with your climate challenge and is suitable for your local area?
7. With your group, you will now design a field test for the innovation you picked. Read *Picking a Field Test Site* and follow the instructions with your group.

Picking a Field Test Site

Location is one of the most important things you need to decide when designing your field test. You want to pick a site that will allow you to understand any problems or issues your innovation will face when it is used more widely. Each field test site might produce slightly different results. Scientists and engineers sometimes field test in several places.

You will not be implementing this field test, so don't worry for now about whether you personally could reach a field test site.

a. Start by discussing the type of place where you would want to test this innovation. For example, if you were testing a sea wall, you would need it to be next to the sea. If you were planting trees as a windbreak, you would probably want them to be somewhere that is currently windy.
b. Determine and write down your criteria. Make a list of everything you need for a field test site. Include:
    - The type of environment where the innovation will be used. For example, does it need to be outside?
    - The type of place that experiences this problem. For example, you want to choose a place where flooding is a problem if you are field testing a flooding innovation.
    - Any additional needs for the innovation? For example, does it need electricity or a lot of space?
    - Any additional research needs? For example, does the site need to be close by, so you can visit to collect data during the field test?
c. Read through the investigations in this box and choose how to investigate your site. You can use either digital mapping, community observations, or both.
d. After completing your investigation or investigations, pick your field test site.

Digital Map Investigation

Many communities have access to digital maps for their area. You can use these as tools to determine where you would want to test your innovation. The *Innovation!* StoryMap has links to some of these tools.

a. Satellite maps: Online maps often have a satellite layer you can view. Often this just means clicking a box on a digital map. You can use a map like this to help you narrow down where you could do a field test site, based on your criteria. Some tools even have older satellite images that allow you to see how a location has changed over time.

- For example, if you are trying to restore mangroves, you could search to find spots along the coast for mangrove restoration. You might even be able to use digital tools to go back 10, 20, or 30 years and identify where mangroves used to be in your community.

b. Street-level maps: Online maps sometimes have a street view layer you can examine. You can use a map like this to help you observe an area more closely to determine whether a space might work for your field test.

- For example, if you are trying to add green walls, you could use the street level view to search for buildings that might be a good spot to test a green wall.

Community Observation Investigation

You can also use direct community observation to select a field test site. This does not have to be far away. It could be in the area just outside your school. Go to a few places you think might work and observe those locations. Do they have everything you need for your field test? Which one might be best?

A community observation can help you observe the environment in more detail. This means you can notice small details about where you might place your innovation. It also means you can notice how people are currently using the space. If you can, observe the space at different times of day or think about what you would notice during different times of year.

8. Find or create a map or photo of your field test site. Record this information on a document or as part of a digital slide show. You will use it when you create a presentation at the end of this activity.
9. Read about Aduwati's experience. What kind of problems did the field test help her identify, and why was that important?

Aduwati says . . .

In 2020 we had deployed the first IoT system and we were analyzing the results. But then we noticed the data was way off. The forest rangers went to investigate and found that the sensors were being bulldozed by wild boars! Then there was another sensor that was not behaving right. When we investigated that one, we found the electrical box for the sensor was full of an ant nest. So we had to fix this. We made an enclosure to protect against the boars. We worked with the engineers to redesign the box so ants couldn't get in. Deploying in the field helps you find and solve new problems.

10. With your group, discuss and make notes on what you hope to learn from this field test. Remember, the field test puts a working prototype into a community setting.
    a. What types of problems do you think the field test could help you identify?
    b. What kinds of data would you be able to gather, and how could you use that data to make your innovation better?
    c. Would you be able to determine any unintended consequences? Remember, unintended consequences are when there is a harmful result, even though you were trying to help a situation.
    d. Record this information on a document or as part of a digital slide show. You will use it when you create a presentation in the next step.
11. Create a presentation about your field test. Be sure to include:
    a. Your data representation from the Discover activity to show why this innovation is important.
    b. A description of the innovation from step 5.
    c. A map or photo of the field test site from step 8.
    d. A description of the types of problems, data collection, and unintended consequences you might identify from step 10.
12. Keep your presentation. You will use it in the Act activity.

Act: *How will we iterate on our ideas?*

Field tests give innovators an important opportunity to learn from community members. Innovators may be experts on an innovation, but community members are experts on their community. The best field tests allow time and space for changes, in response to community feedback. This kind of iteration can help make a better innovation.

1. As a team, find a small group of people who know your community well. This community group could include people from your school, community leaders, elders, or people who live near your field test site.
2. Have each group share the field test presentation they made in the Understand activity with the community group.
3. At the end of the presentation, ask the community group for their feedback.
    a. What do they find exciting about this innovation?
    b. Do they have any suggestions to make the field test better?
    c. What type of information do they think you will get from the field test?
4. Think about the feedback you just received. Are there any changes you would like to make to your field test plan in response? Making changes to a plan in response to a field test is not a sign that your plan was not good. It is a sign that you have paid attention to the perspectives of others and iterated to make the innovation better. This flexibility is an important part of being an innovator.
5. Take out your *Climate Innovation Organizer* and label the next blank row "5. Field Test."
6. Write a description of your revised field test plan in the *Changes to the Climate* column on the new *Field Test* line. Figure 38 shows a blue box where you should write your plan.

	Human Behaviors	GHG Emissions	Changes to the Atmosphere	Changes to the Climate	Impacts on Living Things
1. Define the Problem					
2. Generate ideas					
3. Select a solution					
4. Experiment and Prototype					
5. Field Test					

Figure 38: Climate Innovation Organizer with the Field Test row in the Changes to the Climate column highlighted.

7. Divide your team into four groups and assign each group one of the remaining parts of the climate change story from the *Climate Innovation Organizer*: Human Behaviors, GHG Emissions, Changes to the Atmosphere, or Impacts on Living Things.
8. Read *Field Test to Help Solve Climate Change Problems* and follow the instructions with your group.

Field Test to Help Solve Climate Change Problems

Field Test

Field test: Trial the solution in a real-world context and notice any problems. Iterate on the design based on your results.

Examine the *Field Test* row for your part of the climate change story in the *Climate Innovation Organizer*.

a. Examine the solution you listed in your *Select a Solution* line. Where would you want to trial that solution in your community?
b. Use your mapping tools from the Understand activity to help you select a location. Write it down in the *Field Test* row under your part of the climate change story in the *Climate Innovation Organizer*. If you need support in where to write your ideas, you can visit the *Innovation!* StoryMap.
c. Next, consider what kind of information you think you would get from the field. Write down a description of that information. Use the four perspectives to help you think.

- Social: How do people interact with the innovation? Does it support their existing habits or is it difficult for them to use?
- Environmental: How does the natural world interact with this innovation? Does it support a healthy environment?
- Economic: Does this innovation help or hurt people economically? For example, does it get in the way of economic activity or is it too expensive for many people in your area?
- Ethical: Are the positive or negative effects of this innovation distributed fairly? For example, are there unintended consequences?

9. Share your answers with the rest of your team. As a group, discuss:
    a. What are some unintended consequences you would want to make sure you paid attention to during the field test?
    b. What kind of iterations do you think it is likely you might have to make if you were to field test each of your innovations?
    c. Why do you think testing innovations in a community setting would be important, and how could it help improve your innovation?
10. Keep your *Climate Innovation Organizer*. You will use it throughout the rest of this guide.
11. Read what Aduwati says about the role innovation can play in creating a more sustainable future. What do you want to remember?

Aduwati says . . .

We only have one Earth; let's live our lives more sustainably. Think of what you can contribute back to the Earth. No open burning? No single-use plastic? Plant more trees? You know yourself better, and you know what you can do as an individual. And don't forget to have fun!

Find out More!

For additional resources, activities, and innovation examples, please visit the *Innovation!* StoryMap at https://s.si.edu/InnovationGuide.

Meet Your Research Mentor

Meet Dr. Nathan Phillips. Nathan (pronounced NAY-thun) will be your research mentor for Task 7.

Nathan is a physiological ecologist at Boston University in Massachusetts in the United States. He studies how the land interacts with our climate to keep Earth in a livable state. Nathan is inspired by the example ecosystems show us of how we can build and sustain our own thriving and resilient communities.

Nathan's Identity Map

- Interested in biomechanics between trees and humans
- Maps air quality in cities by foot, car, and bike
- Bikes everywhere
- Born in Detroit and grew up in West Sacramento
- Proponent of community science
- Off-grid office now uses pedal power and a solar panel
- Family from Pennsylvania and North Korea
- Fan of public libraries, including libraries of things
- Both a cat and a dog person
- Fledgling tiny forest cultivator
- EEnriched by immigrant communities in the U.S.
- Convinced that climate solutions are all around us

Before you begin Task 7, think quietly to yourself about Nathan's identity map.

- Are there things you have in common?
- Are there ways in which you are different?

Throughout this task Nathan will share ideas with you. These ideas might give your team new information or help you think of ways to investigate your community.

Task 7: How can we launch innovations?

In this task you will ***discover*** more about the impacts of climate change on living things. Then you will analyze your community to ***understand*** more about the best way to share innovations with them. This will help you learn how to launch and monitor, the sixth step in the innovation process (shown in Figure 39).

Figure 39: The innovation process, highlighting Step 6: Launch and Monitor.

*Finally, you will **act*** by reaching out to your **audience** to share your innovation and receive feedback.

Discover: *How might changes to the climate impact our community?*

The changing climate can cause many changes to parts of our lives and planet. Effects range from problems related to food, water, and shelter to the economic impact of natural disasters to impacts on the natural world such as **biodiversity** loss.[51] An impact is the effect or influence one thing has on another. Biodiversity is a measure of the many different living things in an area. Understanding the current changes and predicting the way things may change in the future can help us adapt. **Adaptation** means changing in a way that helps you adjust to something new.

1. With your team, discuss some of the climate challenges that affect your community. You may want to remember the challenges you explored in Task 6. For example, depending on your local area, maybe extreme heat or sea level rise is a climate challenge for your community.
2. Choose one climate challenge you will use to further explore how climate change affects your community.

3. As a team, take out a piece of paper and title it "Impacts of Climate Change."
4. Draw a circle to the far left and write inside it the climate challenge you chose. Figure 40 shows an example.
5. Draw four ovals in the middle of the paper and label them "Social," "Environmental," "Economic," and "Ethical." Write "Effect" and draw lines next to each oval as shown in Figure 40. A printable version can be found on the *Innovation!* StoryMap.

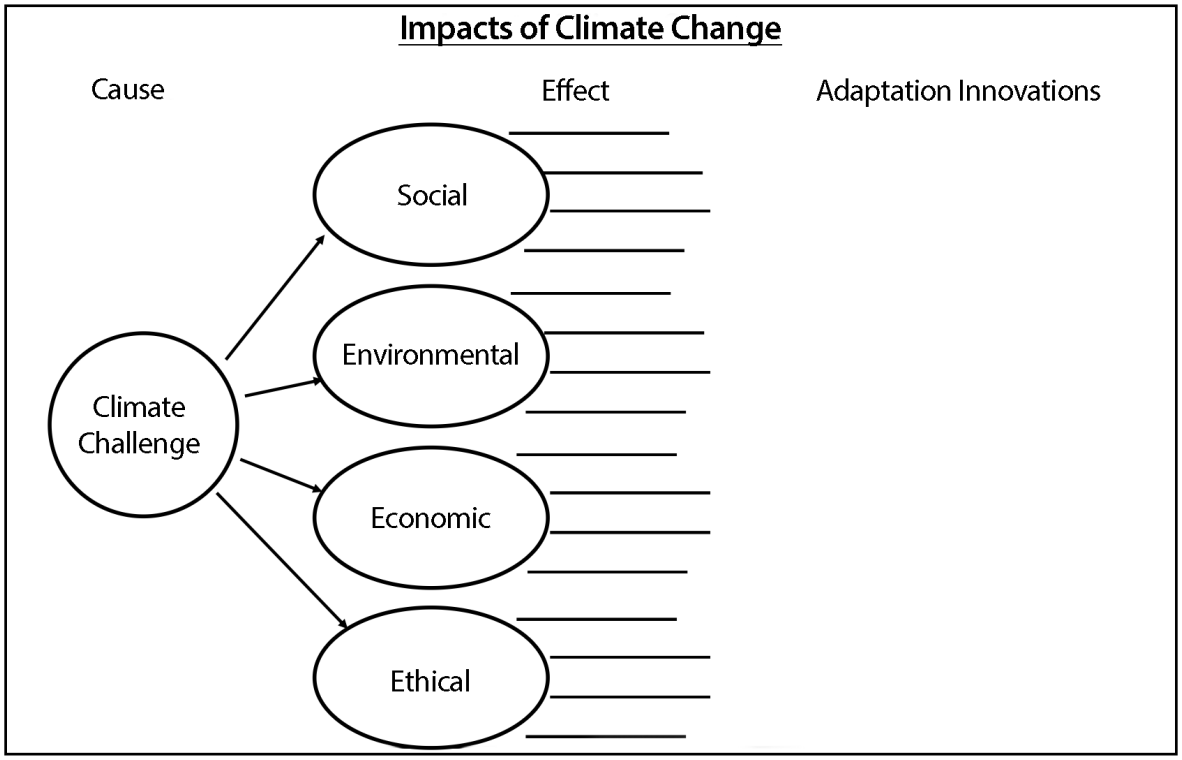


Figure 40: Example of the Impacts of Climate Change chart.

6. Read *Impacts of Climate Change Analysis* and follow the instructions to fill in the lines next to the *Social, Environmental, Economic,* and *Ethical* ovals.

Impacts of Climate Change Analysis

You learned about climate challenges such as extreme heat, flooding, drought, storms, sea level rise, and wildfires in Task 6. Climate challenges can have many impacts on human and non-human communities.[52]

For each of the four perspectives, use the questions in this box to help you list the impacts you can think of on the lines coming out from that perspective's oval. You can list current impacts or impacts you think are likely to occur. Each climate challenge will cause its own set of effects.

Social

How might the climate challenge you are considering affect people's:

- Health: For example, might there be increased disease, decreased access to health care, or decreased access to food or water?
- Well-being: For example, might there be increased stress or decreased ability to do things that bring people joy?
- Interactions: For example, might there be a decrease in opportunities for people to build relationships or an increase in conflicts?
- Education: For example, might it create learning disruptions or make it more difficult to reach a school?

Environmental

How might the climate challenge you are considering affect:

- Natural spaces: For example, a flood might destroy places where living things live or increase water pollution.
- Natural resources, such as land or water: For example, would it change the water or land available? Natural resources are the resources people get from the natural spaces on Earth.
- Living things, such as animals and plants: For example, might it decrease access to water or food, or create a temperature range where some things cannot live?
- Biodiversity: For example, might biodiversity decrease because certain living things could no longer live in an area?

Economic

How might the climate challenge you are considering affect:

- Jobs and economic activity in an area: For example, are there jobs that would change or disappear because of the effects of the changing climate?

- Public property and infrastructure: For example, might it destroy or require new roads, bridges, or public buildings? Infrastructure is built things that stay in your community, for example, bridges, buildings, and train tracks.
- Private property, such as homes or businesses: For example, might there be damage to buildings or other property?
- Businesses that depend on the natural world, such as farming or fishing: For example, might it change the ability to grow crops or affect the fishing stocks?

Ethical

- How might the climate challenge affect people unevenly? For example, are there some people who would be more likely to be impacted by climate change than others?
- Are the people who were most involved in creating the problem of climate change the same people who are most impacted by climate change? For example, are there differences in responsibility and impact between generations or places?
- Are there some people or groups who are given more resources to adapt to this challenge? For example, are there processes that give the most resources to those with the most need?
- Does the climate challenge raise ethical concerns related to the impact people are having on the natural world? For example, are other living things impacted by the choices of humans?

7. Examine your *Impacts of Climate Change* chart as a team and discuss:
   a. Are there effects you already knew about? Did any effects surprise you?
   b. How do the different effects relate to one another?
   c. How certain do you think it is that your community will experience these effects?
8. Think about the effects you listed. As a team, decide how you think the climate change impacts might change if global temperatures changed a lot versus a little.

9. Examine the data shown in Figure 41 that shows the difference in impacts at a climate that is 1.5°C and 2.0°C warmer. Based on the evidence, climate change is happening. But the amount the climate will eventually warm is not yet determined. Each action to reduce emissions helps to limit the amount of warming. Many scientists believe we should try to limit the warming of the global climate to 1.5°C to minimize climate change impacts. With your team, answer these questions.
    a. What do you notice about the relationship between the temperature rise and the climate change impacts?
    b. Remember the different parts of the climate story. Which parts do you think you would need to change to have a smaller rise in global temperature?
    c. What do you wonder about the impacts for different degrees of temperature rise?

Climate Challenge	**Impacts at 1.5°C rise**	**Impacts at 2.0°Crise**
Extreme heat: Percent of global population facing at least one severe heat wave every 5 years[53]	14%	37%
Drought: Global population exposed to severe drought[54]	132.5 million	194.5 million
Sea level: Sea level rise by 2100[55]	+48 cm	+56 cm

Figure 41: Climate challenges and impacts at 1.5°C and 2.0°C warming of the global climate.

10. Examine the *Effects* you listed on your *Impacts of Climate Change* chart. Draw a star next to any effects you think would become worse if the temperature changed more.
11. Read what research mentor Dr. Nathan Phillips shares about how he thinks about innovations related to the climate. Can you think of anything in your community that helps solve more than one problem? For example, is there something that helps with more than one effect or helps reduce emissions while at the same time adapting to a changing climate?

Nathan says . . .

Sometimes we think about nature and people as separate, but they really are coupled. For example, a city itself is a fully interactive system with things such as soils and plants and also things such as people and transportation. When thinking about innovations, there are real opportunities for us to create innovations that help solve more than one problem. Maybe it can make a space better and also help adapt to a changing climate, for example, if you separate cycle lanes and car traffic with curbed **bioswales**. A bioswale is a low area that catches and filters stormwater. So it helps prevent flooding on the road and maintains water quality. At the same time, the bioswale separation is serving as a safety barrier that makes the cycle lane safer.

12. As a whole team or in smaller groups, pick one effect of climate change from your *Impacts of Climate Change* chart and circle it.
13. Write "Adaptation Innovations" on your chart, as shown in Figure 40.
14. In the *Adaptation Innovations* section, list any ways you can think of for humans to innovate to adapt to that change.
    a. For example, if you listed "water scarcity" as a possible effect of climate change, you might list "water-saving devices" or "water-harvesting techniques" as possible innovations to adapt to this climate effect.
    b. You can also list innovations you previously listed in your *Climate Innovation Organizer*.
    c. If you can, try to suggest innovations that help solve more than one problem.
15. Pick one *Adaptation Innovation* you listed. In the Understand activity, you will use this innovation as an example to think about launching an innovation.

Understand: *How can we launch and monitor climate innovations?*

Launching and monitoring is the final step of the innovation process. When you launch your innovation, you share it widely with your community. This means more people can benefit from the work you have done. **Monitoring** the effects of the launch will enable you to continue to iterate and improve your innovation. Monitoring means keeping track of something. In this activity your team will create a launch plan for the adaptation innovation you chose in the Discover activity.

1. Come together with your team and read *Preparing to Launch*. Assign a role to each member of your team.

Preparing to Launch

Imagine you have been working on your adaptation innovation from the Discover activity for a long time. You first understood the climate problem it was trying to solve. Then you generated a lot of ideas and selected the adaptation innovation that fit your criteria. You tested and prototyped your innovation to improve it. Then you conducted a field test and solved any problems you found. At last the day has come and you are ready to share your innovation with the public. It is launch time!

To make sure your launch is a success, you will need a team with many different skills. Divide your team into groups to take on the launch roles listed in this box. If you can, allow everyone to choose the group they are interested in. The groups do not need to have the same number of people, but try to make sure each role has at least one person doing it.

Launch Roles

- **Systems engineer:** Identify and plan for the problems related to producing and transporting your innovation at a larger scale.

- **Impact monitor:** Design an ongoing monitoring plan to track positive and negative impacts related to your innovation.
- **User experience specialist:** Gather feedback to learn about the experience of your users and what would make it better.
- **Communications specialist:** Create **outreach** materials to share with your community to encourage understanding and adoption of your innovation.

2. Before breaking into the launch role groups, come together for a quick whole-team **kickoff** meeting. A kickoff is the official start of something. As a launch team, discuss your goals.
    a. Why do you think this innovation is important?
    b. Where will you launch your innovation?
    c. How many people are you hoping to reach?
    d. Your audience is the group of people who would be most likely to support or find your innovation useful. Who do you think your main audience is for this innovation?
3. Break into groups and use the *Instructions* for your role to help you get started. You will first have seven minutes to discuss your plans with your group. You may want to take notes. Then you will come back together with your whole team for a mid-project meeting and present your **preliminary** ideas to one another. Preliminary means early or in preparation for something to come.

Systems Engineer Instructions

Sharing an innovation widely can increase your impact, but often creates technical challenges. The whole system needs to work together to produce and get your innovation to the users. As a systems engineer, it is your job to identify and solve these technical challenges.

Use the following questions to help you plan.

Production

- How would you produce many copies of your innovation? For example, would you need to use a factory or another location that would help you produce a lot more of your innovation?
- Would you need to consider parts or resources? For example, would you source parts of your innovation from other places? Does your innovation include resources or materials that might be hard to get a lot of?
- What other production problems do you think you would need to solve?

Transportation and Access

- Would your innovation be created locally or would it need to be transported? How would you use the transportation system?
- How would you make your innovation available to people? Would it be given away or sold? Where?
- What other transportation and access problems would you need to solve?

Impact Monitor Instructions

Sharing your innovation widely is wonderful. However, you need to understand the impact it is having—good and bad. As an impact monitor, it is your job to create a plan to continue to monitor or track these impacts.

List Possible Effects

Think about your innovation. As you have learned in this guide, innovations can have very positive effects. However, often there are some negative effects or unintended consequences, as well. Trying to anticipate both is the first step to monitoring.

List the positive effects you hope your innovation has. List any negative effects you think you should watch for. You can use the four perspectives to help you think about the different effects of your innovation, just as you thought about the effects of the climate challenge in the Discover activity. As a reminder:

- Social: Impacts related to the interaction of people in your community and their education, health, and well-being
- Environmental: Impacts related to the natural world, including its systems and living things
- Economic: Impacts related to jobs or costs
- Ethical: Impacts that seem unfair or affect some people or other living things more than others

Design Your Monitoring Plan

For each possible effect you listed (positive and negative), decide how you would monitor that effect.

- What type of data would you need to collect?
- How often would you want to collect that data?
- How long would you continue to collect that data?

User Experience Specialist Instructions

Outreach is about sharing information, and feedback is about getting information back. Getting feedback can allow you to understand the experience of the people using your innovation. As a user experience specialist, you need to design ways to gather feedback from users.

Determine the Information You Need

Choose the most important information to gather about the different parts of your innovation and the experience of using it. For example, you may want to consider:

- What do people find easy or convenient about using your innovation?
- What do they find difficult?
- Was anything confusing?
- Were there any technical problems?

Design Your Survey

Design a survey to get the feedback you need from your users. Survey design requires careful attention. You may want to:

- Limit your survey to five questions or less, since often people will not take surveys if they are too long.
- Try to make your questions as clear as possible.
- Choose whether you are using a scaled or an open-ended survey, or both.
    - A **scaled survey** asks users to rank something. For example, you might ask users to rank "How comfortable did you feel using this innovation?" on a scale of 1 to 5, with 1=not at all and 5=very comfortable.
    - An **open-ended survey** asks questions that people answer in their own words. For example, "What problems have you faced while using this innovation?"
- Consider how to share the survey. Would it be online? In person?

Communications Specialist Instructions

Sharing information through outreach is an important part of your launch. Think about your audience and how you would need to appeal to them or build understanding of your innovation. As a communications specialist, it is your job to design outreach communications to engage with your audience.

Decide on Your Outreach Method

Think about the best way to reach the audience you chose in your kickoff meeting. Where do they get their information and what communication methods are they likely to pay attention to? Pick the outreach method you want to use to communicate with your audience. For example, you could choose:

- Writing: Writing can take many forms—essays, flyers, pamphlets, news reports, fictional stories, poetry, social media posts, and many others.
- Storytelling: Sharing stories can be an important way to communicate ideas. Stories are sometimes shared through public speaking, community conversations, recorded in a podcast or video, or presented dramatically on stage.
- Visual or performance art: There are many different art forms that can be used to share information and encourage others to consider new perspectives. Visual arts like painting, drawing, sculpture, printmaking, textiles, and photography, and performance arts like dance or music, can be powerful ways of communicating.
- Digital tools: Different forms of digital communication, such as memes, gifs, short videos, and other methods, can be used to share information. Often these communications are posted on social media sites and can be shared easily with others.
- Another method: There may be another way you use to communicate with others, or you might combine some of the ways already listed.

Focus Your Message

There may be many things you want to share with your audience about your innovation. However, people sometimes have trouble understanding messages when too much information is shared at once. As a team, choose two to three important things to focus on for your outreach. For example, you may want to make sure you think about:

- The information your community needs to understand why your innovation is important. For example, how might the innovation affect them or make their lives better?

- The information your community needs about how to get access to or use the innovation. For example, where would they get the innovation and what would they do once they have it?

4. Come back together as a whole launch team for your mid-project meeting.
5. As you meet, have each group present their current plan and offer your ideas and feedback.
    a. What are the strengths you notice about the current plan?
    b. Are there any weaknesses you notice? This might include additional ideas they should think about, anything you found confusing, or other suggestions you have that could make their plan even better.
    c. What connections do you notice between your launch role group's plan and the plans of the other groups? How can the different roles support each other?
6. Return to your launch role groups and use the ideas shared during your mid-project meeting to make your plan better.
7. Finalize your plan and get ready to share it formally as part of the team's launch plan. You may want to make a digital slide, a poster, print out a survey, or use another communication method. You can use the method that works best for your group and the information you are sharing.
8. Come back together as a launch team and get ready to share your launch plan. Your launch plan is the presentation you created from each of the four roles on your launch team.
9. Find one or more people in your community to share your launch plan with. If possible, find a member of the audience you identified. If that is not possible, you can share with a teacher, friend, family member, or trusted adult.
10. Share your launch plan and get feedback from your audience member.
    a. What excites them?
    b. What worries them?
    c. Are there suggestions they have to make your launch plan better?

Act: *How will we bring climate innovations to our community?*

Bringing an innovation to your community is often very exciting. However, you still need to continue to monitor your innovation. The best innovators always continue to consider ways they can improve their innovation.

1. Think about your experience creating, sharing, and iterating on your launch plan. Discuss as a team:
    a. Why is it important to have people with different roles on the team, and what did you learn from one another?
    b. What did you learn from sharing the launch plan with your community? If you were really launching an innovation, how many people would you want to get feedback from before launching?
    c. What lessons did you learn while creating the launch plan? Is there anything you could have done earlier in the innovation process that would make the launch easier?
2. Take out your *Climate Innovation Organizer* and label the final row "6. Launch and Monitor."
3. Write down the adaptation innovation you have been working on in the *Impacts on Communities* column on the new *Launch and Monitor* line. Figure 42 shows a blue box where you should write your ideas. Underneath your innovation, add:
    a. One technical problem you would need to solve
    b. One thing you would like to monitor
    c. The outreach method you picked
    d. One survey question you would ask

	Human Behaviors	Producing Emissions	Changes to the Atmosphere	Changes to the Climate	Impacts on Communities
1. Define the Problem					
2. Generate ideas					
3. Select a solution					
4. Experiment and Prototype					
5. Field Test					
6. Launch and Monitor					

Figure 42: Climate Innovation Organizer with the Launch and Monitor row in the Impacts on Communities column highlighted.

4. Gather your four launch team role groups from the Understand activity and assign each group one of the remaining parts of the climate change story from the *Climate Innovation Organizer*: Human Behaviors, Producing Emissions, Changes to the Atmosphere, or Changes to the Climate.
5. Read *Launch and Monitor to Help Solve Climate Change Problems* and follow the instructions with your group.

Launch and Monitor to Help Solve Climate Change Problems

Launch and Monitor

Launch and monitor: Finalize and launch your innovation. Continue to monitor the effects and respond to any areas for improvement.

Examine the *Launch and Monitor* line for your part of the climate change story in the *Climate Innovation Organizer*. If you need support in where to write your ideas, you can visit the *Innovation!* StoryMap.

a. With your group, think about the solution from the *Select a Solution* line for your part of the climate change story.
b. Consider how your role would help launch and monitor that solution. How would your plans be different for this innovation than they were for the innovation you were thinking about in the Understand activity?
c. On the *Launch and Monitor* line on your climate change story part column, write a few lines explaining your role's part of the launch plan for this new solution you are considering. For example, if you are:
    - A systems engineer, write down the new production, transportation, and access problems you identify.
    - An impact monitor, write down some of the different impacts you would want to monitor.
    - A communications specialist, write down who the new audience is and how you would reach them.
    - A user experience specialist, write down a few questions you would want your survey to include.

6. As a whole team, discuss:
    a. How do the things you need to launch and monitor change as the specific innovation changes?
    b. Why is planning to launch and monitor an innovation an important part of the process?
7. By yourself, examine the *Climate Innovation Organizer*. The organizer should now be complete. Think quietly to yourself:
    a. Where in the climate change story do you think are the best possibilities for innovation?
    b. Where do you think you would personally be most interested in contributing to innovating?

8. With your team, discuss:
    a. Why do you think it is important for different people or different groups to innovate on different parts of the climate change story?
    b. How can innovations in one part of the climate change story support innovations in another part?
    c. Can you think of any innovations that solve more than one part of the climate change story?
9. Keep your *Climate Innovation Organizer*. You will use it in the final task as you choose the innovation you will work on.
10. Read what Nathan says about the potential for people to make a difference through innovation. What do you want to remember?

Nathan says . . .

Global environmental change can seem daunting and **intractable**. Often the scale and size of the problem seems overwhelming. And yet there are many opportunities where we can intervene with innovation to change the current system. You can do something a little different and show what's possible. No one has to solve it individually. If we can show others what's possible in how to do things differently, then there's a potential for that idea or that innovation to spread.

Find out More!

For additional resources, activities, and innovation examples, please visit the *Innovation!* StoryMap at https://s.si.edu/InnovationGuide.

Task 8: How will we innovate?

In this task you will ***discover*** how you would like to innovate to help rewrite the climate change story. Then you will develop a plan and put it into action to ***understand*** more about your proposed innovation. The Discover and Understand activities in this task will guide you to complete the entire six steps of the innovation process, as shown in Figure 43.

Figure 43: The innovation process.

Finally, you will ***act*** by reflecting on your innovation, the innovation process, and your own identity as an innovator.

Discover: *Which climate problem will we choose to solve?*

The time has come to choose your own innovation! There are many problems you could choose to solve using innovation to rewrite the climate story. Many innovations might be useful, but choosing an innovation that feels important to you and your team can help increase your persistence.

1. As a team, read *Rewriting the Climate Story* and answer the questions together.

Rewriting the Climate Story

Recall the climate change story shown in Figure 44, which you learned about in Task 2 and throughout this guide. That story began with human behaviors. The activities and industrial processes that result from those behaviors produce GHG emissions. Emissions change the atmosphere. Changes to the atmosphere change the climate. This impacts communities.

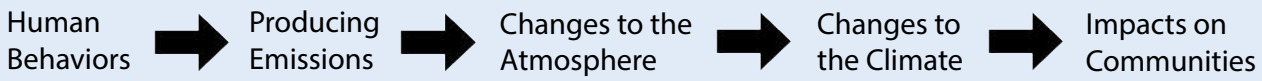


Figure 44: The parts of the climate change story.

In this guide you have thought about how innovation could change each part of this story. As a team, discuss:

a. How could innovation change each part of this story?
b. Why might it be important to try to change the story in multiple ways?
c. Do you think people in other places are also trying to change the story?
d. What have you learned in this guide that can help you think of how to rewrite this story?

2. Think quietly to yourself about which part of the climate change story you would like to rewrite through innovation.
3. With your team, determine the size of the group you will innovate with. In some cases, this innovation group might be your whole team; in other cases you might prefer a smaller group. It is up to you to decide the best size group for you and your teammates. If you want, you can create groups according to which part you would like to rewrite through innovation.
4. With your innovation group, take out your *Climate Innovation Organizer*. You can make copies if multiple groups need to share it.
5. If you formed a single innovation group, try to find consensus on which part of the climate change story you want to rewrite through innovation. Remember, consensus is not competing to win or lose, it is working together to find a balanced decision that works for everyone. If you are having trouble finding consensus about which part of the climate change story you want to rewrite, one or more of these strategies might help.
    a. Share why you care. Tell others why you think innovating on your selected part of the climate change story is important to you. Discuss as a team.
    b. List the good things and bad things about innovations related to different parts of the climate change story. Discuss as a team.

c. Build a sense of group opinion. Each person can vote for two parts of the climate change story and you will innovate on the part with the most votes.

d. Find a slow consensus. Find a partner, and as a pair find consensus on which part of the climate change story you want to rewrite. Then in a group of two pairs (four group members) you can find consensus. Then in a group of four pairs (eight group members) you can find consensus. Keep adding together groups until you have found a group consensus.

6. Review the ideas listed on your *Climate Innovation Organizer* in the column of the climate change part you will be working on. They can help you further refine your innovation.
7. Take out a sheet of paper or open a digital document and title it "Innovation Plan."
8. Divide your paper into six sections to represent the six steps of the Innovation Process.
9. Title the first section of your *Innovation Plan* "Step 1: Define the Problem" and examine what you wrote in the *Define the Problem* row under your climate story part on your *Climate Innovation Organizer*.
10. With your group, think about which specific problem you want to try to solve within this climate change story part. You can use anything you learned or thought about in this guide to help you think.
11. Work together to explain the problem you are trying to solve in a clear statement, starting with "The problem is . . .". For example, "The problem is that people use too much electricity produced in ways that create GHG emissions," or, "The problem is that the sea is rising and threatening the houses built nearby." Your problem will likely be different than these two examples.
12. Write down your problem statement underneath *Step 1: Define the Problem* in your *Innovation Plan*.
13. Read *Defining the Problem* and follow the instructions to add information under *Step 1: Define the Problem* in your *Innovation Plan*.

Defining the Problem

What do you think is causing the problem you defined? Think about whether you can answer this question now or you need more information. You can use some of the previous activities to help you think. For example, you could:

- Analyze the problem using the *Telling the Whole Story Instructions* from Task 2, Discover. You may recall, this activity had you state "The problem is . . ." and then say your problem statement. The next person then states why the problem exists. The next person states the cause of the problem, and so on. Continue until you feel you have come to the end. This is called the root cause. Write it down; this helps to define the problem.
- Gather more information by doing research. You could use the *Defining Climate Change Problems* directions from Task 2, Act, to gather more information. Remember the four perspectives—social, environmental, economic, and ethical. What other information do you think you need to understand the problem, and where could you find it? Gather the information and write it down on your *Innovation Plan* to help define the problem.

14. Title the next section of your *Innovation Plan* "Step 2: Generate Ideas."
15. With your group, start to consider innovative ideas to address your problem. For example, you could:
    a. Use ideas from the *Generate Ideas* row about your climate change story part from your *Climate Innovation Organizer*. Or take some more time to generate new ideas.
    b. Use the *Idea Flurry* instructions from Task 3, Discover, to come up with new ideas. If you recall, in the idea flurry activity you wrote down as many ideas as possible for different types of innovations to encourage behavior change. You considered design, communication, nudge, and model innovations. You could also add or substitute technology or other types of innovation, if you want.
    c. Try **mind mapping** techniques to help you creatively explore new ideas. For example, you could write down your problem in a central circle and then connect it with other circles containing broad categories of ways to innovate to solve the problem. Each of those categories can be further broken down until you capture all your thoughts.

d. Try techniques that look at a problem from different perspectives. For example, what if you adapted a solution that's being used in a different place to address this problem? How could you modify an existing solution to make it better? Or use the four perspectives from this guide (social, economic, environmental, and ethical) to come up with solutions from each perspective.

e. Try tinkering techniques that use materials to help you think. If you have materials such as cardboard, clay, paper clips, or string, you can assemble them in different ways to generate ideas.

f. Any other techniques you like to use to think of new ideas.

16. Write down at least five potential solutions under *Step 2: Generate Ideas* in your *Innovation Plan*. Try to include at least a few solutions you think you would be able to work on right now.
17. Title the next section of your *Innovation Plan* "Step 3: Select a Solution."
18. Just as you did in Task 4, create a list of criteria to help you select your solution. Use the criteria you created in Task 4 as a starting place. Remember that criteria are the list of standards you use to judge or decide something. For example, your criteria might include costs, feasibility, or whether this is something you could do as a young person. Which criteria are most important to your group when selecting your solution?
19. Write your criteria down under *Step 3: Select a Solution* in your *Innovation Plan*.
20. As a group, use these criteria to come to consensus about the best solution to select. If you need more information about how the criteria apply to different ideas, you can do more research about your potential innovation. The *Researching Your Innovation* box in Task 4, Understand, has more information if you need support in researching.
21. Write the solution your group selected under your list of criteria in *Step 3: Select a Solution* in your *Innovation Plan*.
22. Keep your *Innovation Plan*. You will need it to complete this task.

Understand: *How will we create our climate innovation?*

Having a good idea is a very important part of innovating. But for innovators to turn their ideas into actions, they must plan and investigate. You may not be able to complete all the steps of the innovation process before completing this guide. However, the rest of the guide will help you plan when and how to complete this process to bring your innovation out into the world.

1. Title the next section of your *Innovation Plan* "Step 4: Experiment and Prototype."
2. Read *Designing Your Experiments* and follow the instructions.

Designing Your Experiments

Before you can build a prototype of your innovation, you need to consider what additional information you need to know.

a. With your group, list other information you would need to gather before designing your innovation.
   - If you are designing a physical or technology innovation, you might need information about the structure, the best materials to use, or how different parts of the innovation interact.
   - If you are designing an innovation to encourage behavior shifts, you might need information about the best way to present information or opportunities for small behavior nudges.

b. Write down a list of the information you would like to gather under *Step 4: Experiment and Prototype* in your *Innovation Plan*.

c. Choose one piece of information you would like to gather and start to design an experiment for it. If you need help, you can review the experimental design description in *Designing a Green Wall Experiment* in Task 5, Understand.

d. Create and fill in an *Experimental Design Table* like the one shown in Figure 45 under *Step 4: Experiment and Prototype* in your *Innovation Plan*.

Question	What are you trying to find out?	
Independent Variable	What factor will you change?	
Dependent Variable	What do you want to measure?	
Hypothesis	What do you think the effect will be?	
Procedure	What will be the steps of the experiment?	

Figure 45: Experimental Design Table.

3. With your team, think about how you would make a prototype of your innovation. For example, would you:
   a. Build a working model
   b. Draw a very detailed design to scale
   c. Design a **pilot project** for something related to communication or design. A pilot project is a small, early project to test out how well an innovation works and identify any issues.
4. Write a description of your prototype under *Step 4: Experiment and Prototype* in your *Innovation Plan*.
5. Title the next section of your *Innovation Plan* "Step 5: Field Test."
6. With your group, pick a field test site. You can use the *Picking a Field Test Site* box from Task 6, Understand, to help you. You can use mapping or community observations to help you decide on your site.
7. Write a description of your field test site under your prototype description in *Step 5: Field Test* in your *Innovation Plan*.
8. Discuss what information you think you could learn from your field test and add a description underneath what you've already written for *Step 5: Field Test*.
9. Title the final section of your *Innovation Plan* "Step 6: Launch and Monitor."

10. With your group, think about what you would need to create a launch plan, considering the different perspectives of a:
    a. Systems engineer: Consider potential production, transportation, and access issues.
    b. Impact monitor: Consider what impacts you would want to track and the data you need to monitor those impacts.
    c. Communications specialist: Consider the outreach you would need to design to share your innovation with your audience.
    d. User experience specialist: Consider the feedback you would need to understand the experience of your innovation users.
11. Write a description of your launch plan under *Step 6: Launch and Monitor* in your *Innovation Plan*.
12. Is there anything you can do early in the innovation process that would make your innovation easier to launch? If so, go back and make a note of those changes in the previous sections of your *Innovation Plan*.
13. With your group, consider how much time you have to work on your innovation. You completed steps 1 through 3 of the innovation process in the Discover activity. Use the time you have to complete as many additional steps of the innovation process as possible.
14. If you are unable to complete all the steps of the innovation process right now, work with your team to think about what you can do now and how that can be useful in the future. If you are able to, plan when you will complete the remaining parts of the innovation process.

Act: *How have we made our community better?*

Innovators always need to take time to reflect. When something goes wrong it does not mean you did a bad job, it means you have information that can help you make it better next time. Now that you have reached the end of this guide, it is important to think about what you have learned, how you have changed, and what you want to remember the next time you innovate.

1. Find a comfortable place to sit quietly. You may want to have a piece of paper or something else to help you record your thoughts as you reflect on your innovation experience. Or you may just want to think quietly to yourself. Either is fine.
2. Think quietly about the process of completing this guide. Consider:
    a. What went well?
    b. What do you think could have gone better?
3. Think quietly about the process of developing your own innovation with your group. Consider:
    a. How well do you feel you understand the process of innovation?
    b. How would you change your innovation, if you had to do it again?
    c. Do you think you would be more confident about your ability to innovate in the future?
4. Come back together and discuss with your team:
    a. What makes you proud of yourselves as a team?
    b. What do you think you have learned for next time?
5. Examine your *Identity Map* from Task 1. Do you feel any of your innovation characteristics have changed? For example, do you feel more confident or aware of your:
    a. Curiosity
    b. Creativity
    c. Flexibility
    d. Persistence
    e. Collaboration
6. Think quietly to yourself, how will you use these characteristics to continue to innovate in the future?

Congratulations!

You finished the *Innovation!* Community Research Guide!

All of us should be trying to do what we can to change ourselves and our world for the better. Maybe you took a big action. Maybe you took a small action. Maybe it had a big impact. Maybe it had a small impact. The most important thing is that you did something. When you take action to make your community better, you create the world you want to live in. You and your team are changing the world, one step at a time!

Find out More!

For additional resources, activities, and innovation examples, please visit the *Innovation*! StoryMap at https://s.si.edu/InnovationGuide.

End Notes

Task 1

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Glossary

This glossary can help you understand words you may not know. You can add drawings, your own definitions, or anything else that will help. Add other words to the glossary if you would like.

Action researcher: A person who works with their community to discover, understand, and act on local and global problems they learn about

Adaptation: Changing in a way that helps you adjust to something new

Agency: Power

Artistic innovation: A creative expression that encourages individuals and communities think about things differently

Atmosphere: The mixture of gases that surround Earth

Audience: The group of people who would be most likely to support your innovation or find it useful

Baseline: A starting point or level used for comparison

Behavioral innovation: When habits, rules, information, or cultures change to encourage people to make different choices

Biodiversity: A measure of the many different living things in an area

Biosphere: All living things on Earth, including animals, plants, and microscopic organisms such as bacteria

Bioswale: A low area that catches and filters stormwater

Carbon cycle: The natural cycle that moves carbon between Earth's organisms, the ocean, the land, and the air

Carbon sinks: Environments or living things that store carbon

Climate: The long-term patterns of weather in a specific place over an extended period

Climate challenge: A climate-related event that causes problems for people and ecosystems

Climate change: Changes in the patterns of temperature and precipitation on Earth

Co-benefit: A positive effect of an innovation, beyond the primary goal

Collaboration: Working with others for a common goal

Communications specialist: Somone who creates outreach approaches and materials to communicate with an audience

Community: A group of people who share something in common

Complex: Made up of many parts

Consensus: A balanced decision that works for everyone

Creativity: Coming up with new ideas

Criteria: The standards you use to judge or decide something (the singular is criterion)

Curiosity: Wanting to know more

Data: Pieces of factual information

Data trends: The general direction or pattern of change in data over time

Deforestation: The action of clearing a wide area of trees

Dependent variable: The change or effect measured in an experiment

Drip irrigation: A watering method that to uses irrigation tubes to add water directly to the soil next to the plant's roots

Drought: A period of time with much less rain or moisture than usual

Economic: About money, income, and the use of wealth

Emission: Something released into the atmosphere

Environmental: About the natural world

Ethical: The fairness of something

Experiment: A way of finding out the effect of a certain change on an outcome

Extreme heat: When a place gets so hot that it can start to affect the health of people living there

Feasibility: How possible or easily something can be done

Feedback: Receiving information that can help you make something better

Field test: Applying an innovation to a real-world setting

Flexibility: The ability to adapt your thinking

Flooding: When water covers land that is normally dry

Food waste: Food intended for people to eat that is instead discarded

Geothermal energy: Heat from the Earth that can be used to generate electricity

Graywater: Slightly dirty water produced from sources such as baths, sinks, and washing machines

Greenhouse gases (GHG): Gases such as carbon dioxide and methane that cause the atmosphere to get warmer

Green walls: An innovation that adds walls of plants to the walls of buildings

Hurricane: A storm with violent winds that originates over warm ocean waters, also sometimes called a typhoon or cyclone

Hydrosphere: All of Earth's water, whether it is liquid, ice, or in the air, including the ocean, lakes, water vapor, glaciers, and groundwater

Hypothesis: An educated guess about the result of an experiment before you conduct it

Identity: Characteristics that make up each person or thing

Impact: The effect or influence one thing has on another

Impact monitor: Someone who designs an ongoing monitoring plan to track positive and negative impacts

Incremental: Something that happens in small steps over time

Independent variable: The factor that is changed in an experiment

Indigenous: A group of people or other living things that are native to a place and have not migrated from elsewhere

Industrial Revolution: A period starting in the late 1700s when production methods became more mechanized, often powered by the burning of fossil fuels

Informal: Activities that may not be centrally planned or regulated, for example having private transportation operators rather than having a government-run bus system

Infrastructure: Built things that stay in your community (for example, bridges, buildings, roads, and train tracks)

Innovation: Solving a problem with a new idea or method

Innovation motivation: The reason someone creates an innovation

Innovator: Someone who solves a problem in a new way

Integration: Blending two or more things

Iterative: A process that is repeated

Internet-of-Things (IoT): A network of devices with sensors or software that allow the devices to exchange information over the Internet

Intervention: An action taken to improve a situation

Intractable: Hard to control or solve

Kickoff: The official start of something

Launch: To share an innovation widely with your community

Lithosphere: Earth's land, sometimes called Earth's crust, it includes soil, dirt, and rocks.

Machine learning: The process of setting up systems for computers to use data to identify patterns and apply those patterns to make predictions or decisions

Mangroves: Trees or shrubs found in dense masses along the tropical coastlines

Market demand: The interest potential consumers have in buying or using a product

Mind Mapping: A technique to use a visual diagram to represent ideas

Misting: A watering method that sprays plants with a fine mist of water

Monitoring: Keeping track of or watching something

Natural disaster: A natural event that causes harm to people and the environment

Natural resource: The resources people get from the natural spaces on Earth

Nudge: Something in the surrounding environment that makes it a little easier to behave in ways you want to encourage

Open-ended survey: A survey that asks questions people use their own words to answer

Oral history: A record of what people or communities were like in the past

Outreach: An effort to bring information to people

Peatland: A wetland ecosystem

Persistence: Continuing despite obstacles

Perspective: The way we think about the world around us

Photosynthesis: The process plants use to make food, taking in sunlight and carbon dioxide and releasing oxygen

Pilot project: A small, early project made to test out how well an innovation works and identify any issues

Preliminary: Early or in preparation for something to come

Procedure: A list of the steps in the method to conduct an experiment

Prototype: An early model of a product used to test and improve it before making the final version

Question: What an experiment is trying to find out

Radical: A dramatic change from what was there before

Renewable energy: Electricity produced from materials that are easily replenished or ongoing natural systems

Risk: The likelihood of experiencing something that is negative

Root cause: The reason underlying a problem

Scaled survey: A survey that asks users to rank something

Sea level rise: An increase in the height of the world's ocean, relative to land

Sequestration: A process that removes carbon from the atmosphere and stores it in another sphere

Social: The interaction of people in the community and their education, health, and well-being

Social innovation: When people in a community reimagine the way they connect with and support one another

Social norms: Ideas or ways of behaving that are generally acceptable in a place

Storm: A atmospheric disturbance that includes wind and, often, heavy precipitation

Storm surge: A rise in the level of the ocean in an area where there is a storm

Sustainable: An approach that balances different perspectives and can keep working for a long time

Sustainable Development Goals (SDGs): Seventeen goals for a better world, created by the countries of the United Nations

Systems engineer: Someone who identifies and solves problems related to the systems used to produce, transport, and access an innovation

Technological innovation: A new product or process that is engineered to help solve a problem

Thunderstorm: A storm that includes thunder and lightning

Trend: A change in popular behaviors or fashions

Trendsetter: Someone who starts or helps popularize a new way of doing things

Typhoon: A tropical storm, also called a hurricane or cyclone

Unintended consequences: Outcomes of a purposeful action that are not intended or foreseen

User experience specialist: Someone who gathers feedback to learn about the experiences of an innovation's users

Vehicle tailpipe emissions: Emissions such as carbon dioxide, methane, and soot that come out of the tailpipes or exhausts of cars and trucks

Weather: The pattern of temperature, precipitation, wind, and humidity in a place over a short period of time

Wildfire: An uncontrolled fire in a forest, grassland, brushland, or agricultural land

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Innovation!
How can we create new solutions for the changing climate?
Community Research Guide

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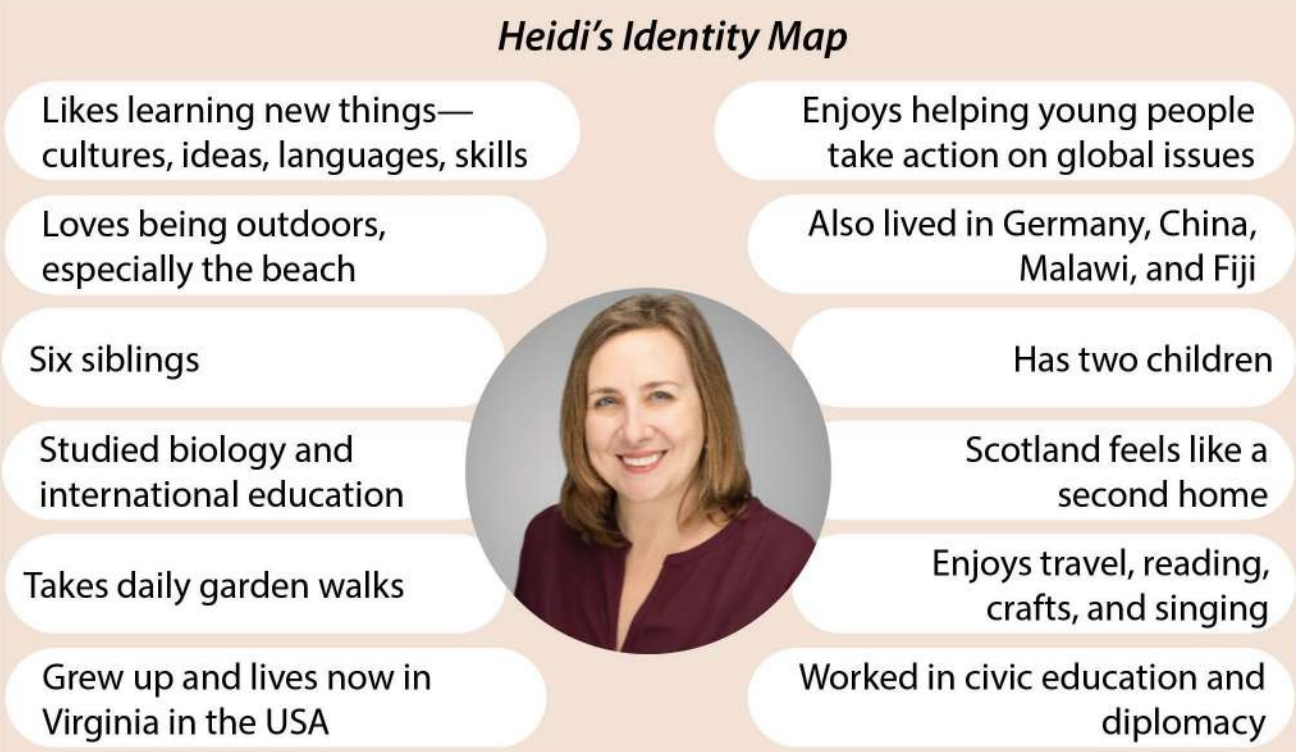
Meet Heidi Gibson, Your Innovation Guide Developer

Meet Heidi Gibson. Heidi (*HI-dee*) was the main person writing this guide. She talked with lots of researchers to get information. However, like anyone, she has her own perspective. You have learned it is important to consider the perspectives of your teammates and research mentors. Perspectives affect what we think and how we think. It is also important to think about the perspective of the writer. This can help you understand why the guide was written the way it was. Considering the source of information is always a good idea. To help you, Heidi filled out an identity map, just like you did in Task 1.

Heidi's Identity Map



Before you finish the guide, think quietly to yourself about Heidi's identity map.

- What questions do you have about the way the guide was written?
- What perspectives does Heidi have that might have made her write the guide the way it is?
- Are there things you would include that were not included?

Do you want to tell Heidi what you would change about the guide? Email her at scienceeducation@si.edu. She'd love to hear from you!

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Attempting to empower the next generation of decision-makers capable of making the right choices about the complex socio-scientific issues facing human society, SSfGG blends together previous practices in Inquiry-Based Science Education, Social Studies Education, Global Citizenship Education, Social Emotional Learning, and Education for Sustainable Development.

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