

Unit 6

Earth's Resources and Human Impact:

How do changes in the Earth's system impact our communities, and what can we do about it?

Student Procedure Guide



THIS BOOK IS THE PROPERTY OF:			
STATE _____		Book No. _____	
PROVINCE _____		Enter information in spaces to the left as instructed.	
COUNTY _____			
PARISH _____			
SCHOOL DISTRICT _____			
OTHER _____			
		CONDITION	
<i>ISSUED TO</i>	<i>Year Used</i>	<i>ISSUED</i>	<i>RETURNED</i>
_____	_____		
_____	_____		
_____	_____		
_____	_____		
_____	_____		
_____	_____		
_____	_____		
_____	_____		
_____	_____		

PUPILS to whom this textbook is issued must not write on any page or mark any part of it in any way, consumable textbooks excepted.

- 1. Teachers should see that the pupil's name is clearly written in ink in the spaces above in every book issued.
- 2. The following terms should be used in recording the condition of the book:
New; Good; Fair; Poor; Bad.



Earth's Resources and Human Impact:

How do changes in the Earth's system impact our communities, and what can we do about it?

Student Procedure Guide

Core Knowledge Science®



Creative Commons Licensing

This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.



You are free:

- to Share**—to copy, distribute, and transmit the work
- to Remix**—to adapt the work

Under the following conditions:

Attribution—You must attribute the work in the following manner:

CKSci 6–8 was originally developed and authored by OpenSciEd, <https://www.openscienced.org>, Copyright 2019. It is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0). The OpenSciEd 6–8 Science Curriculum is available at:*

<https://www.openscienced.org/access-the-materials/>

Additions to the OpenSciEd 6–8 Science Curriculum are marked as “Core Knowledge Science Literacy”. This additional content is the work of the Core Knowledge® Foundation (www.coreknowledge.org) made available through licensing under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.

Noncommercial—You may not use this work for commercial purposes.

Share Alike—If you alter, transform, or build upon this work, you may distribute the resulting work only under the same or similar license to this one.

With the understanding that:

For any reuse or distribution, you must make clear to others the license terms of this work. The best way to do this is with a link to this web page:

<https://creativecommons.org/licenses/by-nc-sa/4.0/>

Copyright © 2022 Core Knowledge Foundation

www.coreknowledge.org

All Rights Reserved.

*Please see full attribution at the back of this book for credited contributors to the development and field testing of the OpenSciEd unit.

Core Knowledge®, Core Knowledge Curriculum Series™, Core Knowledge Science Literacy™, and CKSciLit™ are trademarks of the Core Knowledge Foundation.

Trademarks and trade names are shown in this book strictly for illustrative and educational purposes and are the property of their respective owners. References herein should not be regarded as affecting the validity of said trademarks and trade names.

ISBN: 978-1-68380-733-9

Earth's Resources and Human Impact

Table of Contents

Student Procedures

Lesson 1: Why are floods and droughts happening more often?	3
Lesson 2: What would we normally expect for these places and how do we know it's really changing?	7
Lesson 3: How would increased temperatures affect evaporation?	11
Lesson 4: Are rising temperatures affecting anything else in Earth's water system?	15
Lesson 5: How are rising temperatures changing water stories in these communities? ..	17
Lesson 6: How are rising temperatures connected to two seemingly different phenomena?	19
Lesson 7: Are there any changes in the air that could be related to rising temperatures? .	22
Lesson 8: Are changes in carbon dioxide and methane related to or causing temperatures to increase?	24
Lesson 9: Are the changes in the amount of CO ₂ in the atmosphere part of normal cycles that Earth goes through?	27
Lesson 10: What is happening in the world to cause the sharp rise in CO ₂ ?	29
Lesson 11: Why could burning fossil fuels create a problem for CO ₂ in the atmosphere? ..	34
Lesson 12: How are changes to Earth's carbon system impacting Earth's water system? .	37
Lesson 13: Why is solving the climate change problem so challenging?	40
Lesson 14: What things can people do to reduce carbon dioxide going into the atmosphere?	42
Lesson 15: How can large-scale solutions work to reduce carbon in the atmosphere? ...	45
Lesson 16: How are these solutions working in our communities?	48
Lesson 17: What solutions work best for our school or community?	50
Lesson 18: What can we explain now, and what questions do we still have?	55

References and Readings

About the Data	57
Changes to Snowpack	61
Changes to Groundwater	63
Changes to Glaciers and Land Ice	65
Changes to Sea Level	67

Changes to Streamflow	69
Peer Feedback Guidelines	71
What Causes Wildfires?	73
Transcript: Alaskan Whaler Interview	74
Alaska Graphs	75
Tips for Using Tuva	78
World Energy Consumption, 1800 to Today.....	81
Population and CO ₂ Emissions Graphs.....	82
Carbon Solution Cards	84
Boston: Community Resilience Plan	100
Phoenix: Community Resilience Plan	102
Oscarville: Community Resilience Plan.....	104
Yakima: Community Resilience Plan.....	106
Project Options	108
Water Solution Cards	109
Water Solution Cards Sources	124
Changes to Groundwater	127
What Is Air?	129
Glaciers and Water Supply	130
Gases that Vibrate.....	132
Powering our World	134

Changes to Streamflow	69
Peer Feedback Guidelines	71
What Causes Wildfires?	73
Transcript: Alaskan Whaler Interview	74
Alaska Graphs	75
Tips for Using Tuva	78
World Energy Consumption, 1800 to Today.....	81
Population and CO ₂ Emissions Graphs.....	82
Carbon Solution Cards	84
Boston: Community Resilience Plan	100
Phoenix: Community Resilience Plan	102
Oscarville: Community Resilience Plan.....	104
Yakima: Community Resilience Plan.....	106
Project Options	108
Water Solution Cards	109
Water Solution Cards Sources	124
Changes to Groundwater	127
What Is Air?	129
Glaciers and Water Supply	130
Gases that Vibrate.....	132
Powering our World	134

Lesson 1: Why are floods and droughts happening more often?

Exploring Some Interesting Phenomena

In your notebook



1. Set up two Notice and Wonder charts with the headings “Porterville, CA” and “Vicksburg, MS.”

What I notice	What I wonder

With your class



2. Record what you notice and wonder about each community.
3. After each video, share some of your noticings and wonderings with the whole class.
4. Discuss ideas for what it would be like to live in one of these communities.

Identify patterns in headlines about floods and droughts in small groups.

This map shows locations that have had droughts and floods in just the past few years. Brown markers represent a location that has experienced a drought, while green marks a location of a flood.



With your group



5. Individually read the headlines assigned to your group.
6. Discuss and group similar headlines together. (It may be helpful to highlight similar words.)

7. Add a label for the patterns you are seeing and record on a sticky note.
8. Add the patterns that you recorded on sticky notes to the class T-chart.

Home Learning

Home learning



9. Talk to members of your family and/or community and find out:
 - Has our community experienced anything like this?
 - Have you or your family lived in or traveled to a community that experienced anything like this?
 - Has a member of your family or community experienced anything like this?
 - Bring these stories back to our next class!

Share our water stories.

In addition to Porterville and Vicksburg, we analyzed headlines for other places that are experiencing something similar. Our own community may be experiencing some problems, too.

With your class



10. Share your “headlines” from your own stories and think about where they fit in relation to the other stories and headlines we’ve already seen.

Discuss patterns in headlines about floods and droughts as a class.

With your class



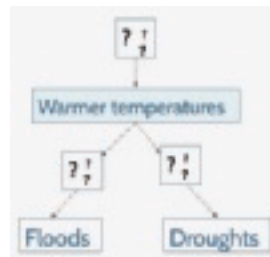
11. Discuss patterns that your group noticed in the headlines.
 - What is similar and different between the drought-related headlines and flood-related headlines?
 - What is happening in these stories that is “not normal?” What is the “new normal?”
 - What did we find in our headlines that could be contributing to our new normal?

Developing and Comparing Initial Models

With your class



12. Discuss what we need to include in our models:
 - What things (components) might we include to explain how a drought or flood happens?
 - How can water move from place to place? What are some processes we might want to include in our models?



In your notebook



13. Individually develop an initial model to explain:

- What is causing the temperatures to increase?
- How can increased temperatures lead to both droughts AND floods?

14. Record any questions that come to mind as you are developing your model.

With a partner



15. Share your initial models and explanations with the group. Together, keep track of the similarities in your models by placing a (✓) next to those items. In each other's models, mark the differences or areas where the group is less certain by placing a (?) next to those items. As you listen, think about the following:

- How did your partner explain how a small change in temperature leads to large changes in other parts of the system?
- What cause did your partner identify that led to an effect of temperature going up?
- Did they explain how or why that caused an increase in temperature?

Initial Consensus Model Discussion

With your class



16. Develop a whole group record of what we agree on and where we have competing ideas across the initial models.

- What do we all seem to agree on?
- What do we disagree on?
- What are some new ideas that we may want to consider?

Individually ask questions.

On your own



17. Look back at:

- your Notice and Wonder chart from the video,
- the patterns from the headlines, and
- your initial models and our classroom consensus models.

18. Choose one or two questions to share with your class, and write each question on a sticky note. Write the question in dark marker and large enough for others to read. Be sure to think about both parts of the model.

19. Be prepared to post your questions to our Driving Question Board (DQB).

Build the Driving Question Board.

With your class



20. Bring your sticky notes with your questions on them, your science notebook, and a chair to our Scientists Circle.

21. Review these steps for forming the DQB:

- a. The first student reads his or her question aloud to the class, then posts it on the DQB near the part of the model to which the question most relates.
- b. Students should raise their hand if any of their questions relate to the question that was just read aloud.
- c. The first student selects the next student whose hand is raised.
- d. The second student reads his or her question, says why or how it relates, and posts it near the question it most relates to on the DQB.
- e. The student selects the next student to share a related question or a new question.
- f. We will continue until everyone has at least 1 question on the DQB.

22. Organize questions into similar categories or groups.

Brainstorm ideas for data and information we need.

With your group



23. Focus on one category of questions.

24. Brainstorm data and information that could help answer these questions.

25. Write your ideas down in your science notebook and be prepared to share them with your class.

With your class



26. Share your ideas for data and information we need and help your class build a list for each category of questions.

Lesson 2: What would we normally expect for these places and how do we know it's really changing?

Navigation

In your notebook



1. Look at the Driving Question Board (DQB) and Ideas for Investigation. Are there any additional ideas you want to add? Put those into your science notebook.

Where is water on Earth?

On your own



2. Record all of the places on Earth that you think water can be found. Consider:
- What areas on the ground can you find water?
 - What areas in the air can you find water?
 - What areas below the ground can you find water?

With your class



3. Share your ideas as a class and work with your class to develop an Earth's Water System Model.

Our Community

With your class



4. What is happening in our community? Consider:
- What is normal for us?
 - How would we know that something is not normal? What would we expect to see?

Data We Need and Why

In your notebook



5. In your science notebook, create a three-column table like this:

Data	Why	

6. Add a list of data we might need to investigate our community and determine if things are normal here or not. Consider:
- What kind of data would we want to look at and why?
 - What information would the data provide us?

With your class



7. Share your ideas for data and your reasoning behind why this is important.

In your notebook



8. Now add “Predictions” to the third column of the chart and consider what we would see in the data to show whether temperature and precipitation are normal or not normal for our community.

Introduce the data and the data sources.

On your own



9. Read about the first three data sources in *About the Data*. Consider where the data comes from and what it means. Complete question 1 on your handout.

Use the I² strategy to analyze and interpret data.

With your group



10. Look at long-term local data in part 2 of your handout.
- This is data from the last 125 years.
 - What do you notice about the graphs?
11. With your group record on your handout:
- “What I see” statements—what observations can you make about the data? What do you see in the data?
 - “What it means” statements—what initial ideas do you have about what these data mean?

What else might we need?

Home learning



12. Consider these ideas:
- Is there any data from today that you want to look at closer? If so, what is it?
 - What else could help us figure out what is normal or not normal for us?

Share information about the data.

With your class



13. How did you interpret the graphs of long-term data? Share your ideas with your class.

With your group



14. Look at short-term local data that your teacher projects.

- Notice how this data is similar and/or different from the long-term data we reviewed.
- Share WIS and WIM statements with your class.

15. With your group record on your handout:

- “What I see” statements—what patterns do you see in the data?
- “What it means” statements—what initial ideas do you have about what these patterns mean?

Making Sense of All Local Data

With your class



16. Share your WIS and WIM statements from all the data with the whole class.

Ways to communicate our findings with one another:

- Our group saw that, too, and we also want to add...
- We saw that pattern, but we have a different interpretation...
- We are still confused about _____. Did anyone else have a question about what that means?

Expand our case sites.

With your group



17. Explore one more case site in depth. You will use a StoryMap at <https://arcg.is/08qrG8> to explore the following:

- a map,
- a video about the place,
- a short paragraph about the place, and
- 4-5 graphs with precipitation, temperature, PDSI, and 1-2 additional graphs.

18. Read about your team’s case site and watch the video of the case site. Work with your group to divide up the data sets among the group members.

19. Use the I² strategy to analyze one data set for your group’s assigned case site.

Consensus Building Across Our Data

On your own



20. Set up a new entry in your Progress Tracker with the lesson question:

What would we normally expect for these places and how do we know it’s really changing?

21. Share claims and evidence about your case site.

- Keep notes in your science notebook about all case sites.
- Add to your Progress Tracker to answer the lesson question.
- Focus on similarities and differences between your site and the other sites investigated.

Scientists Circle



22. Come to consensus:

- What similarities did we hear across sites?
- What differences did we hear across sites?
- What do you need to add to your Progress Tracker?

Next Steps

With your class



23. What should we investigate next to help us understand this problem?

Consider:

- What do we already know about rising temperatures and how they can affect Earth's water system?
- Could we plan an investigation to test to see how temperature affects evaporation?
- How could the same change in temperature cause wet places and dry places? What would we need to do?

Lesson 3: How would increased temperatures affect evaporation?

Taking Stock and Brainstorming How to Test Our Ideas

With a partner



1. Discuss with your partner:
 - What do you think causes evaporation?
 - What is happening at a particle scale when water evaporates? What causes the particles to do what they do during evaporation?
 - Using these ideas, what do you predict will happen with evaporation in warmer temperatures? Why?

With your class



2. Share your ideas with the class.
3. We think temperature is related to evaporation. We may predict that an increase in temperature is causing a change in evaporation.
 - What investigations can we do (or have you done before) where we could gather evidence to see if an increase in temperature affects evaporation?

Collaboratively plan the temperature and evaporation lab.

With your class



4. Get a copy of *Temperature and Evaporation Investigation Planning* from your teacher. Write the investigative question on your planning sheet.
5. Review the lab setup that your teacher shared.
 - How can we use this setup to study things happening at the large scale in the real world?
 - What are the parts of this setup that map to things in the real world?
6. Compare the bottle setup to the real-world and record your thinking on your handout.
7. Now that you know our procedures, which places do our bottles map to? Which do they not map to?
8. Think about the sensor we are going to use.
 - How could we use this tool to answer our question about temperature and evaporation?
 - What exactly does humidity measure?

With a partner



9. Turn and talk with a partner about the following questions:
 - What is the one thing we would want to change to see if it has had an effect on evaporation?
 - What data are we collecting to see if the one thing we've changed matters?
 - How would we know if our one change has had an effect? What are we comparing to each other?
10. Be ready to share your thinking with your class and complete your lab planning sheet.

Conduct the temperature and evaporation lab.

In your notebook



11. Open up to a new page in your science notebook.
12. Draw a data table in your science notebook:

	Start (0 min)	2 min	4 min	6 min	Final (8 min)	Change
Temp						
Humidity						

With your class



13. Look at the *Group Humidity and Temperature Lab* instructions with your class. Ask your teacher any questions you have about the lab.

With your group



14. Obtain the materials you need and follow the instructions to set up your lab.
15. Conduct the lab.
 - Remember to record your data in your science notebook.
 - Calculate the change in temperature and humidity.
 - Average your data with the other group with your same condition.
 - Post your data to the class data table using sticky notes.
 - Follow your teacher's instructions to clean up your lab station.

Analyze the temperature and evaporation lab for patterns.

With your group



16. With your partner, compare the average temperature and humidity level change in the unheated bottles with the average temperature and humidity level change in the heated bottles. What patterns do you notice?

With your class



17. Consider these questions:

- Our question was whether increased temperature affects evaporation. What can we conclude now?
- What patterns did we notice that surprised us or that we weren't expecting?

With a partner



18. Discuss with your partner:

- How are these small-scale bottles useful for investigating large-scale systems?
- What are important differences and limitations?

19. Be prepared to share with your class.

Tracing Water Vapor Visualizations

We have a NASA visualization that shows what happens to water vapor over a period of time. This visualization is made using satellite data and data from weather stations on the surface. It is only for 1 month, June of 2014.

With your class



20. Discuss the following with your class:

- What should we pay attention to that might be different from the bottles?
- Do you have any concerns about using this new data for what we're trying to understand?

21. Take a moment to look over our questions on the Driving Question Board.

- Do we have any other questions on our DQB that might also be answered when examining water vapor using this new data source?

22. As your teacher plays the first visualization, make noticings of what you observe. You do not need to record these noticings in your notebook, but be prepared to share them with a partner or your class.

23. You will watch the visualization again. What do you want to pay attention to in connection to the drought and flood locations?

24. Watch the visualization again and share new noticings.

25. Discuss with your class:

- What patterns are we noticing?
- Based on where there is water vapor, where would we predict precipitation to occur on the map?
- Do our predictions line up with what we observed about data for our flood or drought story locations?

- 26.** View the second visualization that adds ocean temperature data. What new noticings can you make?
- 27.** Discuss with your class:
- What do you notice about this new visualization?
 - What do we think could be happening over here on the West Coast?
 - What new ideas do we have about the flood and drought locations?

Conclusions: Temperature and Evaporation

In your notebook



- 28.** In your Progress Tracker, update what you figured out to our question about how increased temperature affects evaporation.

Turn and talk



- 29.** Share your thinking to this question:

- Does our data support a causal relationship between increased temperatures and increased evaporation?

With your class



- 30.** Work with your class to update the class model. Think about:

- What can we conclude about the effects of an increase in temperature on evaporation?
- There is more water vapor in the atmosphere overall, but precipitation does not fall evenly. What new information might we want to add on the precipitation side of our model?

Navigation

We have updated our model to show the effect of temperature on both evaporation and precipitation. Could other changes also be happening to our system?

With your class



- 31.** Brainstorm with your class: What other sources of water do these communities use that may be important to investigate further?

Turn and talk



- 32.** Talk with your partner: Could increased temperature affect these sources as well? What do you predict?

Lesson 4: Are rising temperatures affecting anything else in Earth's water system?

Obtain information about Earth's water system components.

Our question: Is a small rise in temperature affecting other components of the water system, and if so, how?

With your class



1. Think about and discuss with your class:

- As we read, what are some helpful things we could look for in the text and the data to help us answer this question?

On your own



2. Read about your component of the water system and complete the Obtaining Information checklist as you read.

With your group



3. Gather in a group with students who read the same text.

- Compare your notes.
- Integrate any new information into your checklist.
- Write a summary conclusion about your component.

Consensus Discussion

With your group



4. Share with your class.

- What did the scientists claim was happening and did their data support this claim?
- How did scientists' claims match or not match our initial predictions?

With your class



5. Draw conclusions with your class.

- How are changes to Earth's resources, like water, impacting communities we've looked at?
- How are these different water problems connected to each other?

Update your Progress Tracker.

Take some individual time to capture what we have figured out about our question: Is a small rise in temperature affecting other components of the water system, and if so, how?

On your own



6. Go to your Progress Tracker section and draw a line below your last entry.
 - What question were we trying to figure out?
 - Record what you've figured out and how you learned it.

Navigation

Turn and talk



7. Share with a partner.
 - How has your understanding of the problem changed since the first lesson? Any lingering confusions?
 - How is the small rise in temperature affecting more than just droughts and floods?

Lesson 5: How are rising temperatures changing water stories in these communities?

What have we figured out?

With your class



1. Consider:
 - How are rising temperatures changing water stories in these communities?
 - Have your ideas about droughts and floods changed or stayed the same since the beginning of the unit? Why or why not?

Develop a cause-and-effect diagram.

With your class



2. Using the Model Ideas lists the class has developed, create a cause-and-effect diagram to represent how rising temperatures can cause droughts and floods.

Planning for Our Explanations

With your class



3. What would our explanations include?
 - Who is our audience?
 - What is our purpose?
 - What key model ideas would we need to use?
4. Consider options for communicating with the audience:
 - Write a headline for the site and give a news story that includes a scientific explanation of one community's water story.
 - Create an infographic that communicates how and why water is changing in the community.
 - Other ideas?

Writing in science



5. Use *Initial Water Story Explanation* or blank paper to draft your initial explanation for one community.
6. Refer to column 1 on *Peer Feedback Instructions* to make sure you include important elements of a scientific explanation.

Instructions for Providing Peer Feedback

With a partner



- 7. Read the second column of *Peer Feedback Instructions* and underline and circle places in the explanation that provide either science ideas and reasoning or evidence.
- 8. Refer to *Peer Feedback Guidelines* for guidance on how to provide useful feedback. Here are some examples:

Examples of productive feedback	Examples of unproductive feedback
"Your explanation said that less snow means less water for the community. I think you should add details about why snow matters to this community and how they use the water source."	"I like your explanation."
"Your explanation provides really clear patterns from the data for the community, but it doesn't explain how temperature and precipitation are related, and why that matters for this community."	"I agree with everything you said."

Revise your explanation.

Writing in science



- 9. Read through the feedback and revise your explanation. Follow these guidelines:
 - Read the feedback carefully. Ask someone else to help you understand it, if necessary.
 - Decide if you agree or disagree with the feedback and reflect on why you agree or disagree.
 - Revise your work to address the feedback.
- 10. Turn in both your first draft and your revised explanation when complete.

Exit Ticket

On your own



- 11. Think about:
 - On a scale of 4 (totally independent) to 1 (need lots of help with this), how are you feeling right now about writing a scientific explanation? Briefly explain what makes you feel that way and what help you could use as you develop this practice?
- 12. Write your response on the bottom or back of your explanation.

Lesson 6: How are rising temperatures connected to two seemingly different phenomena?

Navigation and Celebration

Turn and talk



1. Discuss the following questions:

- How has your understanding of the problems of droughts and floods changed?
- What are some big takeaways for you so far in our study of this problem?

Be ready to share your ideas with the class.

Revisit the Alaskan headline.

With your class



2.



Read the headline with your class. Do you think this headline could be related to the other case sites we have learned about?

In your notebook



3. Set up a chart to record the claims and data we might need to explain if the claims in Alaska are related to the other case sites.

Turn and talk



4. Discuss the following question:

- What does the headline claim is happening in Alaska?
- What data would we need to determine if the changes in Alaska are due to temperature increases and precipitation changes?

Be ready to share your ideas with the class.

Listen to the Alaskan whaler claims.

In your notebook



5. Using your chart, record the claims you hear the whaler making and any data sources you think we need to look at as the video is playing.

Be ready to share your claims and any potential data we might need with your class.

Turn and talk



6. With a partner, discuss the following questions:

- What were the claims from the Alaskan whaler that we can add to our chart?
- What data would we need to look at to investigate these claims?

Be ready to share your ideas with the class.

With your class



7. Do we think these changes in Northern Alaska are also related to the claims made in the headline?

Investigate new graphs from Alaska.

With your class



8. Look over the handouts with your teacher. Ask any questions you may have about the task.
9. Work with your group to read the wildfire handout and look at the data. Record your noticings, along with any connections between the graphs and the claims on your handout.

Begin Alaska assessment.



10. Listen carefully as your teacher goes over part 1 and part 2 of the assessment. Ask any questions you may have.

11. Begin the assessment. Use the following to help guide your answers:

Part 1

- Determine if there are any connections between the headline claims and the whaler claims.
- Use your data from yesterday's note-taking page to help you support your answer.

Part 2

- Compare the Alaskan claims and your case site. Are they related phenomena or not?
- Use your data from your news article and your note-taking page to help support your answer.

Think about future projections.

Turn and talk



11. Turn and talk to a partner about the following questions:

- What trends did we notice on our graphs?
- Do you think this trend in data will continue to head in the same direction in the future?

Be ready to share your ideas with the class.

Revisit the Driving Question Board and consensus model.

With a partner



12. With a partner, use *DQB Check-In* to revisit the Driving Question Board (DQB). Mark which questions we have fully answered, partially answered, and not answered yet by placing a checkmark in the appropriate column.

Be ready to share which questions we have made progress on with the class.

Turn and talk



13. What trends did we notice on our graphs?

14. Do you think this trend in data will continue to head in the same direction in the future?

With your class



Work with your teacher to revisit your initial model.

15. Add any new questions, ideas for investigation, or data we might need to the class charts.

Developing New Questions

With your class



We have several ideas about what is causing the temperature of the air to increase and cause our climate to change.

16. What new questions do we have about what is happening for air temperatures to increase?

17. Record your new questions on a sticky note to share with the class!

Be ready to add our new questions to the Driving Question Board.

Lesson 7: Are there any changes in the air that could be related to rising temperatures?

Navigation

With a partner



- 1. Share with your partner: What do you know about what makes up the air?
- 2. Be prepared to share your ideas with your class to record a list of what makes up the air.

With your class



- 3. Record a list of what you already know about what makes up the air.
- 4. Examine the pie chart. Compare with your initial ideas. What do you notice is similar or different from what you were thinking?

Building Understandings Discussion About Parts per Million

With a partner



- 5. Examine the data table showing both percent and “parts per million.” Discuss with your partner: What does the unit “parts per million” mean as a measure of gases in the air? Be prepared to share your thinking with the class.

Gas in atmosphere	Percent by volume (%)	Concentration in parts per million (ppm)
Nitrogen	78.084%	780,840
Oxygen	20.946%	209,460
Argon	0.934%	9,340
Carbon dioxide	0.041%	411
Other trace gases	0.003%	27
Water vapor	varies by location	

Data source: UCAR

- 6. Practice writing one gas as a fraction using a parts per million measurement.
- 7. Share how you would turn the fraction into a percent.

With your class



Analyze changes in composition of cases in the air.

With your class



8. The question we are trying to answer is: Are there any changes in the air that could be related to rising temperatures? What additional data do we need to answer this question?

On your own



9. Complete step 1 on your handout. Annotate the graphs with your noticings. You can write directly on the graph. Add wonderings, too.

With a partner



10. Share your annotations with a partner or small group and add additional notes.
11. Complete step 2, calculating the percent change for each gas over time.
12. Complete step 3, drawing initial conclusions from the data.

Building Understandings Discussion and Add to the DQB

With your class



13. Share your conclusions with your class. Sort the gases into the different categories.

Not really changing	Changing a little	Changing a lot

14. In your own words, share what you've learned about the concentration of gases in the atmosphere.
15. Write new questions for the DQB. Post and organize these questions.

Navigation

With your class



16. What ideas do you have about how changes to carbon dioxide and methane could be related to or causing temperatures to rise?

Lesson 8: Are changes in carbon dioxide and methane related to or causing temperatures to increase?

Navigation

With a partner



1. Share with your partner:
 - What ideas do you already have about what happens when things warm up?
 - Could any of those ideas be useful for explaining how the atmosphere is warming up and whether the gases have anything to do with that?
2. Be ready to share your ideas with your class.

With your class



3. Share ideas with your class that you have about how we could simulate adding energy to the molecules?

Investigate and model molecular motion.

With your group



4. Observe the motion of your molecules as your teacher demonstrates.

Predict molecular motion.

With a partner



5. Share which molecules you think will move the most when they receive energy.
6. Be ready to share your ideas and reasoning with your class.

Describe molecular motion from the interactive.

Writing in science



7. Describe on your handout how each molecule moves when it encounters energy.
8. Describe all the ways each molecule moves when energy is added to it. Record this on your handout.

Share your observations.

With your class



9. Share what you noticed happened to the molecules.
10. Categorize the motion of these molecules into two groups: 1) Molecules that wiggle a lot and 2) Molecules that DO NOT wiggle much.

Navigation

With a partner



- 11.** What do you think we'll see when the energy reaches the molecules? What do we predict happens to the energy next? Be sure to give a reason for your prediction.

Use an interactive to understand more about gases in the atmosphere.

With your class



- 12.** Complete the analogy map with your classmates.
- 13.** Predict which molecules will interact more with energy.
- 14.** Use the interactive, https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_en.html?openSciEd, to figure out what happens to the energy after it makes a GHG molecule wiggle.

Discuss observations from the interactive.

With your class



- 15.** Share observations from the interactive.
- 16.** Contribute to a Building Understandings Discussion with your classmates.

Read about gases.

With a partner



- 17.** Read the article and summarize the main ideas with your partner.
- 18.** Think about how you would develop a model to show how gases in the atmosphere respond to energy.
- 19.** Be ready to share your ideas with your class to make a list of ideas that will help us answer our lesson question.

List ideas that might help answer our question.

With your class



- 20.** Share your ideas that might help us answer the question: Are changes in carbon dioxide and methane related to or causing temperatures to increase?

Update your Progress Tracker.

On your own



21. Our question: Are changes in carbon dioxide and methane related to or causing temperatures to increase? Go to your Progress Tracker section and draw a line below your last entry.

- What question were we trying to figure out?
- Record what you've figured out and how you learned it.

Navigation

With your class



22. Share your ideas about questions you have about increasing GHGs in our atmosphere.

23. What can we do to answer your questions?

Lesson 9: Are the changes in the amount of CO₂ in the atmosphere part of normal cycles that Earth goes through?

Navigation

With your class



1. Discuss these questions:

- What did we figure out about the gases in the atmosphere?
- How do greenhouse gases affect the temperature on Earth?

With a partner



2. Brainstorm:

- Where could you go on Earth today to find snow or ice that lasts from one year to the next?

What might we find in layers of ice?

With your class



3. Take a moment to think: We know things about fossils, and when they lived can be figured out by analyzing rock layers.

4. If you could sample layers of ice or snow from one or more of these areas on Earth, what do you think you might find in these layers that could provide data about what Earth was like long ago?

What do you notice in ice cubes?

With your class



5. Look at an ice cube and make observations. What are some things you notice about it?

6. Watch the short video clip of carbonated water being poured.

- What do you notice about carbonated water?
- What do you know about carbonated water?

Ice Cubes Made with Carbonated Water

Scientists Circle



7. Look closely at ice cubes made of carbonated water.

8. Turn and talk with a partner:

- What are some things you notice?
- How is this ice cube different from the other one made from non-carbonated water?
- How does it compare to what you saw with the carbonated water?

Make predictions.

With a partner



9. What do you predict we will see happen in each of the baggies of ice cubes?
- What do you think will happen in each of these baggie setups?
 - Why do you think this?

How do scientists use ice samples today?

With your class



10. Set up a page in your science notebook titled "Ice Core Sampling" and make a Notice and Wonder chart. As you watch the video clips, record what you observe and any questions you have.

Analyzing Ice Core Data

With a partner



11. Carbon dioxide levels over time can be obtained from ice core data. Analyze the graphs of carbon dioxide levels in the atmosphere and consider:
- Is the change in the amounts of carbon dioxide a normal change?
 - Has this been happening over time?
 - Or is this not normal?

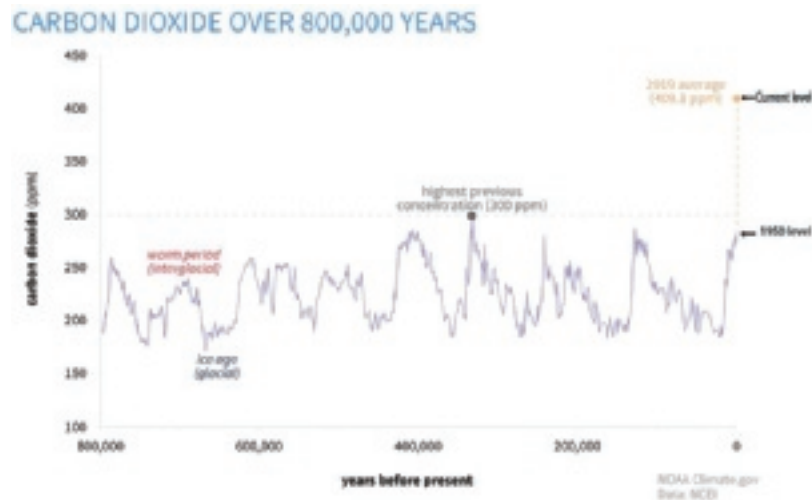
Lesson 10: What is happening in the world to cause the sharp rise in CO₂?

What did we figure out last time?

With your class



1. Take a moment to summarize what we figured out last time related to normal cycles of CO₂ in the atmosphere. Add your ideas to your Progress Tracker.



Climate.gov

Let's zoom in and take a closer look...

With your class

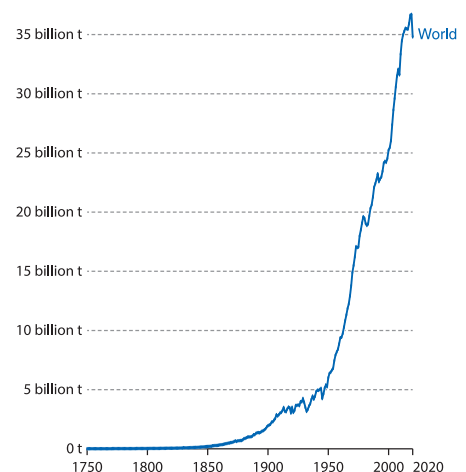


2. As you look over the following graph, think about:

- When did the rise start?
- What does the data show after that point?
- What do we know about this time period? What was happening in the world?

Annual CO₂ emissions

Carbon dioxide (CO₂) emissions from the burning of fossil fuels for energy and cement production. Land use change is not included.



Data Source: Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC)

Where is the CO₂ coming from?

In your notebook



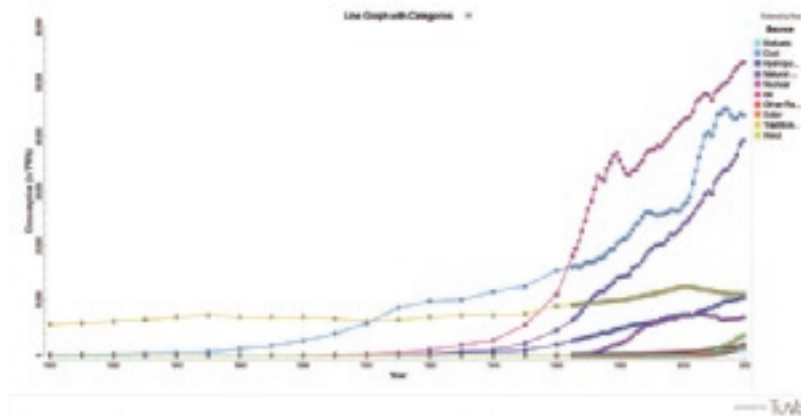
3. Watch a visualization showing where CO₂ is coming from, and take notes in your science notebook about what you notice. Consider:
 - Where is it coming from?
 - Why there?

Changes in Energy Consumption Over Time

On your own



4. Read through *Powering our World*. Mark any places on the text where there are ideas or events that you think might be related to the changes in CO₂.
5. Annotate the graph on *Examining Data Over Time* to show human activities that have led to changes in the types of energy sources that people used over time.



Data Source: Our World in Data

6. Share your noticings with the class and create a shared annotated graph.

Humans and Fossil Fuels

With your class



7. Discuss the following questions:
 - How long have people been using fossil fuels?
 - Why have they been going up so fast since the 1800s and especially since 1950?

What patterns do we notice now?

On your own



8. Use *Population*, *CO₂ Levels*, and *Fuel Consumption* to look at other patterns in population and CO₂ over time.

- First, look at each individual graph and make annotations of patterns in the graph.
- Then, look across the three graphs to notice similarities and/or differences in the data.

With your class



9. If we had to write a formula to say how these things seem to be related, what might we do?

Update Progress Trackers.

In your notebook



10. Add a new idea to your Progress Tracker for our lesson question: What is happening in the world to cause the sharp rise in carbon dioxide?

Navigation

With your class



11. Think about and share your ideas on:

- How is it that this dead plant and animal matter from so long ago can become an energy source for us?
- What is in the fossil fuels that we use for energy?

Navigation and Preparing for Demonstration

With your class



12. Discuss with your class:

- What do we know about fossil fuels?
- How do we get energy from fossil fuels?
- What do fossil fuels react with to produce energy?
- What else do they produce?

13. Consider the following general chemical reaction for the combustion of fossil fuels:

(reactants) (products)

Fossil fuel + oxygen (O₂) → ??

- Is burning fossil fuel *causing* a rise in CO₂ in our atmosphere?
- What questions can you ask and answer to get evidence to answer the question above?

In your notebook



14. Predict the results of reacting a fossil fuel with oxygen gas. Use the following questions to help you with your prediction.

- What happens to the atoms and molecules of the fuel and O_2 ?
- What products do we get?

15. Prepare a clean page in your notebook for recording data from the demonstration.

- Make a two-column chart in your notebook with the headings "Before" and "After."

Burning Fuel Demonstration

With your class



16. What measurements and observations do you need to make with the following setup?



In your notebook



17. Record initial observations and measurements.

Scientists Circle



18. Watch the demonstration and record measurements and observations as your teacher directs.

With your class



19. Participate with the class as you discuss the results of the demonstration.

- Is this sufficient evidence to know the products of a reaction of any fossil fuel and oxygen?
- What additional questions can you ask?

Scientists Circle



20. Participate in another demonstration of burning fossil fuel. This demonstration will burn methanol fuel gel.

- Do you think you will get similar results with this setup or different results?



With your class

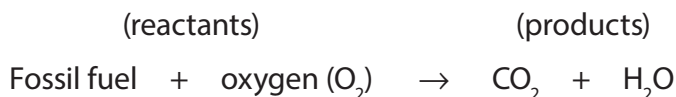


21. Are you convinced that CO_2 and H_2O are products of burning fossil fuels?

- What additional questions can you ask?

Examining the Reactants and Products

We can now add to our equation:



With your class



22. Discuss the following questions with your class.

- What did we learn about the atoms that make up products in a chemical reaction from the *Bath Bombs Unit*?
- How can we use what we know about atoms in a chemical reaction and what we figured out to be products of the reaction to help us predict what fossil fuels are made of?

On your own



23. Jot down what atoms you think make up fossil fuels.

With your group



24. Examine the molecule cards for fuels and sugars. Look for similarities and differences between the two groups of molecules.

- Participate in a class discussion of your observations.

Building Understandings

With your class



25. Participate in a class discussion about what you have figured out so far in this lesson. Consider questions such as:

- Why is extra CO₂ (from burning fossil fuels) in the atmosphere a problem?
- Where did the carbon in the CO₂ come from?
- Where did the fossil fuel come from?
- Where is the carbon from fossil fuel now?

In your notebook



26. Continue to work with your class to add two new model ideas to the Model Ideas list. Add these ideas to your Progress Tracker.

With your class



27. Prepare for the next class by considering these questions:

- What things burn fossil fuels?
- Is there any way to remove the extra CO₂ from the atmosphere?
- Are there natural processes that remove CO₂ from the atmosphere?

Lesson 11: Why could burning fossil fuels create a problem for CO₂ in the atmosphere?

Navigation

Turn and talk



1. Brainstorm with your partner:
 - What things do you know about that give off CO₂?
 - What things do you know about that take in CO₂?

Review and modify the Earth's Carbon System Model.

System models show important system parts and how the parts interact. These models are useful to explain something that is happening or changing in the system and to make predictions about what could happen.

With your class



2. Obtain an Earth's Carbon System Model from your teacher.
3. Examine the carbon system model. Think about:
 - What parts of this model seem familiar to us?
 - Where do you notice different molecules that have carbon in them?
 - Where do you see carbon moving between places?
 - What parts of this model are new or different from what we've talked about?

With a partner



4. Think about the new things you learned about that are not represented in this model.
5. Pick a new color to represent "changes humans make for energy needs." Color the key with the new color.
6. Change the model to show
 - new parts if you want to add any,
 - processes that humans do that move carbon into our out of the atmosphere, and
 - processes that humans do that move carbon from underground.

With your class



7. Let's use our model to predict what could be happening in the system to cause carbon dioxide to increase in the atmosphere. What are some of our ideas?

Carbon Dice Game

With your class



- 8. Listen as your teacher explains the game.
 - Stations represent locations where there’s a lot of carbon.
 - You are carbon atoms that will move through the system.
 - You will roll the dice and move to different locations based on the number you rolled. When you move, it represents a carbon atom moving along an arrow in our model.
- 9. **Round 1** of the game is the carbon system when fossil fuels were locked underground. Some of you will be locked in place.
- 10. **Round 2** of the game is the carbon system when people started to use fossil fuels for energy.
- 11. Make observations during rounds 1 and 2.
- 12. Return your dice to your teacher when complete.

Carbon Dice Game Discussion

With your class



- 13. Discuss the following:
 - How did carbon move through the system before combustion of fossil fuels?
 - What changed when we added combustion?
 - Why do we think this change happened?

Noticings: Rates of Carbon Moving In/Out of Atmosphere

Scientists measure and estimate rates of CO₂ given off and taken in from the atmosphere. Below are estimates of how many gigatons (1 billion tons) of CO₂ are given off or taken in each year.

With your class



- 14. Examine the rates. What do you notice?

Process in Carbon System	Gigatons Carbon Per Year
Photosynthesis	121 GtC/year
Cellular respiration by plants, animals, and decomposers/soil	119 GtC/year
Combustion of fossil fuels	10.5 GtC/year

Building Understandings Discussion

With your class



15. Discuss with your class:

- What do you notice about the rates of the natural processes of photosynthesis and cellular respiration?
- What do you notice about the rates of processes putting CO₂ into the atmosphere compared to the process taking CO₂ out of the atmosphere?
- What is the difference between CO₂ going into and out of the atmosphere?
- What can we conclude from our simulation with dice and these rates?

Add new model ideas.

With your class



16. Work with your class to summarize what you figured out using the rates of each process in our Earth's Carbon System Model.

17. Add ideas to your Model Ideas list.

Navigation

On your own



18. Look at the rates on our carbon system model. Using these numbers, explain what is causing a buildup of CO₂ in the atmosphere.

- Include the rates in your response to help you make comparisons.

Lesson 12: How are changes to Earth's carbon system impacting Earth's water system?

Review our cause-and-effect diagram from Lesson 5.

Turn and talk



1. In your partner pairs, review the diagram to explain how an increase in temperatures can lead to an increase in droughts and floods for some communities.
2. Go from box to box to explain the causal chain.

Compare and update models.

With your group



3. Work with your group to update your models showing the connection between fossil fuel use and our increases in temperatures.
 - Complete your diagram boxes with your group. Start with the “fossil fuel use” box and work your way over to the “increases in temperatures” box. Explain how each box is connected in your groups.
 - Discuss how each box is supported by a model idea(s). Write that model idea(s) number under the box.
 - After the boxes from “fossil fuel use” to “increases in temperatures” have been constructed and supported with model ideas, determine which model ideas support our Lesson 5 model by adding in the model ideas numbers.

Develop a consensus model.

With your class



4. Work with your class to determine what fossil fuel use causes to happen and how that would cause changes to different community water resources.
5. Make sure to trace each added box in our diagram back to our science ideas.
6. Complete the diagram with your class.

Discuss social media claims.

Turn and talk



Gayatri Sundar @Gayat72s · Nov 12
So concerned about the [#Philippines](#).

...

[#Climatechange](#) is affecting the whole world. Droughts and wildfires in some places, typhoons, flooding, and landslides in others. We need to plant more trees and stop polluting the air to prevent more flooding in the future.

Read the tweet above.

7. Turn and talk with your partner about the following questions:

- What does this person claim climate change is doing?
- What other claims are being made in this tweet?

Be ready to share your ideas with the class.

With your class



8. Work with your class to identify the claims being made in the tweet.

Turn and talk



9. Look at the claims on our Tweet Claims chart. Turn and talk to your partner about the following questions:

- Which claims match our understanding?
- Which claims need to be clarified and explained?

Be ready to share your ideas with the class.

Clarify the claims based upon evidence.

Turn and talk



10. Look at the claims that we have identified as needing clarification. Turn and talk to your partner about the following question:

- How would you clarify these claims using our science ideas?

Be ready to share your ideas with the class.

With your class



11. Work with your class to complete the Tweet Claims chart.

Reflect on past experiences with misinformation.

Turn and talk



12. Turn and talk with your partner about the following questions:

- Have you encountered another tweet or a different social media post about global warming or climate change that may not be fully accurate?
- Did you correct the inaccuracies, either in your head or on the social media platform? What was the inaccuracy?

Be ready to share your ideas with the class.

Complete an assessment.



13. Read the tweet and assess the claims being made.

- **Break down** the tweet into **individual claims**, just like we did as a class.
- Determine which claims match our science ideas.
- Determine which claims **do not** match our science ideas.
- If you are unsure if a claim does or does not match our science ideas, place it in the “does not match” section.
- Pick 2 claims to rewrite so that they are **scientifically accurate**.
- Explain how our **evidence and model ideas** support the newly rewritten claim.

14. Return your assessment to your teacher when you are finished.

Navigation

Turn and talk



15. Turn and talk to a partner about the following questions:

- Do you think this carbon dioxide imbalance is going to stay the same or get worse?
- In our group tweet, we saw that someone mentioned trees as a way to help with the carbon dioxide imbalance. What ideas do you think would help with this carbon dioxide imbalance?

Be ready to share your ideas with the class.

Writing in science



16. Add any new questions you have about the carbon imbalance or any solutions to our carbon imbalance to the Driving Question Board.

Home Learning

Home learning



17. Take a piece of paper home and record any ideas you can think of to help with the carbon dioxide imbalance problem.

Lesson 13: Why is solving the climate change problem so challenging?

Find the source of the carbon dioxide imbalance.

With your class



1. Examine your class's Earth's Carbon System Model. Discuss with your class:
What problem did we discover by looking at this model?

Turn and talk



2. Discuss with your partner:
 - What area of our model is causing this imbalance?
 - What makes the most sense to cut or limit to fix this carbon imbalance?

With your class



3. Share your ideas with your class.

Simple Carbon Model

With your class



4. Make observations of the Simple Carbon Model simulation.
5. Make a prediction: *Our current emissions are set at 10.5 gigatons per year. What would we expect to happen if we pressed play on this simulation to all 3 lines?*
6. Observe the projected data and share your noticings with your class.
7. Use this data as your "baseline data" for comparison.

With a partner



8. Work with your partner or small group to test different emission rates. For each simulation run you will need to:
 - a. record different emission rate scenarios you want to test in the first two columns,
 - b. make predictions for CO₂ concentration and temperature, and
 - c. record observations of the graphed data after you run the simulation.
9. Once you complete the simulation runs, answer the questions at the bottom.

Cutting Emissions Observations

With your class



10. Discuss with your class:

- What observations did you make about cutting carbon emissions to the following levels?
 - eliminating all emissions
 - cutting emissions in half
- What other observations did you make?
- What needs to be done to limit the increase of global temperatures?

Brainstorm how we might be contributing and what we can do about it.

With your class



11. Share with your class:

- What are some solutions you have heard your family or friends are doing or have tried to do to reduce carbon emissions?
- What are some of the things that we might be doing at home that we could make changes to?

Home Learning

Home learning



12. Gather information about your home energy, transportation, and food use using *Home Carbon Audit*.

Lesson 14: What things can people do to reduce carbon dioxide going into the atmosphere?

Navigation

With your class



1. What did we figure out in the previous class about carbon emissions and what we can do about it?

Calculate your carbon emissions (footprint).

On your own



2. Locate the *Home Carbon Audit* handout that you did as home learning. Use this to help you enter your information.
3. Go to the *Carbon Emissions Calculator* website at <https://ei.lehigh.edu/learners/cc/carboncalc.html>.
4. Enter your data for each question.
5. Record your emissions score on a sticky note.
6. Post to the class's Carbon Scoreboard. Remember to:
 - post it anonymously,
 - place it from least (on the left side) to greatest (on the right side), and
 - place your score near similar scores.

Calculate class average.

With your group



7. Talk about what you notice and look for the following:
 - Range of scores
 - Trends in scores

8. Discuss how to calculate the average score.

9. Calculate the average score and be prepared to share.

With your class



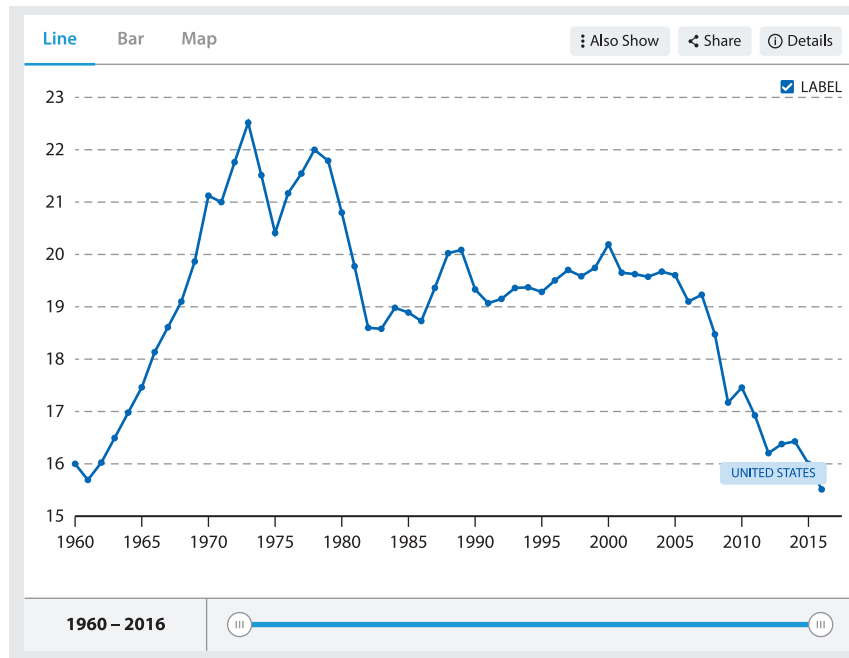
10. Share your calculations and observations of the data.

11. Discuss:

- What actions tend to make your scores go up quickly?
- What do these numbers mean for the problem we are trying to solve?
- How well are we doing right now on the solutions we thought could be helpful and easy to do?

Compare CO₂ emissions for the average American.

With a partner



Data Source: The World Bank.

12. Look at the data and turn and talk about:

- What do you notice about the range—highs and lows?
- What do you notice about the overall trends?
- How does the most recent average compare to our class average?

13. Share with your class.

Carbon Reduction Priorities List

On your own



14. Return to your carbon footprint.

15. Identify the actions you entered with the highest impact. Think about whether you can change these things and, if so, by how much.

16. Look for other things you are willing to change. Select 2-4 changes to make.

17. Recalculate your footprint and post to the Carbon Scoreboard. Remember to:

- post it anonymously,
- place it from least (on the left side) to greatest (on the right side), and
- place your score near similar scores.

18. Calculate the new class average score with new carbon savings.

Building Understandings Discussion and Carbon Calculation Savings

Scientists Circle



19. Discuss the impact of changing everyday habits.

- What kinds of changes do you want to make?
 - Do they lead to big or small impacts on carbon?
 - Are they realistic for you and your family?
- What actions are not realistic?
- How could these changes benefit your family in other ways beyond carbon reduction?
- Why are each of your changes different from each other? Is this important?

20. Think about how your individual actions matter in relationship to others' actions:

- How much did our class save per person?
- What if we could get more people to make changes?
 - How many people? Family? School? Town?

21. Work with your class to decide what percent is realistic.

With a partner



22. Pick a percent you think is realistic. Pick a population (school, community, church community, sports team, family) and calculate the carbon savings you can achieve if you can convince a certain percent of them to change some of their daily habits. Check your number with a partner and be prepared to share with the class.

Scientists Circle



23. What do these numbers mean for the problem we are trying to solve? Discuss with your class:

- What other important things can you summarize from these numbers with respect to the problem we are trying to solve?
- What assumptions did we make about our numbers?
- What is the importance of having larger numbers of people making these changes?
- When you look back at the data, at what scale do you think the biggest impact can be made, and why?

Navigation

On your own



24. Complete an Exit Ticket:

- What other solutions could we consider that will reduce carbon on a larger scale?

Lesson 15: How can large-scale solutions work to reduce carbon in the atmosphere?

Define criteria for analyzing solutions.

Scientists Circle



1. Share with the class possible large-scale solutions for reducing carbon dioxide in the atmosphere.

With a partner



2. Discuss with a partner what our solutions would need to do to be successful and what the main goal of the carbon imbalance solutions would be.

With your class



3. Share what criteria you propose for analyzing our large-scale solutions.
4. Share what kinds of data would be needed for us to determine if a solution would reduce the amount of carbon dioxide released into the atmosphere.

Gather initial data on solutions.

With your class



5. With your class, choose 12 solutions out of 16 that you would like to investigate.

With your group



6. Read through your solutions and share with your group what you read.
7. With your group, determine which three solutions best fit the class criteria for solving the problem.

Initial Solution Proposals

With your group



8. With your group, revisit the discussion you had with your group at the end of the previous class:
 - Remind yourselves about the solutions you analyzed and your top three suggestions.
 - Be ready to share with the class your reasoning behind the top three suggestions.

With your class



9. Share the top solutions that your group agreed would best meet our criteria of reducing the amount of carbon dioxide in the atmosphere.
10. As groups are sharing, listen carefully so that you can connect your thinking.

11. Work with your class to record a list of proposed solutions and why you think they will work.

Identifying the Constraints

With your class



12. Work with your class to set up the *Carbon Reduction Solution Matrix*.
13. Write down the problem you are trying to solve. Look back at the class's Defining the Problem chart you completed in the previous class period.
14. Write down the criteria your class agreed upon.
15. Look at your Proposed Solutions chart. Record the solutions that your class wants to evaluate.

With your group



16. Brainstorm constraints, or limitations, that you think there would be to doing these different solutions.

With your class



17. Discuss with your class which constraints you want to use.
18. Record the constraints on your *Carbon Reduction Solution Matrix*.

Reanalyze solutions with new constraints.

With your class



19. When you evaluate the solutions against the criteria and constraints, use dots, or circles, to show how well it meets the criteria and constraints. Use a scale of 1 to 5 dots.
 - 1 dot or circle means it doesn't meet it well.
 - 5 dots or circles means it meets it very well.
20. You will work with a new group to revisit the solution you evaluated in our last class. With this new group, you will fill in the matrix for the three solutions you evaluated. The groups are as follows:
 - Group A - everyone who evaluated solutions #1-3
 - Group B - everyone who evaluated solutions #4-6
 - Group C - everyone who evaluated solutions #7-9
 - Group D - everyone who evaluated solutions #10-12

With your group



21. Evaluate the solutions with the criteria and constraints.
22. Keep your *Carbon Reduction Solution Matrix* handout and the *Carbon Solution Cards* in a safe place, like your science notebook, for the next class period.

Consensus Discussion to Categorize Solutions

With your group



23. Return to your original group.

24. Each person in your group should share

- which solutions they evaluated,
- the rating for this solution as to how well it meets the criteria and constraints, and
- the reason your jigsaw group rated each solution the way you did.

Scientists Circle



25. Work with your class to decide: How realistic are the different solutions for us to implement?

26. Categorize solutions into one of three decisions:

Likely solutions	Not sure	Not good solutions

Update Progress Trackers.

In your notebook



27. Turn to the Progress Tracker section in your notebook:

- draw a line before your last entry;
- write down what question we were trying to figure out;
- record what you’ve figured out and how you learned it.

Examine the impact of solutions on Earth’s systems.

With your class



28. Look at the Earth’s Systems Model that we developed in Lesson 11 and decide where our “likely solutions” would have an impact.

29. Discuss who would be responsible for implementing our “likely solutions.”

Lesson 16: How are these solutions working in our communities?

What are we wondering about?

With your class

1. Think, then share: What were we wondering about last time?



Community Resilience

With your class

2. What does the word “resilience” mean?

- For individuals?
- For a community?



Obtaining and Evaluating Community Resilience Plans

With your group

3. Before your group reads through the text, consider the following:
 - What information do we hope to gain from reading it?
 - What will it help us figure out?
4. Use a close reading protocol and your handout, *Evaluating Community Solutions*:
 - Read once for understanding to see what the reading is about.
 - Read a second time to highlight a few key ideas that help answer the questions you had.
 - Summarize the key idea(s) in your own words, in diagrams, or both.
 - Jot down new questions that this raises for you.



Come to agreement: How do these solutions work?

With your class

5. Across each community resilience plan, add solutions to the Carbon System Model to show how they work and who is doing them.
 - Add solutions with sticky notes.
 - If the solution is already represented, add a + sign to the sticky note.



Does our community have a plan?

Home learning



6. Consider your own community:

- Does your community have a similar plan? Could you evaluate it?
- Or, using the ideas you have learned, could you develop a plan for your community?

Lesson 17: What solutions work best for our school or community?

Navigation

With your class



1. Last time, we wondered about our own community. Why would it be important for our community to have a plan?
2. Should we make a community plan or school plan?
 - What could be easier or more difficult about each option?
 - What do we want to do?

Develop a Criteria Checklist for what the plan needs to do.

With your class



3. Think back to the resilience plans you’ve seen.
 - What did you notice about the plans we’ve already seen?
 - How do you think those places decided what to include in their plans?
 - Who was the audience, and what did the authors try to communicate to the audience?

Turn and talk



4. Based on what you saw in the examples, what do you think needs to be in a community resilience plan to make it effective?

With your class



5. Work with your class to develop a Criteria Checklist. This checklist will include:
 - What an effective community resilience plan does (criteria)
 - What your plan should include to meet the criteria (checklist)

What an effective plan does (criteria)	What our plan should include (checklist)

6. In thinking about solutions consider the following questions:
 - What were the different kinds of solutions we saw in the example resilience plans?
 - What solutions make sense for our community given the changes we are experiencing?

- What can we do for long-term carbon rebalancing? What can we do for changes happening right now?
- Can everyone participate in these solutions? Who can and who can't?

Come to consensus on changes in your community.

Turn and talk



7. Brainstorm with a partner:

- What changes in our community have we already established?
- What evidence did we have to support that these changes are occurring?

In your notebook



8. The Climate Explorer is a new tool that shows projections of temperature and precipitation based on trends in the past.

9. Set up your science notebooks to make new noticings of projections from this tool.

10. Make observations from the Climate Explorer together as a whole class. Record observations in your science notebook.

Scientists Circle



11. Share your observations from the Climate Explorer with the class.

- What did you notice in projections about temperature?
- What did you notice in projections about precipitation?
- What, if anything, should we change or add to the first part of our criteria checklist?

Turn and talk



12. In the next class, we'll think about how these problems affect people in our community.

- Who do you think could be affected the most?
- Who is most vulnerable to these changes?

Navigation

On your own



13. Obtain a copy of *Community Resilience Plan: Project Planning Sheet*.

14. Think about: What has our class concluded about the future changes to temperature and precipitation our community is facing or will face? What evidence do we have now to support this?

15. Record your thinking in Part 1 of your handout.

Think about community members.

With your class



16. Discuss with your class:

- Who in our community may be more directly impacted?
- Who may be more vulnerable to the problems?

Develop your community resilience plan.

With your class



17. We've already investigated a lot of solutions for carbon. We saw that communities were including these solutions in their plans, but they were also including other solutions to prepare or adapt to change. What were some of the solutions we've seen?

18. Observe the new *Water Solution Cards*. Ask your teacher if you have questions about them.

With your group



19. Review the class Criteria Checklist. This is what your plan needs to do.

20. Discuss and write up your plan. Each group member records a plan.

- Part 1: Review and make any edits.
- Part 2: Review the Community Member chart. Agree on the stakeholders you want to target and their concerns.
- Part 3: Look through your science notebook and class models. Agree on the *most important science ideas and evidence* to communicate.
- Part 4: Agree on 2-3 Carbon Solutions and 2-3 Water Solutions to include. Make a short, but convincing, argument for why each solution will work for your community and the stakeholders you identified in Part 2.

21. Choose a Project Option and share your choice with the teacher.

Interview community members.

Home learning



Gather more information:

22. Share your mix of solutions with a family member, neighbor, or someone from your community.

23. Ask them what questions they would have if the community wanted to do these things.

24. Record the questions. Bring them back to your group.

Exit Ticket: Self-Assessment

On your own



I need a lot of help



I feel totally independent

25. Using the scale shown above, how are you feeling right now about your plan?

26. Briefly explain what makes you feel that way and what extra help you could use.

Evaluate each other's plans by asking questions.

On your own



27. Evaluate another person's plan in two ways:

- Take the stance of a community member who is skeptical of the need for a plan or the solutions being proposed. Ask questions to challenge the plan.
- Take the position of a thought partner to offer suggestions to help the plan better meet the class's agreed upon Criteria Checklist.

Make your final product.

With your group



28. Work with your group to develop your resilience plan using the format you selected.

29. Take advantage of the different expertise each member in your group brings.

Goal: Make your final product

Use feedback to make improvements:

Think about the questions your classmates and teacher asked. Adjust your plan to answer these questions.

30. Review the class Criteria Checklist.

- Where does your plan meet the criteria?

31. Review the teacher and peer feedback.

- Did you make adjustments to your plan using the feedback? Where and how?

Communicating Our Plans

With your class



32. What next steps should we take to share our plans with others?

- Who do we want to see our plans?
- How can we make sure they see them?
- Do we want them to give us feedback to improve them even more?

Share learning on an individual assessment.

Your community is debating which solution to invest in. They are requesting suggestions from community members.

On your own



33. To make a convincing suggestion you need to:

- explain the most pressing change, or problem, that needs to be solved, and,
- argue for the solution you are recommending is the best option.

Navigation

On your own



34. Take a look at the DQB. What progress do you feel you've made in answering the very first question you asked?

35. Come prepared to share as we reflect on the DQB next class.

Lesson 18: What can we explain now, and what questions do we still have?

Evaluate our DQB questions.

With a partner



1. Turn and talk with a partner. Discuss which questions you think we've answered on our DQB. Mark any questions you think the class has answered on *Reviewing Our Driving Question Board* with the following symbols:

- We did not answer this question or any parts of it yet: **O** or **?**
- Our class answered some parts of this question, or I think I could answer some parts of this question: **✓**
- Our class answered this question, or using the ideas we have developed, I could now answer this question: **✓✓**

2. Pick three questions and write an answer to them on your handout.

On your own



3. Take your handout and 10 sticky dots over to the DQB.

4. Place your sticky dots on the sticky notes that match questions you think we've made progress on.

5. Once you have placed your 10 dots, move to the Scientists Circle.

6. As you are waiting for others to place their sticky dots:

- Finish writing answers to the three questions you chose.
- Notice and wonder about which questions have the most sticky dots.

Revisit our Driving Question Board.

Scientists Circle



7. As a class, discuss the answers to the questions that have the most sticky dots.

- Which questions have we made the most progress on?
- What have we figured out?
- What can we say now about the big question on our DQB: *How do changes in Earth's system impact our communities and what can we do about it?*

Add to your Progress Tracker.

During your time revisiting the DQB, new ideas that you want to include on your Progress Tracker may have surfaced. Add an entry to your Progress Tracker that either reflects upon our big unit question or another question that came up for you when we evaluated the DQB.

On your own



8. Write the big question we've been working on in the left column: *How do changes in Earth's system impact our communities and what can we do about it?*
9. What have you figured out about this question?

Celebrate our science learning.

Scientists Circle



10. On a piece of scrap paper, write a tweet with your own hashtags. The tweet may share:
 - a big idea you learned in this unit or school year that will always be with you,
 - a challenge you faced in this unit or school year that you overcame, or
 - a rewarding thing about this unit or school year that you want to share.
11. Crumple up the paper into a "snowball."
12. When everyone is ready, toss the snowball in the air.
13. Pick up a new snowball and be prepared to share.

Build a new DQB of unanswered or new questions.

Scientists Circle



14. Think about: *What questions did we pose this year that we didn't answer, but we want to carry forward into future science learning?*
15. Write 1-2 new questions. Write questions that went unanswered in previous units and/or new questions that came up for you about phenomena you have observed in the world and want to explain.
16. Post your questions to a new DQB.
17. Cluster the questions by unit or phenomena.
18. Brainstorm how you can go about answering your questions on your own or in a future science class.

About the Data

The following data may appear with your case site. This reference provides you with information about the data, including who collects it, how it is collected and organized, and what it is used for. Most of the data is gathered from the National Oceanic and Atmospheric Administration (NOAA), a government agency that uses land-based weather stations to gather and track weather and climate data across the United States.

Total Annual Precipitation (all sites)

This is a measurement that adds together all precipitation for each day during a year. Data is collected by rain gauges or other tools used to collect precipitation. These instruments are located at weather stations all over the US. Frozen precipitation, like snow, is converted to “snow water equivalent,” which is how much liquid water is in the snow. For example, 30 inches of light, fluffy snow might only be 2-4 inches of water.



A land-based weather station.
Source: NOAA

Average Annual Temperature (all sites)

Temperature data come from weather stations placed all over the US. Sensors collect the highest and lowest temperature of the day at each station for the entire month. Those data are then used to calculate the station’s monthly averages, and then all monthly averages are averaged again to create the Average Annual Temperature for a site.

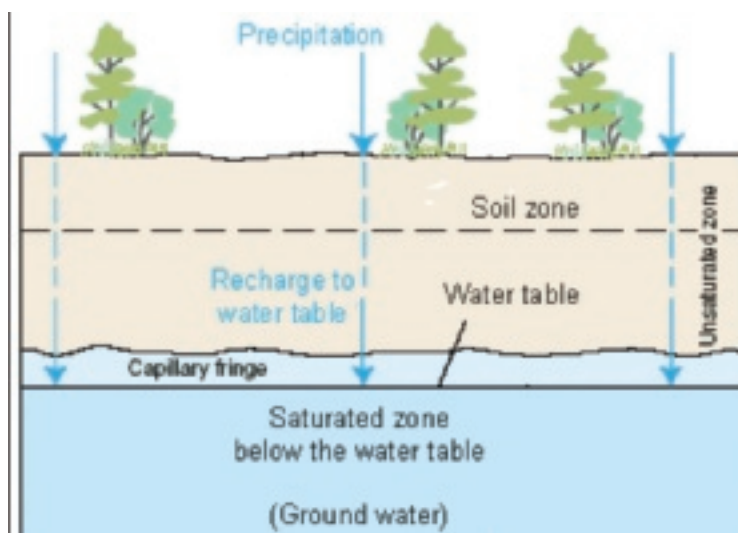
Palmer Drought Severity Index (all sites)

The Palmer Drought Severity Index (PDSI) is a combination of temperature and precipitation data to estimate relative dryness in a place. It also includes the available water content in the soil. It is a standardized index that spans from a score of -10 (very dry) to +10 (very wet). Most places stay within -4 to +4, but some places will show more extreme dryness or wetness. One drawback to the PDSI score is that it does not account for water that comes from melting snow or ice.

Drought Index Range	Moisture Conditions
$4.0 \leq$	Extremely wet
$3.00 \sim 3.99$	Very wet
$2.00 \sim 2.99$	Moderately wet
$1.00 \sim 1.99$	Slightly wet
$0.50 \sim 0.99$	Incipient wet spell
$0.49 \sim -0.49$	Near normal
$-0.50 \sim -0.99$	Incipient drought
$-1.00 \sim -1.99$	Mild drought
$-2.00 \sim -2.99$	Moderate drought
$-3.00 \sim -3.99$	Severe drought
≤ -4.0	Extreme drought

Groundwater Supply Estimate (Porterville only)

Groundwater supplies can change during the years and also over the years, so close monitoring is important. In order to measure the amount of water in the ground, a person typically uses a shallow well (a hole dug into the ground to reach the water) and places a measuring tape into the well to determine the level of the water. Below is a cross-section image in which the groundwater is located under the surface. Home owners drill wells into the ground until they reach the water source, and then they pump it to the surface.



NOAA

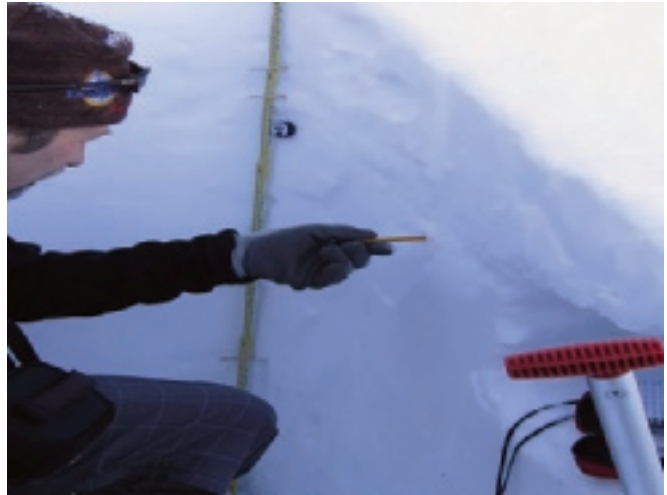


USGS

Person using a well to measure the distance to the groundwater supply.

Snow Water Equivalent (Yakima only)

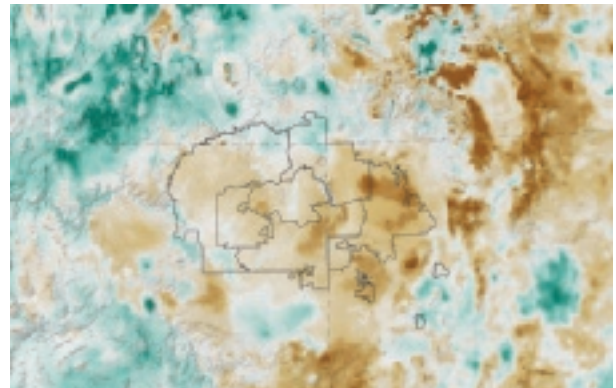
This is a measurement of how much liquid water is stored in a snowpack, and it is especially helpful for places that receive high amounts of snow in the winter. As more and more snow accumulates throughout the winter, it compresses on itself and becomes more and more packed together. This is how “snowpack” gets its name. As air temperatures warm into the spring and summer, snowpack slowly melts and the water drains off the land into creeks, rivers, and lakes. This slowly melting snow can sometimes take months to completely melt away and drain into the water systems.



Palmer Drought Severity Map (Navajo Nation only)

The Palmer Drought Severity Index (PDSI) can also be made into a map that shows which parts of a place have higher or lower readings on the index. Darker browns indicate places that are receiving negative scores on the index, meaning they are in drought conditions. Darker greens indicate places that are receiving positive scores on the index, meaning they are in wetter conditions.

The Navajo Nation is a large section of the United States Southwest, and different parts of the Navajo Nation have different PDSI scores. By analyzing the data on a map, we can see which parts of the Navajo Nation are experiencing drought conditions and which parts are not.



NASA Earth Observatory images by Lauren Dauphin using data from NASA's Drought Severity Assessment Tool (DSET).

PDSI map of the Navajo Nation. Source: NOAA.

Storm Events (Vicksburg, Boston, and Windom only)

Storm events are measured in multiple ways, such as by collecting rainfall totals, recording water levels on flood gauges placed on rivers, or monitoring streamflow rates (how much and how fast water is flowing in a stream or river).

For these towns, the only storm events included in the data set are: Heavy Precipitation (Rain), Heavy Snowfall, Flood events, and Flash Flood events. Flood events can happen over longer periods of time while flash floods are very quick events. For Boston, the data also includes coastal floods and storm surges. These occur when water from the ocean floods onto the land.



USGS hydrologic technicians Alec MacDonald and Rogelio Hernandez measure floodwaters caused by Hurricane Harvey. Photo by Cassi Crow, USGS.

Sea Level and Tides (Boston only)

Sea level is measured by a set of instruments that is mounted to docks or piers. The instruments are able to measure the distance between this fixed point and the water levels. Tides, sea levels, and ocean currents are also measured by buoy systems anchored offshore.

As tides come in and out, the instruments provide accurate readings of the rising and falling tides. But they also record long-term data for the constant levels of water at the point. When this data is combined over time, it allows scientists to monitor rising ocean water.



NOAA

Instruments that measure sea levels and tides. Source: NOAA.

Changes to Snowpack

Snowpack

This data measures trends in mountain snowpack in the western United States.

Background

Claim: With warmer temperatures, more precipitation will fall as rain rather than snow in most areas. This will cause there to be less snowpack. Higher temperatures in the spring can cause snow to melt earlier, too.

Temperature and precipitation affect snowpack. Snowpack is the amount or thickness of snow that builds up on the ground. Mountain snowpack plays a key role in the water cycle in western North America. It stores water in the winter when the snow falls and melts in spring and summer. Millions of people in the West depend on the melting of mountain snowpack for power, farming, and drinking water.

About the Data

Scientists have measured snowpack since the early 1900s. A long time ago, scientists measured snow by hand. Since 1980, measurements at some locations have been collected with automated instruments. This data is from about 700 sites in the western United States.

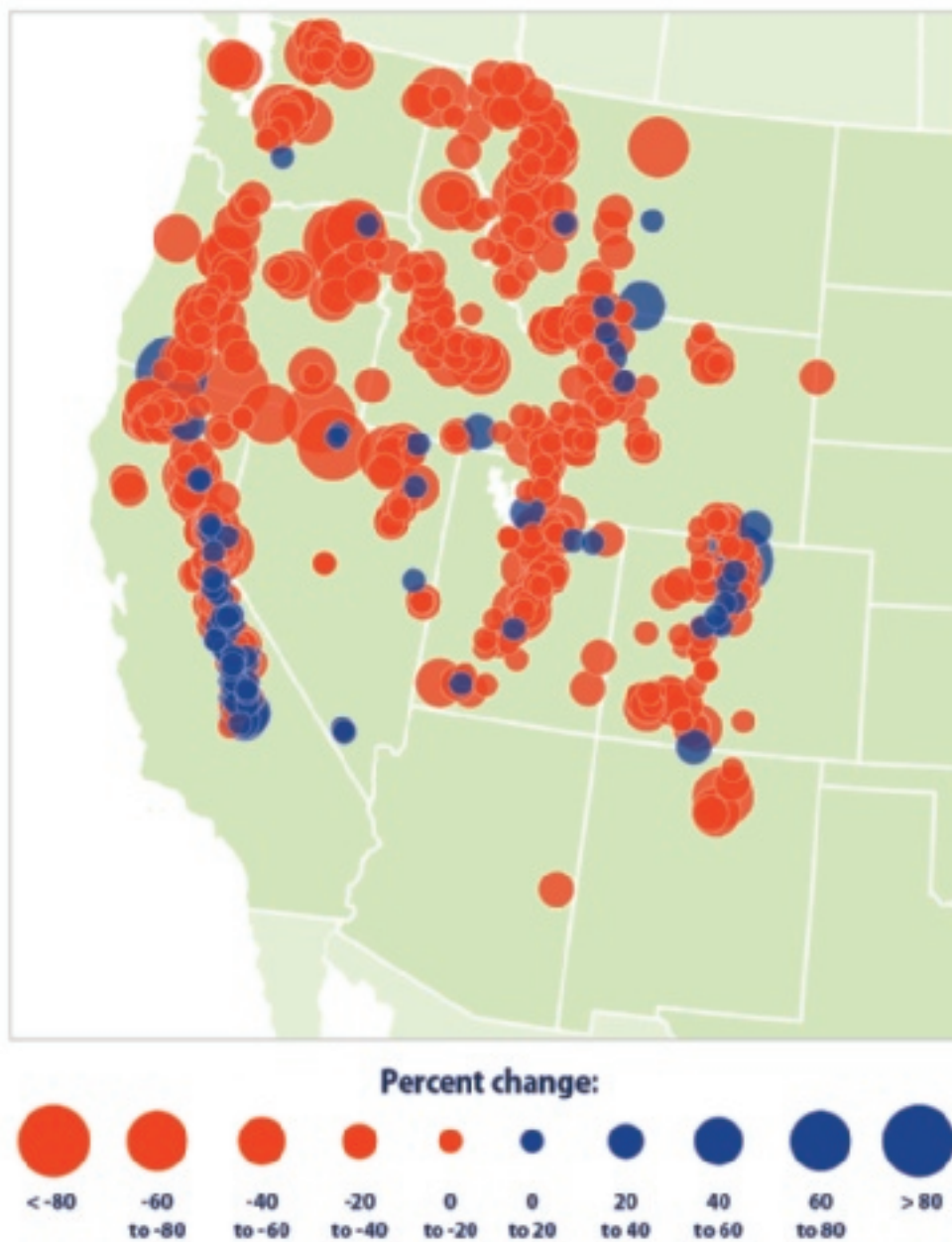
Sources:

Reading adapted from Environmental Protection Agency Climate Change Indicators: <https://www.epa.gov/climate-indicators/climate-change-indicators-snowpack>

This information is provided by scientists and researchers at the Environmental Protection Agency and the U.S. Department of Agriculture. Both are United States government departments.



Trends in April Snowpack in the Western United States, 1955–2020



Data Source: USDA Natural Resources Conservation Service, 2020. Snow telemetry (SNOTEL) and snow course data and products. Accessed October 2020. www.wcc.nrcs.usda.gov/snow/index.html.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Data source: USDA Natural Resources Conservation Service

Changes to Groundwater

Groundwater

This data describes how much water is stored under the surface.

Background

Claim: Changes in air temperature do not directly affect groundwater. Warmer air temperatures can cause less precipitation so that groundwater does not refill as quickly as it's pumped.

Groundwater is the water that exists under the ground. Water can seep deep underground. Gravity pulls the water down through sand, soil, and rock, and the water fills the spaces between solid particles. The water eventually reaches a layer of rock where it cannot seep any farther. When there is precipitation, the water will slowly seep into the ground and refill the groundwater. An aquifer is another word we use to talk about groundwater. Some aquifers are named, such as the High Plains Aquifer (shown on the map). The High Plains Aquifer is also known as the Ogallala Aquifer, and is the largest in the United States.

People get groundwater by drilling wells and pumping the water to the surface. Groundwater is an important backup water source when precipitation is lower than normal or when there is not a water supply at the surface. When there is not enough water at the surface, people pump groundwater to meet their needs. Farmers depend a lot on groundwater when precipitation is not enough or not happening at the right time for their crops.

About the Data

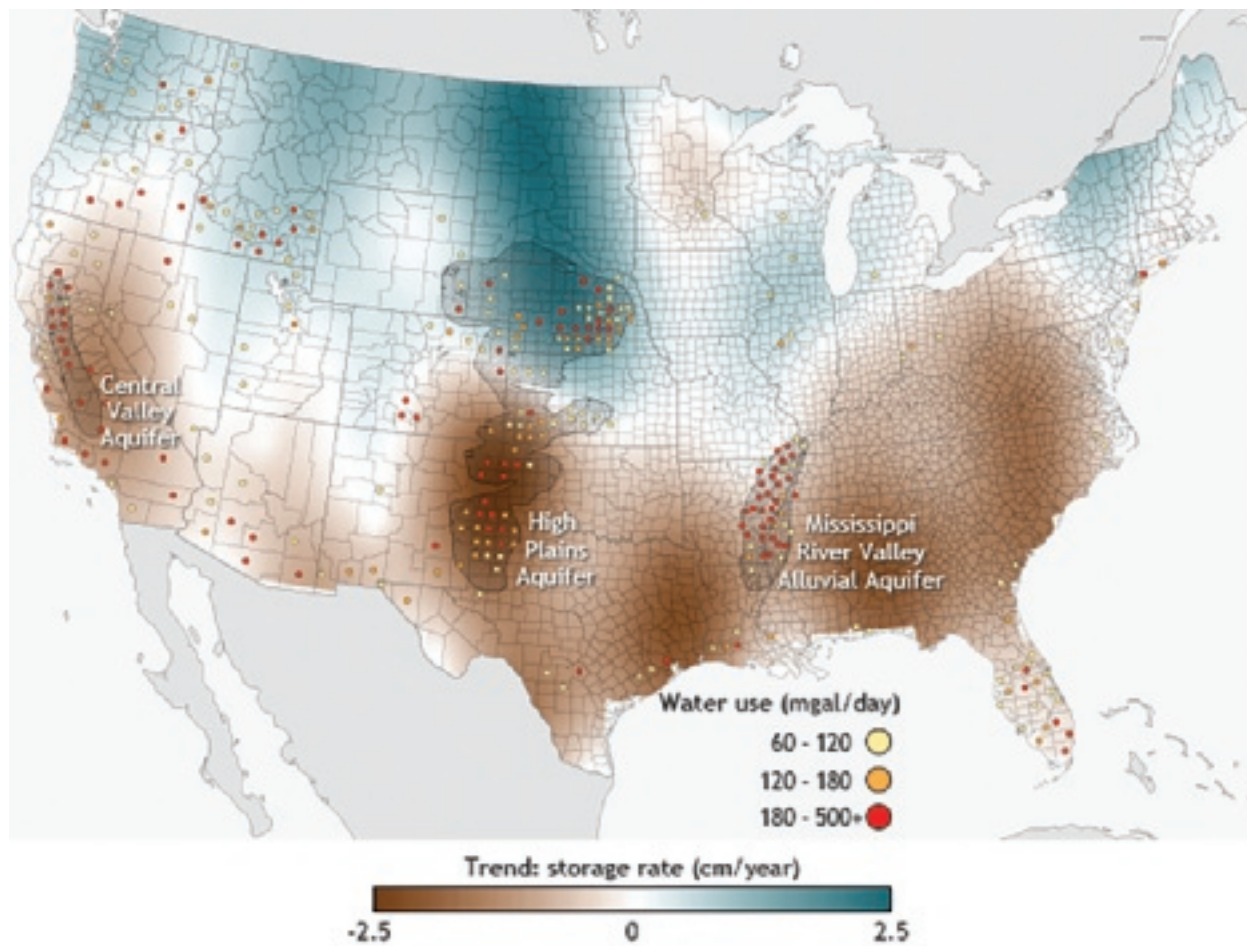
This data shows trends in the areas where there is more groundwater than normal (green) and less groundwater than normal (brown). This data is measured by satellites and by measuring water pumped in different locations (noted with little dots). Red dots mean more water is being pumped and yellow means water is being pumped, but only a little.

Sources:

This data is provided by scientists and researchers at the U.S. Geological Survey and NASA. Both are United States government departments.



Erin Murray, Idaho Water Science Center. Public domain.



Climate.gov

Changes to Glaciers and Land Ice

Glaciers

This data describes how glaciers around the world have changed over time.

Background

Claim: Warmer temperatures cause glaciers and ice sheets to lose more water to melting than is added from new snow.

A glacier is a large mass of snow and ice that has built up over many years. In the United States, glaciers can be found in the Rocky Mountains, the Sierra Nevadas, the Cascades, and throughout Alaska. A glacier flows like a river, only much more slowly. In the mountains, glaciers get new snow added to them, which slowly turns into ice. A glacier loses ice because the ice melts and breaks off. When the melting and breaking off of ice is balanced by new snow added, the amount of water in the glacier stays about the same. When a glacier melts, it adds water to the oceans. When a lot of ice melts, this can cause sea levels to rise. The same kinds of changes occur on a much larger scale with the giant ice sheets that cover Greenland and Antarctica.

In many areas, glaciers provide communities with a source of drinking water as ice melts and flows into streams and then lakes.

About the Data

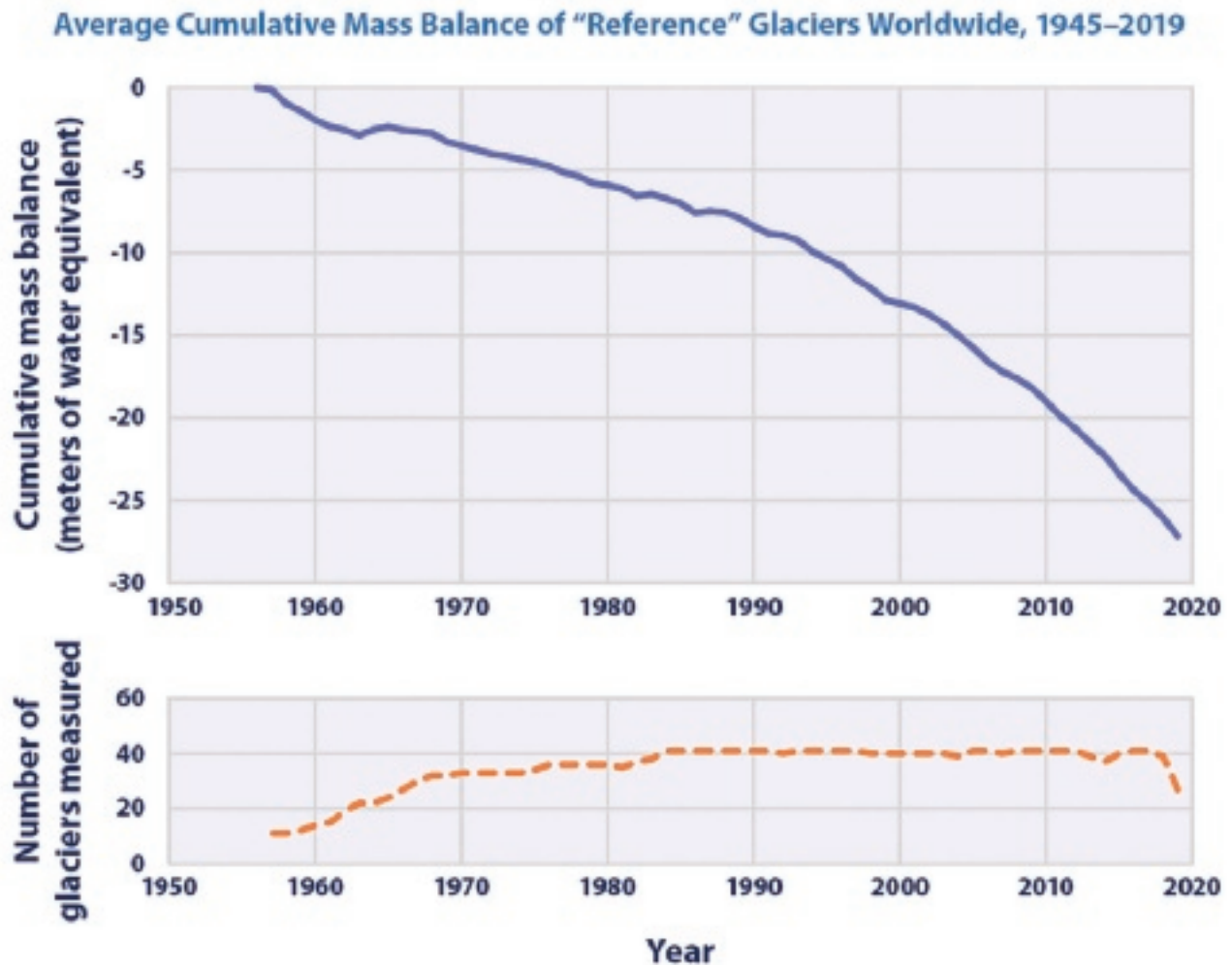
This data is from long-term data collected at glaciers around the world. Scientists collect measurements to determine how much ice is in a glacier. A negative amount means that a glacier has lost ice. A positive amount means the glacier has gained ice. (Post, 1958; Nolan, 2003). The graph shows 40 glaciers around the world. These glaciers have been measured consistently since the 1970s. Some have been measured since the 1940s. Data from these glaciers have been averaged together to show changes over time.



Sources:

Reading adapted from Environmental Protection Agency Climate Change Indicators: <https://www.epa.gov/climate-indicators/climate-change-indicators-glaciers>

This information is provided by scientists and researchers at the Environmental Protection Agency and the U.S. Geological Survey. Both are United States government departments. Worldwide data is gathered by World Glacier Monitoring Service, a group of scientists from countries around the world.



Data source: WGMS (World Glacier Monitoring Service). 2020. Global glacier change bulletin no. 3 (2016–2017). Zemp, M., L. Gärtnner-Roer, S.U. Nussbaumer, F. Hüsler, H. Machguth, N. Mölg, F. Paul, and M. Hoelzle (eds.). ICSU (WDS)/IUGG (IACS)/UNEP/UNESCO/WMO. Zurich, Switzerland: World Glacier Monitoring Service. doi:10.5904/wgms-fog-2019-12.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Changes to Sea Level

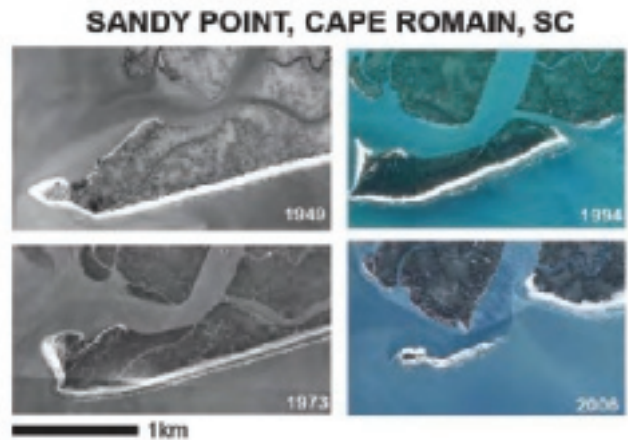
Sea Level

This data describes how sea level has changed over time.

Background

Claim: As the temperature changes, so does sea level. With warmer temperatures, ice on land melts and adds water to the ocean.

Changing sea levels can affect people who live near the coast. Rising sea level comes into low wetlands and dry land, erodes shorelines, and causes flooding. Higher sea level also makes homes and buildings more vulnerable to damage from storms.



USFWS

About the Data

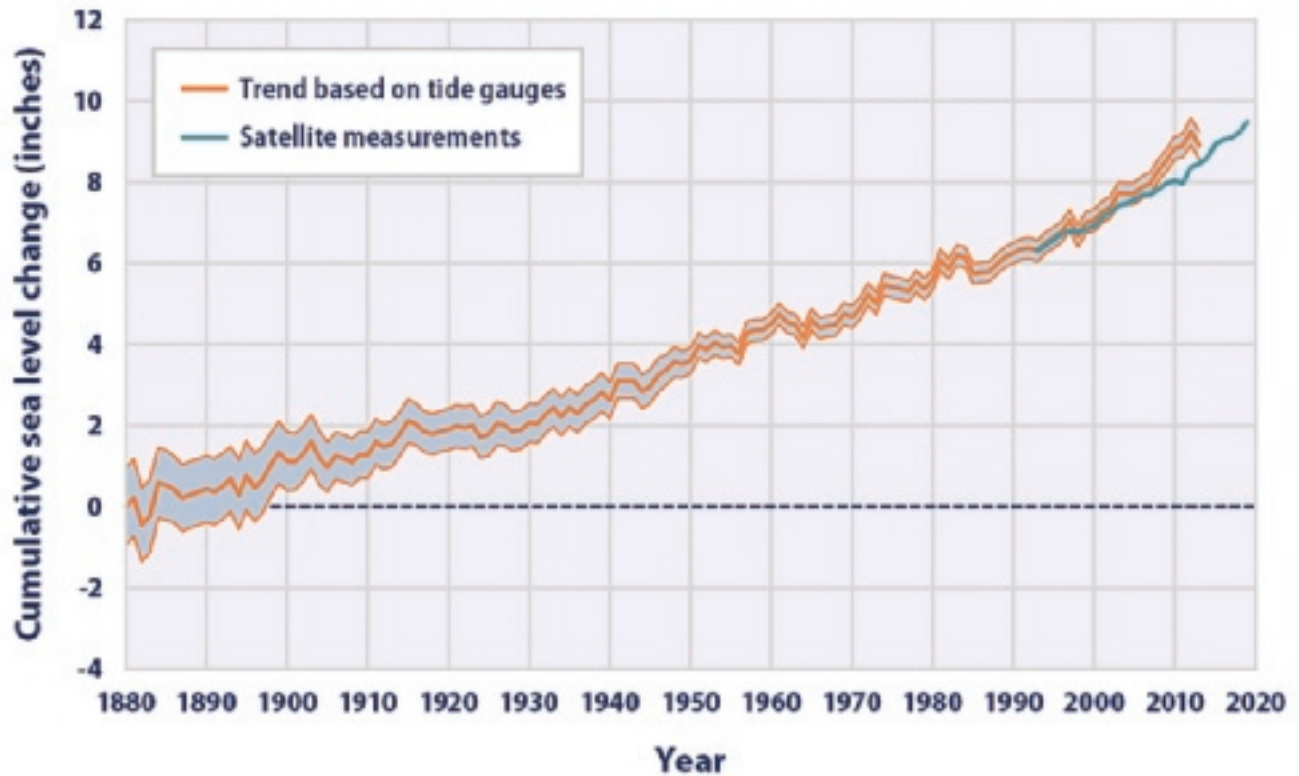
This data shows trends in sea level based on measurements from tide gauges and satellites that orbit Earth. Tide gauges measure sea level at points along the coast. Satellites measure overall sea level over most of the ocean surface. Tide gauges have collected data for more than 100 years. Satellites have collected data since the early 1990s. The graph below shows the overall change in sea level.

Sources:

Reading adapted from Environmental Protection Agency Climate Change Indicators: <https://www.epa.gov/climate-indicators/climate-change-indicators-sea-level>

This information is provided by scientists and researchers at the Environmental Protection Agency and the National Oceanic and Atmospheric Administration. Both are United States government departments.

Global Average Absolute Sea Level Change, 1880–2019



Data sources:

- CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2017 update to data originally published in: Church, J.A., and N.J. White. 2011. Sea-level rise from the late 19th to the early 21st century. *Surv. Geophys.* 32:585–602. Accessed September 2017. www.cmar.csiro.au/sealevel/sl_data_cmar.html.
- NOAA (National Oceanic and Atmospheric Administration). 2021. Laboratory for Satellite Altimetry: Sea level rise. Accessed March 2021. www.star.nesdis.noaa.gov/sod/lsa/SeaLevelRise/LSA_SLR_timeseries_global.php.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

US EPA using data sources CSIRO (2017) and NOAA (2021) non-commercial use only

Changes to Streamflow

Streamflow

This data describes trends in the amount and timing of water carried by streams.

Background

Claim: Warmer temperatures can cause snow to melt faster and earlier in the year. Warmer temperatures cause some places to get more precipitation and other places to get less precipitation.

Streamflow measures the water in rivers and streams. Streams are an important resource for people and the environment. Changes in streamflow can affect drinking water and the water for watering crops, making electricity, and other needs. Many plants and animals depend on streamflow, too.

Streamflow naturally changes over the course of a year. Rivers and streams have their highest flow when snow melts in the spring and their lowest flow in late summer. Very high flows can cause damaging floods. Low flows can harm living things and mean less water for people to use. The timing of high flow is important because it affects how people store water in lakes to meet needs later in the year.



U.S. Geological Survey

About the Data

Scientists use devices called stream gauges to measure streamflow. Stream gauges measure the water all of the time. This data is from 192 stream gauges on streams and rivers that do not have a lot of changes made to the streams and rivers by people, like dams or canals.

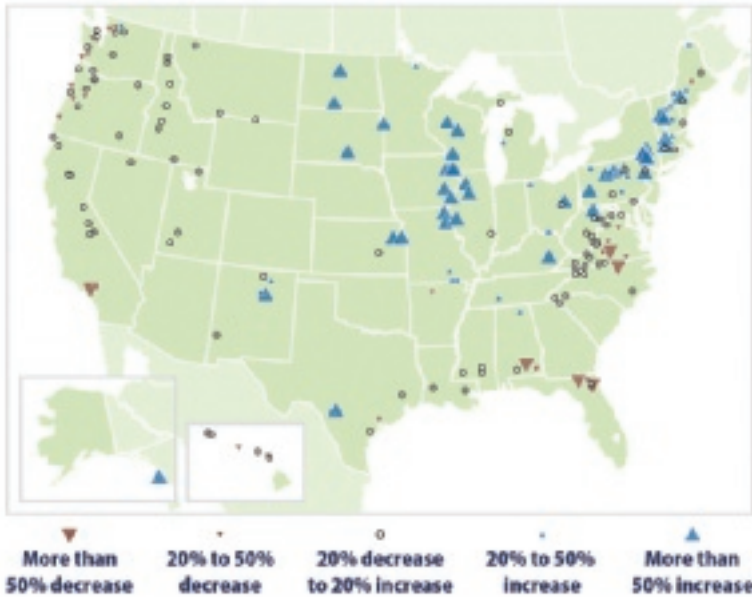
- The first map shows changes in the average amount of streamflow across the year.
- The second map shows trends in the timing of winter and spring runoff.

Sources:

Reading adapted from Environmental Protection Agency Climate Change Indicators: <https://www.epa.gov/cli-mate-indicators/climate-change-indicators-streamflow>

This information is provided by scientists and researchers at the Environmental Protection Agency and the U.S. Geological Survey. Both are United States government departments.

Seven-Day Low Streamflows in the United States, 1940–2018

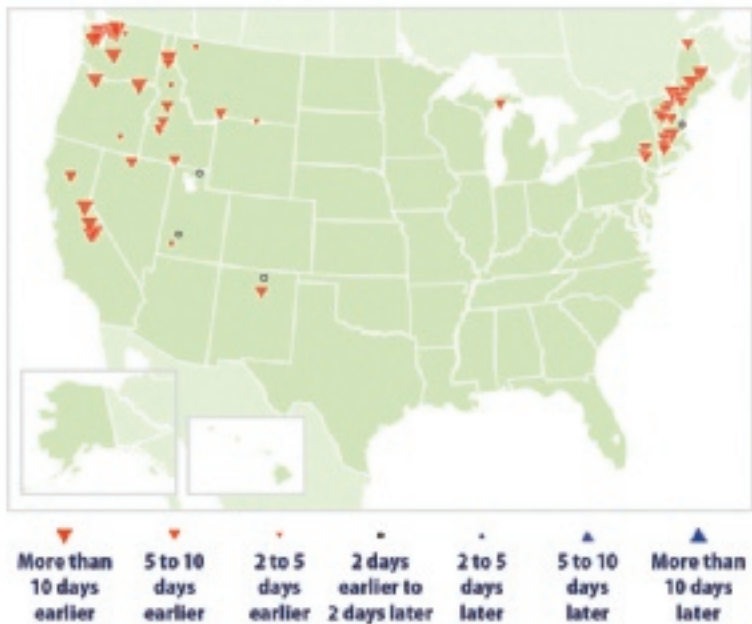


Data source: USGS (U.S. Geological Survey), 2020. Analysis of data from the National Water Information System. Accessed June 2020.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

US EPA using US Geological Survey data source non-commercial use only

Timing of Winter-Spring Runoff in the United States, 1940–2018



Data source: USGS (U.S. Geological Survey), 2020. Analysis of data from the National Water Information System. Accessed June 2020.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

US EPA using US Geological Survey data source non-commercial use only

Peer Feedback Guidelines

Giving Feedback to Peers

This tool was inspired by the Sticky Note Feedback resource originally developed by Ambitious Science Teaching at <https://ambitioussciencelearning.org/sticky-note-student-feedback/>.

Feedback needs to be specific and actionable.

That means it needs to be related to science ideas and have your own suggestions for improvement.

Examples of productive feedback:

- “Your explanation said that the precipitation is getting heavier for this community. I think you should add details about what data supports that finding.”
- “Your explanation said that the community doesn’t have water to pump from the ground anymore. I think you should add details about what is causing them to have less water than before.”
- “Your explanation said that the flooding is not getting worse. I disagree with your explanation because I noticed that in the last five years, this place has had more floods and more rain than in years before.”

Examples of unproductive feedback that do not help other students improve:

- “I like your explanation.”
- “I agree with everything you said.”

How to Give Feedback

Your feedback should give ideas for specific changes or additions the person or group can make. Use the sentence starters below if you need help writing feedback.

- I like how you _____. It would be more complete if you added _____.
- I see you’re thinking about _____. Do you think you should add _____?
- The explanation said that _____. I disagree because _____. I think you should change _____.
- I agree that _____. I think you should add more evidence from the _____ investigation.
- I agree/disagree with your explanation that _____. However, I do not think the _____ (evidence) you used matches your explanation.

Receiving Feedback from Peers

The purpose of feedback is to get ideas from your peers about things you might improve or change to make your work more clear, more accurate, or better supported by evidence that you have collected. It can also help you to communicate your ideas more effectively to others.

When you receive feedback, you should take these steps:

- Read the feedback carefully. Ask someone else to help you understand it, if necessary.
- Decide if you agree or disagree with the feedback and reflect on why you agree or disagree.
- Revise your work to address the feedback.

What Causes Wildfires?

Wildfires can have a variety of causes, such as fires started by humans and lightning strikes. In Alaska, the majority of the fires are started by humans and tend to occur closer to communities, where the fires are put out more quickly. However, lightning strikes have also been occurring more frequently than in previous years. Lightning strikes can happen in many places, including areas that are further from communities. Because of this, fires started by lightning strikes normally burn many more acres. Wildfires start when “fuel” on the ground (dead wood, shrubs, grasses) is ignited, and the fire spreads from that location. Conditions like drier vegetation and higher temperatures aid wildfires in spreading. The drier and warmer the land, the easier it is for wildfires to spread.

Surprisingly, wildfires in Alaska are not uncommon. Each year an average of 550 wildfires occur. Wildfires happen every year during their wildfire season, which generally goes from April 1st to August 31st. Not all wildfires are bad, and some help to return nutrients to the soil and spur new plant growth.

However, in the past few decades, the wildfire season has lengthened, with fires burning before and after the normal fire season dates.

And while Alaska is used to major fires (a million acres or more) occurring in some years, these large fires are happening more frequently now. These larger, more frequent, and more intense fires are posing a challenge to the firefighters and to the land that many people rely on for their way of life.

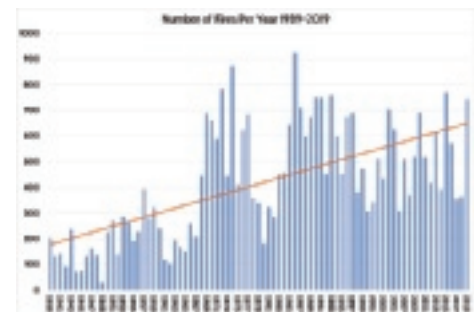
Consider these questions with your group:

What could be contributing to larger and more frequent wildfires?

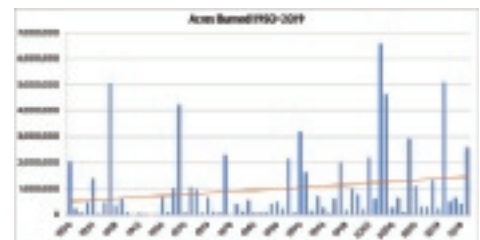
How could lightning be increasing in a region known for its arctic climate?



Credit: Rachel Loehman, USGS. Public domain.



AICC/Alaska Fire Service



Data source: Alaska Interagency Coordination Center

Transcript: Alaskan Whaler Interview

The transcript below comes from the *Alaskan Whaler Interview*.

00:02 Narrator: Whales have always been a crucial food source in this harsh and isolated environment and even today food that's shipped into grocery stores can be wildly expensive so the ability to hunt really matters here that's why indigenous communities in Utqiaġvik and across the arctic fought hard for the right to keep their subsistence whale hunt when most commercial whaling was banned a few decades ago.

00:24 Gordon says they use every part of the whale and they share the food throughout the community to be part of a crew providing this food was and is a major source of pride.

00:34 Gordon Brower: The whale brings on a festival of its own. And everybody gets new garments and clothing and, and sometimes people get married and other things happen. And it feels good because a whale means so much. Because there's the widows, there's the ill, there's the children, there's the ability to make food manageable for a large community. It makes me feel good that I'm doing a service for my community.

1:09 Narrator: The whales hunted here are mostly bowheads, which can grow up to 60 feet long and weigh 100 tons. Gordon learned how to hunt whales as a child and he says a big part of that education involved learning about sea ice.

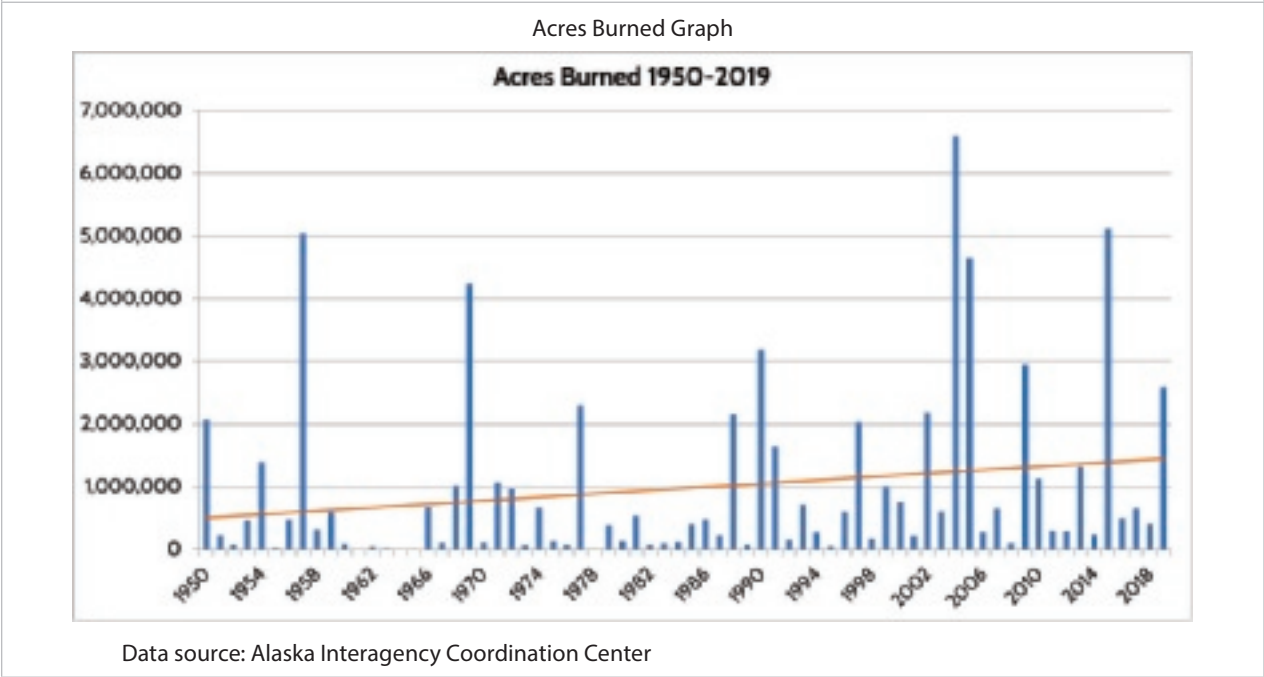
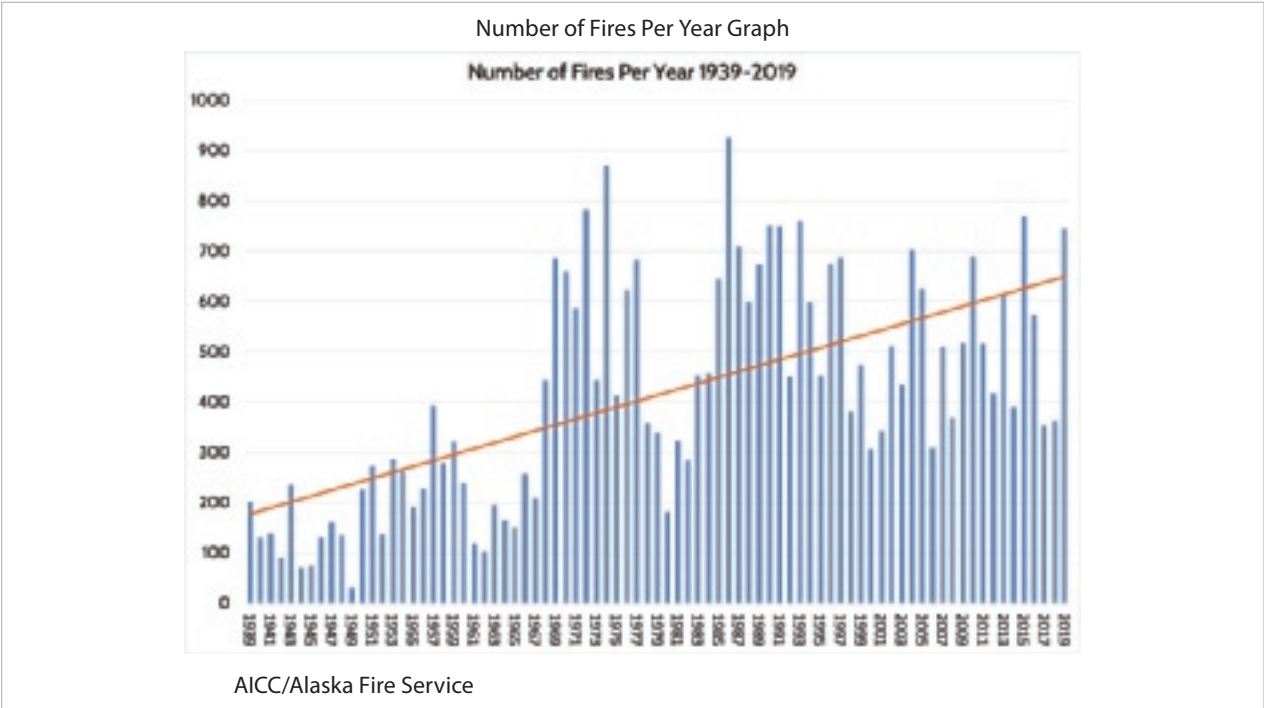
1:24 Gordon Brower: Our camps were sometimes 15 miles out offshore. We would live offshore for up to a month trying to harvest these marine mammals.

1:34 Narrator: They'd bring food and shelter but they didn't need to bring fresh water because they could get that from the ice itself. As sea ice gets older, it squeezes the salt out. So if you have ice that's five or ten years old you can melt it and drink it.

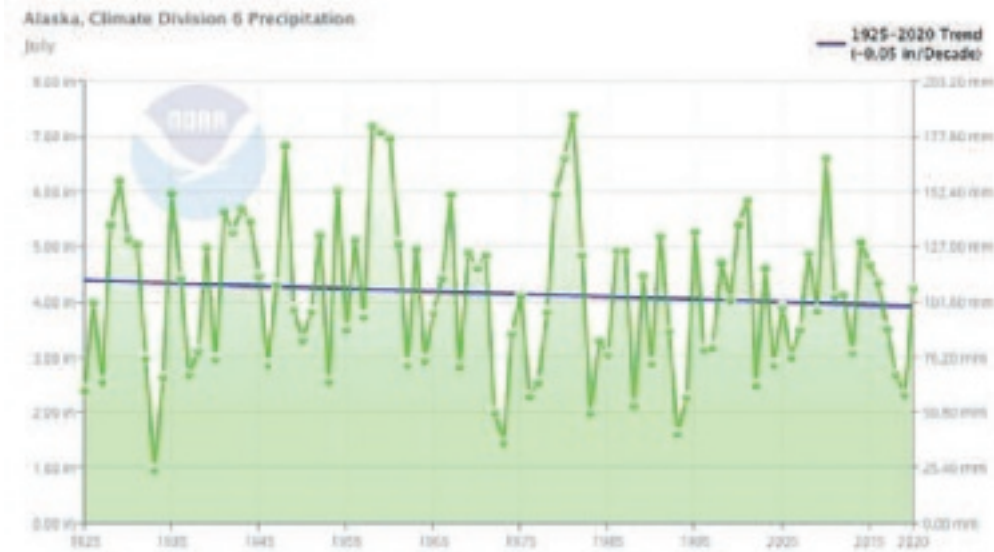
1:48 Gordon Brower: You don't see that anymore, and now you gotta bring your own water from shore to your camp offshore, because you're not seeing these glaciated type ice that develop over long periods of time that are salt free.

2:03 In the 70s you had multi-year ice all the way up to maybe 1980s. And to me that's a vivid memory because that's when I was very active as a young person. Then from the 80s to the 90s another era of change in the ice, and then from the 90s to today a much more accelerated pace.

Alaska Graphs

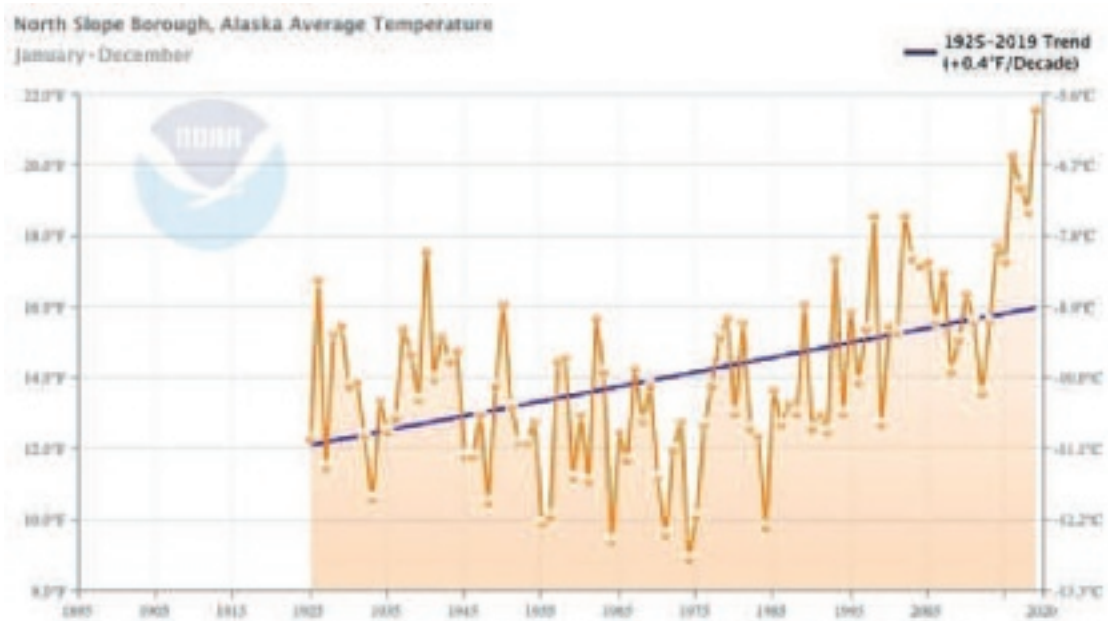


Precipitation Data Graph

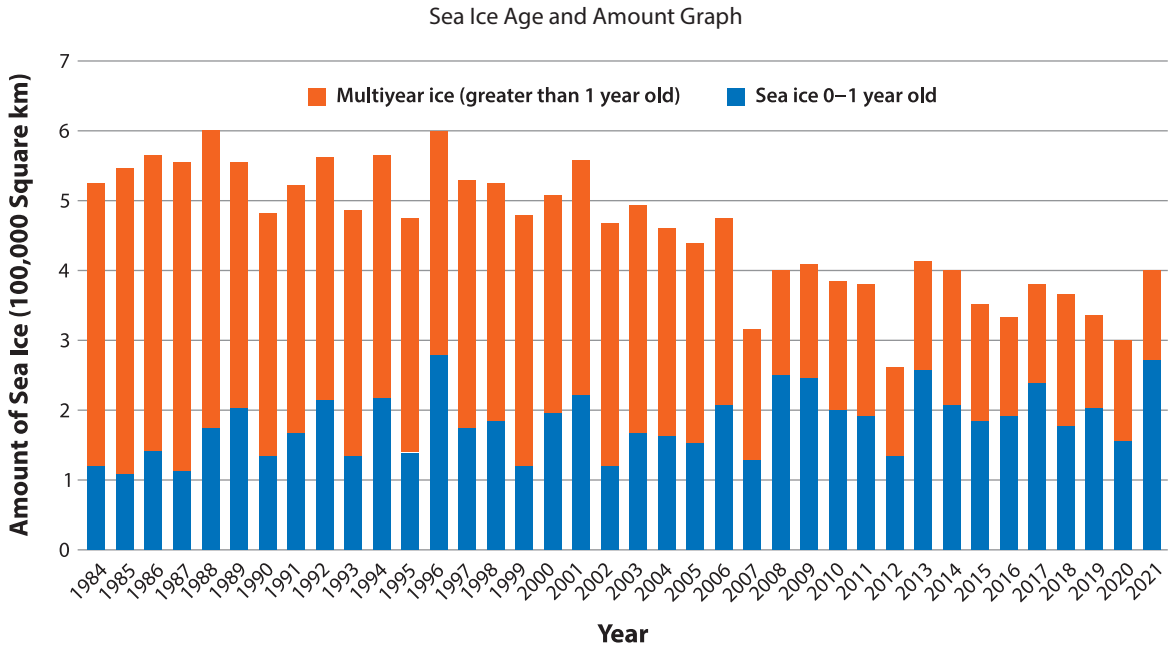


NOAA/National Centers for Environmental Information

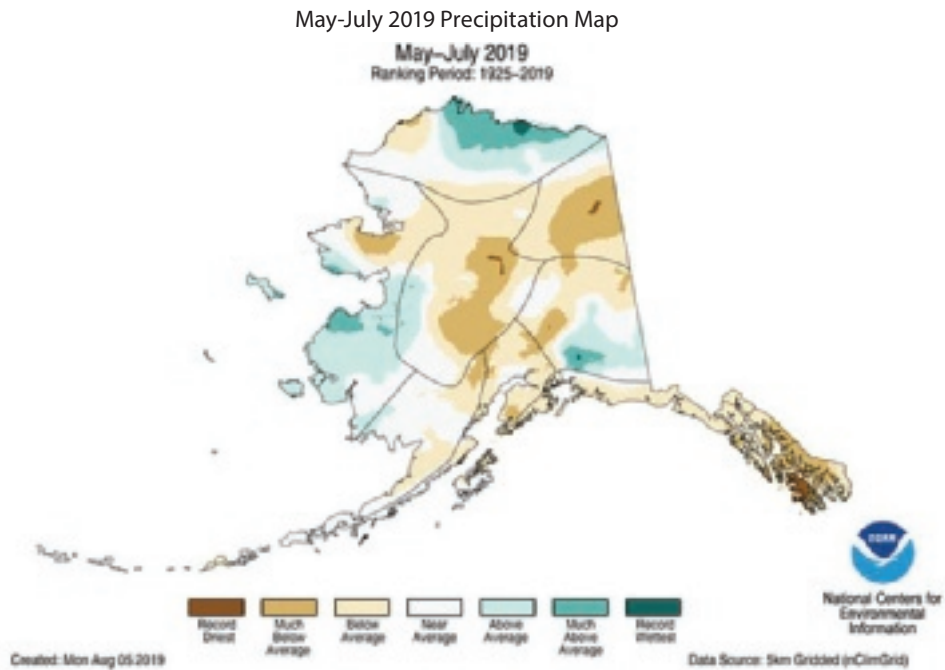
Average Annual Temperature Graph



NOAA/National Centers for Environmental Information



Data Source: Walter Meier National Snow and Ice Data Center



NOAA/National Centers for Environmental Information

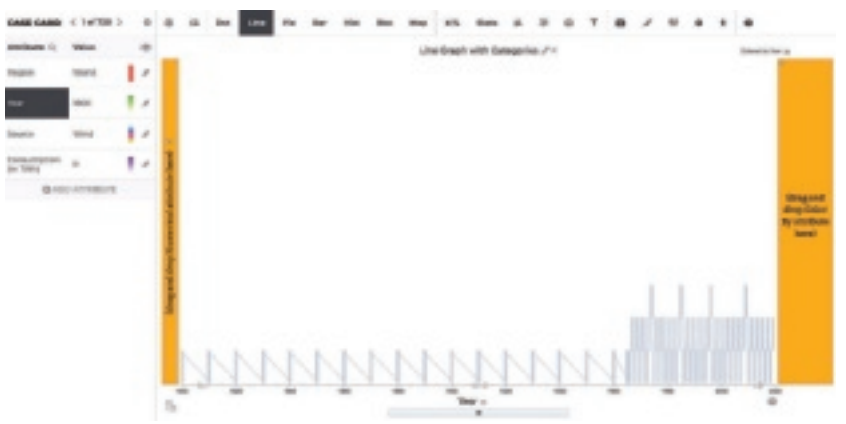
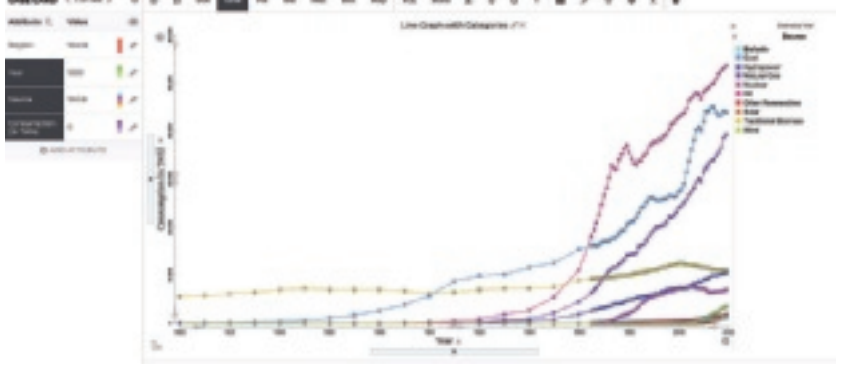
Tips for Using Tuva

Tuva is a graphing and data analysis platform. You may have used Tuva in other units. It is a way to create, analyze, and annotate your own graphs.

How to look at Fuel Consumption over Time

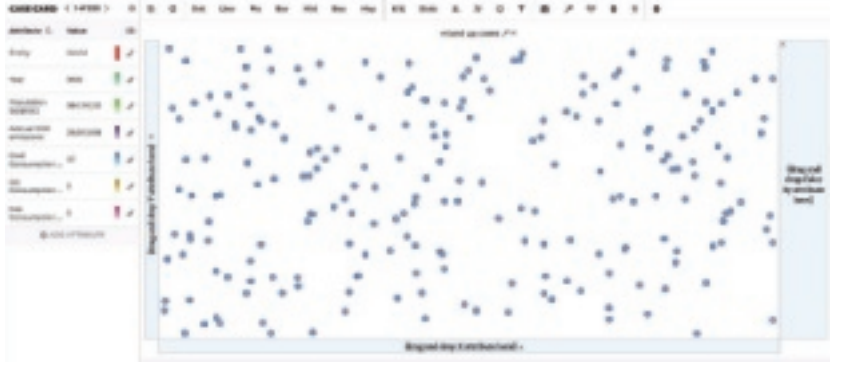
For this lesson you, if you are using Tuva, you will want to look at different information *over time*. To make a graph to show data over time, you will want to put “time” on the x-axis.

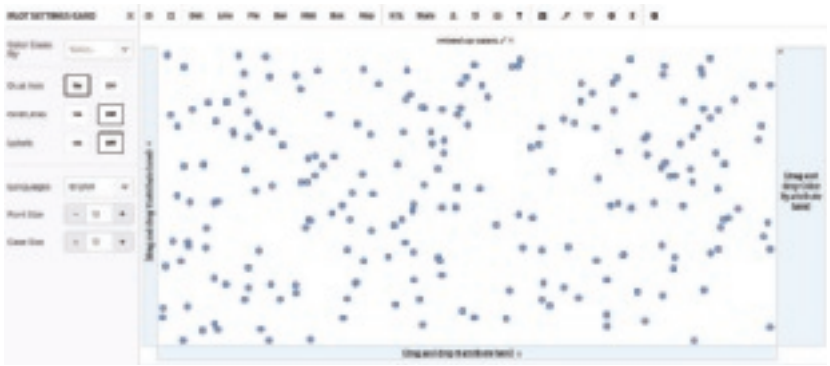
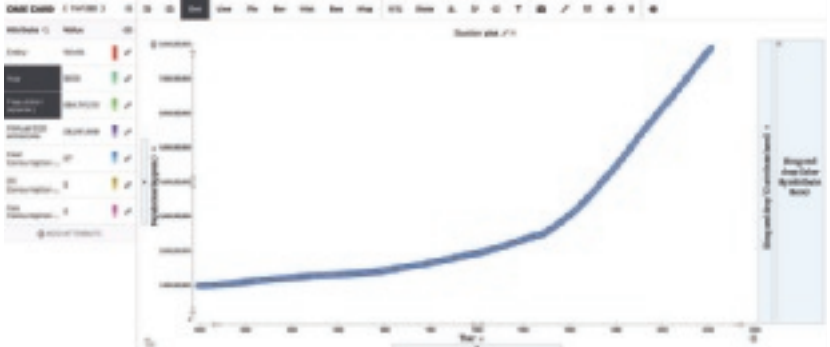
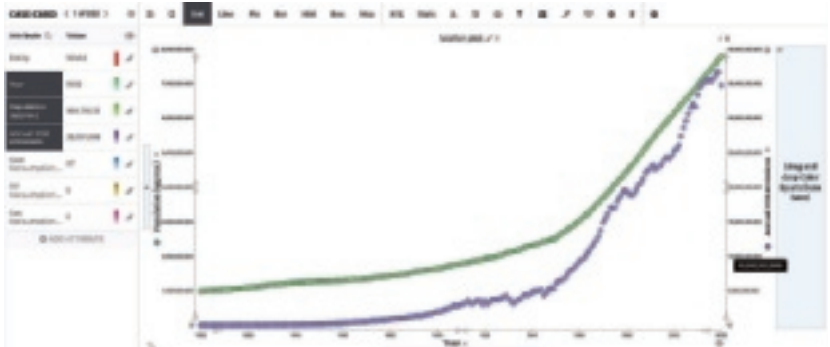
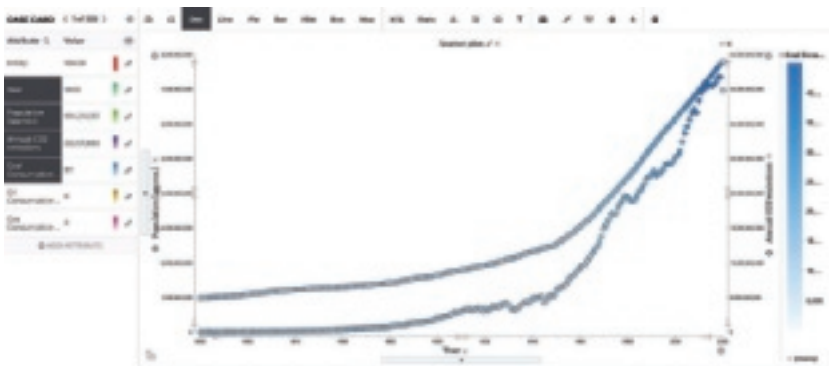
Instructions	Image from Tuva
1. If you are starting from a blank graph, take a moment to notice the different functions.	
2. You will want to make a line graph for this activity. From the top menu bar, click on “Line” and then choose “Line Graph by Category.”	

Instructions 3. Now you will move the data the appropriate axis. To make a graph to show data over time, you will want to put “Year” on the x-axis. You’ll move “Consumption” to the numerical axis on the left side (the y-axis). Finally, tell the system to code all the data by “Source” using the space on the right-most section of the graph titled “color by attribute here.”	Image from Tuva 
4. Now you have a line graph with data showing how much fuel is consumed per year and per source of fuel.	

How to look at Population Growth and CO₂ Emissions over Time

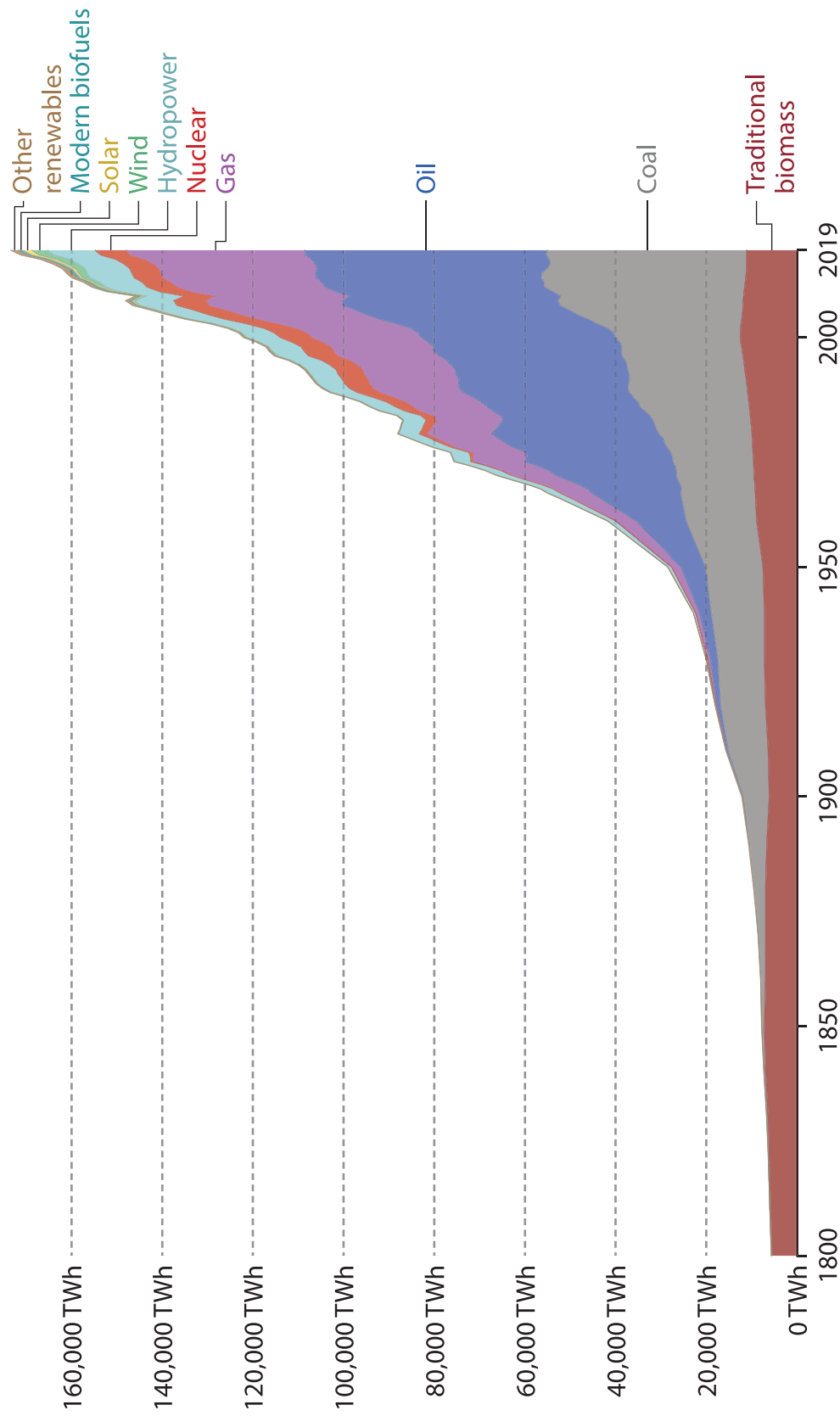
For this lesson you, if you are using Tuva, you will want to look at different information *over time*. To make a graph to show data over time, you will want to put “time” on the x-axis.

Instructions 1. If you are starting from a blank graph, take a moment to notice the different functions.	Image from Tuva 
---	--

Instructions 2. You will want to make a dot graph for this activity. By default, it should be on “Dot” in the top menu. You will also need to click on the Settings “wheel” in the top menu and turn on the “Dual Axis.” Then click the X in the settings menu to close it out.	Image from Tuva 
3. Now you will move the data the appropriate axis. To make a graph to show data over time, you will want to put “Year” on the x-axis. You’ll move “Population” to the numerical axis on the left side (the y-axis).	
4. A second axis will appear on the right side of the graph. Move “Annual CO₂ Emissions” to the second axis.	
5. Optional: Tell the system to code all the data by different types of fossil fuels. Use the space on the right-most section of the graph titled “color by attribute here.”	

World Energy Consumption, 1800 to Today

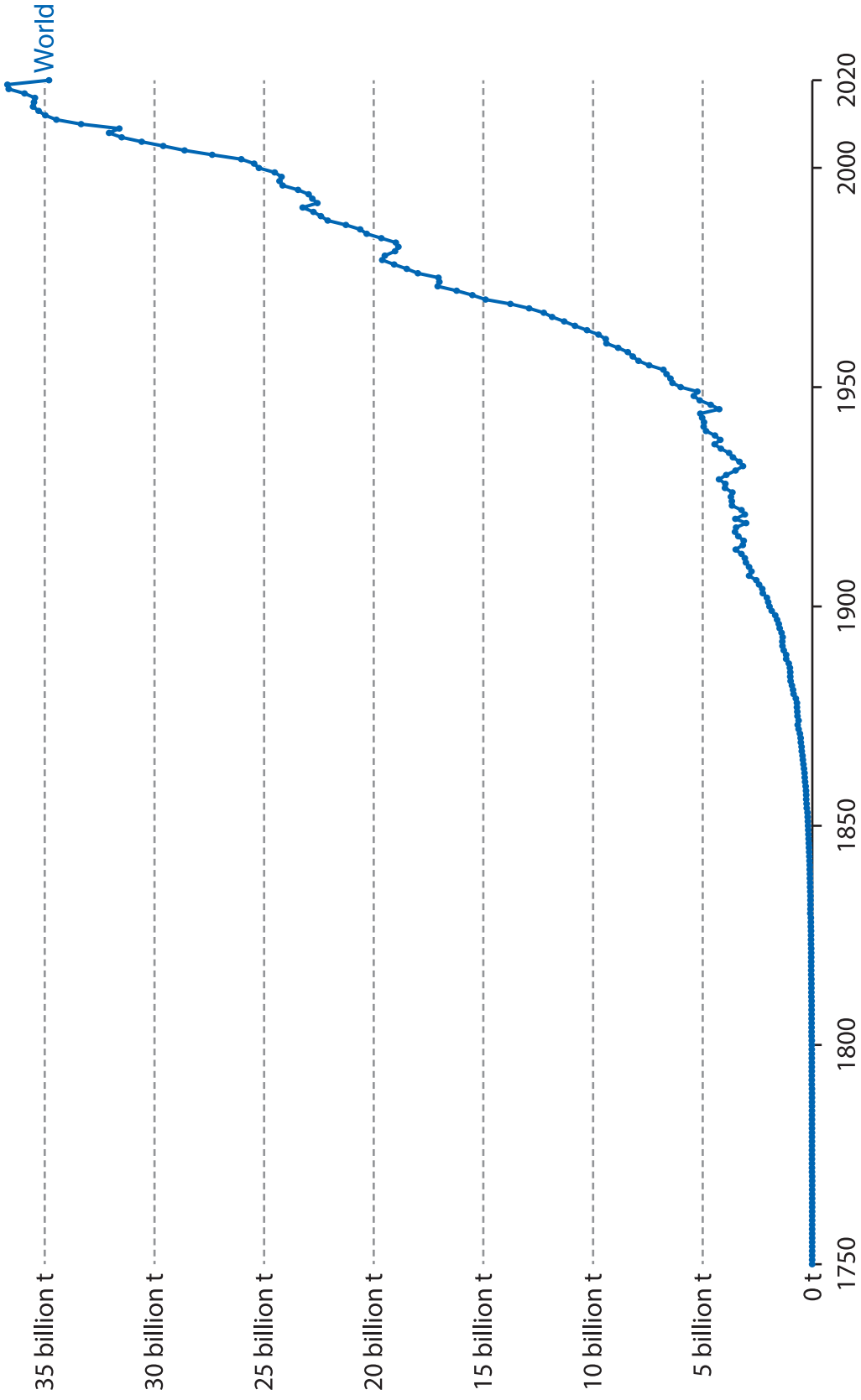
Notes: "Traditional biomass" is the use of wood or charcoal as fuel. Natural gas is referred to as "gas" on the graph. This is not gasoline. And the unit TWh is a measure of watts, or energy consumption.



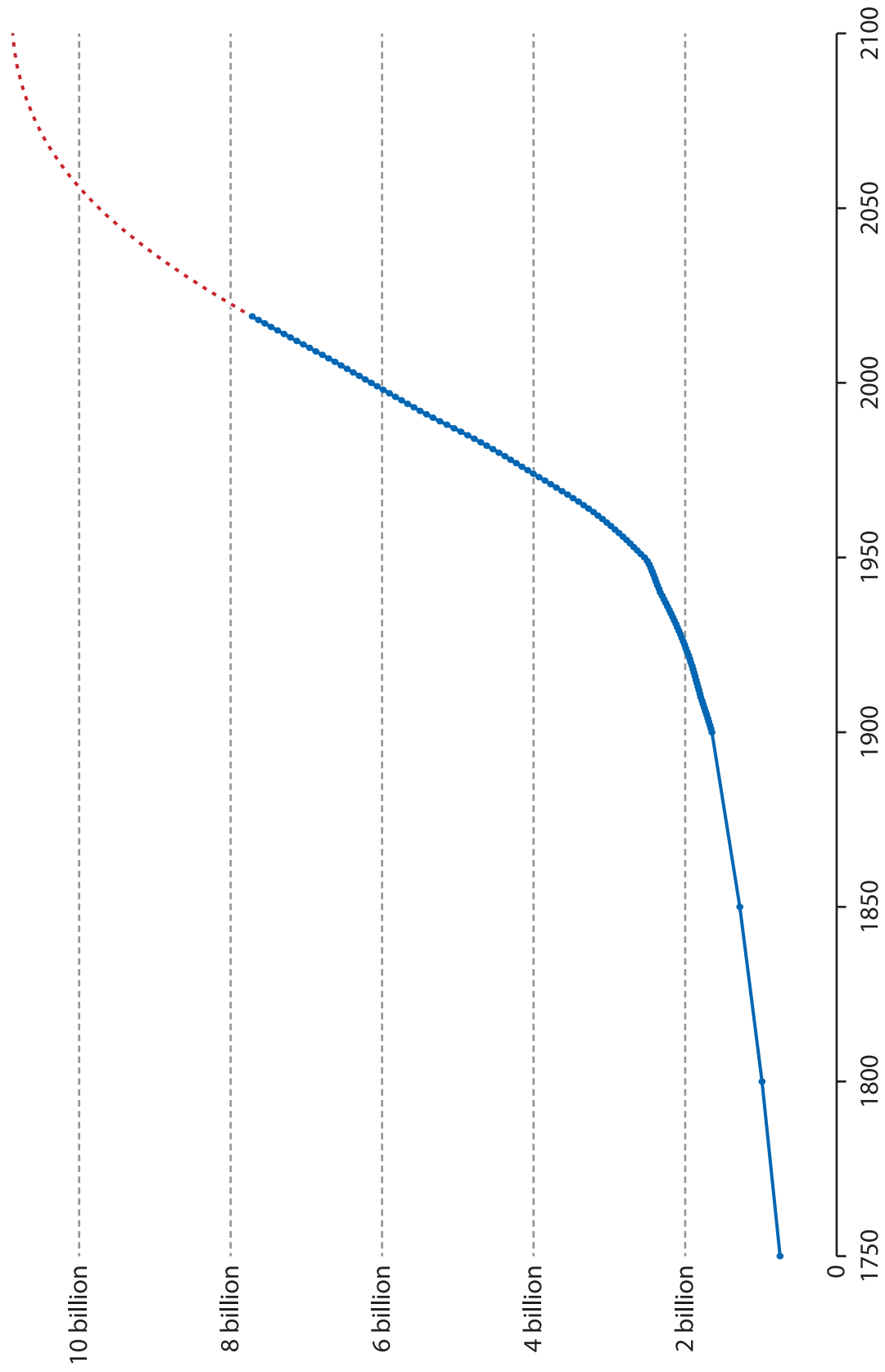
Population and CO₂ Emissions Graphs

Annual CO₂ emissions

Carbon dioxide (CO₂) emissions from the burning of fossil fuels for energy and cement production. Land use change is not included.



World Population over the last 12,000 years and UN projection until 2100



Carbon Solution Cards

PROPOSED SOLUTION #1 – Plant-Rich Diets

WHAT IS THIS SOLUTION?

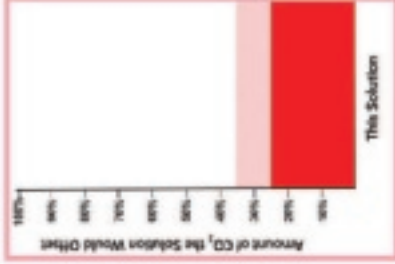
A lot of farmland is used to grow grain to feed livestock that people eat, like beef, chicken, and pork. If we eat less meat, we would need less land to grow the grain. If we can turn some of this farmland back into forest, this solution could help even more by cutting up to 3.1 gigatons of the 9 gigaton imbalance.

HOW WOULD THIS AFFECT PEOPLE?

- Meat is expensive, so buying less meat would save families money.
- More money can go to local produce farmers.
- Eating a plant-rich diet can make communities healthier and reduce healthcare costs.
- Not everyone can buy fresh produce.
- Some neighborhoods do not have grocery stores.
- Could negatively affect cattle, dairy, fish, chicken and other livestock farmers.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- Less animals would be killed for food.
- Less forest land would be cleared to raise livestock.
- Less land will be used to grow grain for livestock.
- Clearing less land would help maintain biodiversity.



Data Source: <https://www.ourworldindata.org/>

If 50%-75% of people on Earth are a plant-rich diet by 2050, this solution would reduce our carbon imbalance by 21%-34%, or 1.4-2.3 gigatons of the 9 gigaton carbon imbalance per year.

WHAT WOULD WE HAVE TO DO?

- Eat 2 oz or less of meat and under 2250 calories per day worldwide.
- Buy locally grown fruits and vegetables when we can.

PROPOSED SOLUTION #2 – Reducing Food Waste

WHAT IS THIS SOLUTION?

Approximately 30-40% of the food we grow is not eaten. This means the resources, such as the land and water to grow the food, the energy used to farm the food, the use of fertilizer, the human labor, and the transportation of that food are being wasted.

HOW WOULD THIS AFFECT PEOPLE?

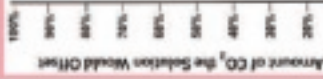
- » Reducing food waste can lower a family's grocery bill by up to 30%.
- » Better food storage may be needed, like a refrigerator or a cellar.
- » People would need access to fresh food.
- » Buying only what we can eat will reduce the amount of food that is packaged and shipped. This could negatively affect people working in the shipping, growing, and packaging of these foods.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Buying imperfect foods can reduce what stores throw in the trash, reducing food waste that ends up in a landfill.
- » Farmland that once grew food could be turned into natural space and could help bring wildlife back into those areas.



Amount of CO₂ the Solution Would Offset



This Solution

Data Source: <https://www.farmed.org/>

If 50-75% of food waste is reduced worldwide by 2050, this solution could reduce our carbon footprint by 3.8%-7%. Reducing food waste could cut 0.34-0.63 gigatons of the 9.6 billion carbon emissions per year.

WHAT WOULD WE HAVE TO DO?

- » Reduce food waste by 50-75% worldwide.
- » Eat fresh produce before it goes bad.
- » Spend time planning weekly meals so that food is not wasted.
- » Be open to eating a variety of produce, even if it's something you have never seen or tried before.
- » Buy imperfect ("ugly") produce, like fruit that is a different color or shape than normal.

PROPOSED SOLUTION #3—Carpooling/ Ridesharing

WHAT IS THIS SOLUTION?

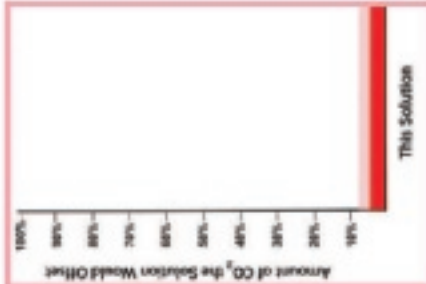
Carpooling, or ridesharing, is when people are a ride together. Sharing rides leads to less fuel used per person. Some cities have created special carpool lanes to encourage carpooling. Anyone almost anywhere can carpool, but carpooling makes a bigger difference in cities.

HOW WOULD THIS AFFECT PEOPLE?

- » A family of 3 that normally drives their own cars could save up to \$2000 on gas a year by riding in the same car.
- » People ridesharing can use carpool lanes to get to their destinations faster.
- » Finding someone to carpool with can take a bit of time and effort.
- » People would need to be reliable and on-time.
- » More ridesharing could affect jobs of some people who work with fossil fuels.
- » Some people are concerned about safety.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » People are less likely to throw trash out car windows when others are watching.
- » Fewer cars on roads means fewer animals hit by cars.
- » Fewer parking spots would be needed, so more green spaces could be built for people and animals.



Data Source: <https://www.drivetrain.org/>

If people in cities share a ride with at least 2 other people per trip regularly worldwide, it could cut 0.15–0.16 gigatons of the 9 gigaton carbon imbalance per year. Our carbon imbalance could be reduced by 3.6%–7%.

WHAT WOULD WE HAVE TO DO?

- » If you know someone who rides in a car alone, suggest they share a vehicle with 2 or more people. This would have to happen worldwide.
- » High-traffic areas could create policies that encourage people to carpool. This could include reduced tolls.

PROPOSED SOLUTION #4 – Electric Cars

WHAT IS THIS SOLUTION?

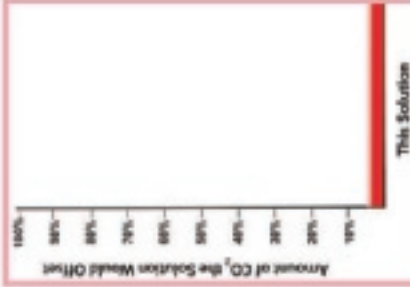
Electric vehicles run on electricity instead of fossil fuels. When compared to gas cars, electric cars are much better for the environment. Right now, there are over 1 million electric vehicles being used.

HOW WOULD THIS AFFECT PEOPLE?

- » Electric cars cost more than gas cars (about 30% more in the United States).
- » Charging stations must be added to homes and businesses.
- » Electric vehicles' batteries cost more than a battery for a gas car.
- » Electric cars generally travel shorter distances than gas cars.
- » Buying an electric car can cause loss of jobs for people who work in fossil fuels.
- » Many people cannot easily to afford a new electric car.
- » Some people do not like the way that electric cars look.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Electric vehicles do not generally require oil changes, spark plug replacements, or other maintenance that can lead to pollution.
- » The energy used to charge electric vehicles comes from fossil fuels, but they still make 50% less emissions than a gas car.
- » If solar power is used to charge electric cars, then emissions can be reduced by 95%.



Data Source: <https://www.fundcarbon.org/>

If we increase the number of people who own electric cars by 16-23%, this solution would cut 0.4-0.5 gigatons of the 9 gigaton carbon imbalance per year. We could reduce our global carbon imbalance by 4.4%-5.8%.

WHAT WOULD WE HAVE TO DO?

- » 16-23% of people would have to use electric cars worldwide.
- » If your family is interested in buying a new car, you can suggest they look into an electric car.

PROPOSED SOLUTION #5—Onshore Wind Turbines

WHAT IS THIS SOLUTION?

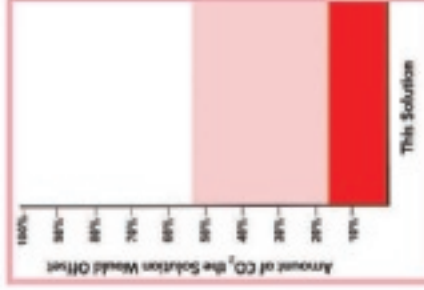
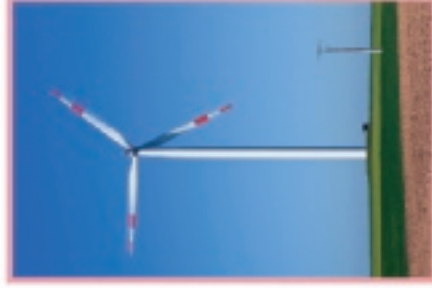
Wind turbines on the land can be used to replace power that was once made by fossil fuels. Wind turbines are built in groups called wind farms. Wind farms already exist in many windy locations. They are the cheapest way to make energy, but can cost several million dollars a piece.

HOW WOULD THIS AFFECT PEOPLE?

- » Some people are against wind farms because they can block views or be in their backyards.
- » Most individuals cannot afford them.
- » Wind turbines need less people to care for them than fossil fuel plants, so some fossil fuel jobs could not be replaced with wind farm jobs.
- » Wind turbines are safer and do not cause cancer or other harm to humans like fossil fuels can.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Wind turbines take up less space than a fossil fuel plant, so the land around them can be used for farming or other purposes.
- » Wind turbines do not emit carbon.
- » Wind turbines cause less noise pollution than fossil fuel plants.



Data Source: <https://www.davebrun.org/>

If land wind turbines make 19.6–29.6% of the world's electricity by 2050, this solution could reduce our global carbon imbalance by 17.4%–54.4%. Onshore wind turbines could cut 1.6–4.9 gigatons of the 9 gigaton carbon imbalance per year.

WHAT WOULD WE HAVE TO DO?

- » Power companies would have to build wind farms and use them to produce 19.6–29.6 of electricity worldwide.
- » Spend money teaching or retraining people on the special skills needed to work at wind farms.
- » Some cities and countries would have to update codes to allow for the building of wind farms.

PROPOSED SOLUTION #6 – Silvopasture

WHAT IS THIS SOLUTION?

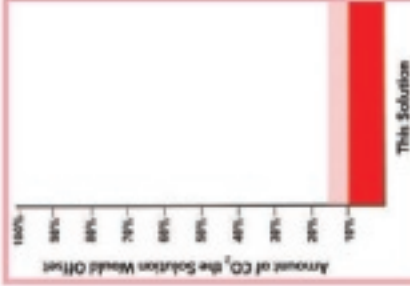
A silvopasture is a pasture used for raising animals that also has trees. These pastures with trees capture 5-10 times more carbon dioxide than a wide open field. To create silvopasture, animals on the land would have to be moved so trees could be planted. Newly planted trees have to grow to a height where livestock would not eat and kill the trees before animals could use the land again.

HOW WOULD THIS AFFECT PEOPLE?

- » Silvopasture can be expensive to create.
- » Silvopasture is easy to do if your land already has trees where animals can graze.
- » Ranchers would have to raise less animals while the silvopasture trees were growing. This could temporarily make them less money.
- » After the trees are adults, the farmer could make more money from the land by selling the produce.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Silvopasture can only be added to fields in moist areas with good soil.
- » By adding back native trees to a field, silvopasture can help increase biodiversity.
- » Tree shade, reduced runoff, and root uptake can reduce the effects of droughts and flooding.



Data Source: <https://www.danaburton.org/>

If 40-50% of ranchers turn their land into silvopasture by 2050, this solution could reduce our global carbon imbalance by 9.8-15.6%. Turning grazing land into silvopasture could cut roughly 1.1 gigatons of the 9 gigaton carbon imbalance per year.

WHAT WOULD WE HAVE TO DO?

- » 40-50% of farmers and ranchers would have to turn their land into silvopasture worldwide.
- » If you are a farmer, consider the costs and benefits to converting fields to silvopasture.

PROPOSED SOLUTION #7 – LED Lighting at Home

WHAT IS THIS SOLUTION?

LED light bulbs are much more energy efficient than incandescent light bulbs (i.e., regular light bulbs). In the past, incandescent bulbs have gotten very hot and converted a lot of electricity into heat. LED light bulbs use about 90% less energy than an incandescent bulb and use most of their energy to make light instead of heat.

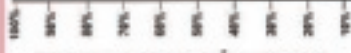
HOW WOULD THIS AFFECT PEOPLE?

- » LEDs can cost up to 6 times more than incandescent bulbs but they last 10 times longer. This means it will cost less to use LED bulbs over time.
- » Some people do not like the look of LED light bulbs when the lights are off.
- » Some states have already required stores to sell only LED lighting.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Throwing out old LEDs can have a negative impact on the environment if they are put in the regular trash and not recycled.
- » Most LEDs have to be safely thrown out like computers or other appliances.

Amount of CO₂ the Solution Would Offset



This Solution

Data Source: <https://www.davebruney.org/>

Using LEDs would cut 0.3–0.35 gigatons of the 9 gigaton carbon imbalance per year. If we can change 90–95% of the world's household light bulbs to LED by 2050, we could reduce our global carbon imbalance by 3.8–4%.



WHAT WOULD WE HAVE TO DO?

- » Change 90–95% of household light bulbs worldwide to LED light bulbs.
- » Using LEDs in schools and workplaces can reduce the global carbon imbalance even more than what is stated on the graph to the right.

PROPOSED SOLUTION #8 – Rooftop Solar Panels

WHAT IS THIS SOLUTION?

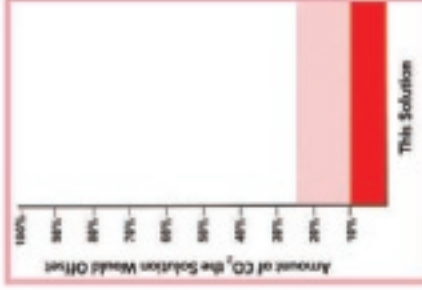
Solar panels convert sunlight into electricity. The energy is either stored by batteries or sold to the local electric company. The rooftop solar panels work well in very sunny locations.

HOW WOULD THIS AFFECT PEOPLE?

- » Home solar panels can cost between \$15,000–\$25,000. People can get about 20% of their money back in some states when they do their taxes.
- » In some sunny locations, power plants end up paying homeowners for their electricity.
- » Some people do not like the look of solar panels on houses.
- » Individuals would have to hire someone to fix or maintain the solar panels.
- » Some fossil fuel employees would lose their jobs.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Less animals would be killed for food.
- » Less forest land would be cleared to raise livestock.
- » Less land will be used to grow grain for livestock.
- » Clearing less land would help maintain biodiversity.



Data Source: <https://www.fuelburning.org/>

Rooftop solar panels could cut 0.9–2.3 gigatons of the 9 gigaton carbon imbalance per year. Right now, roughly 0.5% of the world's power comes from solar panels from homes and businesses. If we can generate 13.5–14.2% of the world's energy from rooftop solar panels by 2050, we could reduce our global carbon imbalance by 10.4–25.4%.

WHAT WOULD WE HAVE TO DO?

- » Install enough rooftop solar panels worldwide to generate 13.5–14.2% of the world's energy from rooftop solar panels.

PROPOSED SOLUTION #9 – Recycling

WHAT IS THIS SOLUTION?

Most household items, such as glass, paper, and plastics, can be recycled. Recycling products would reduce the amount of fossil fuels needed to make new plastics and other materials.

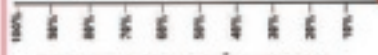
HOW WOULD THIS AFFECT PEOPLE?

- » Recycling means some people will lose waste management jobs initially, but shifting to recycling will create more jobs than were lost.
- » It can be expensive to start recycling and it can cost extra money in some communities.
- » Recycling can make areas near landfills smell more pleasant.
- » Some people do not like the look of recycling bins at their homes or workplaces, and it requires effort to separate out the items.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Recycling can help keep areas clean by recycling what does not decompose in nature.
- » Recycling helps to reduce water pollution and help keep pollution out of the oceans.

Amount of CO₂ the Solution Would Offset



This Solution

Data Source: <https://www.wasteandrecycling.org/>

Recycling 68-70% of recyclable items could cut up to 0.34 gigatons of the 9.6 gigaton carbon imbalance per year. If all families were to recycle 68% of the products that can be recycled, we could reduce our global carbon imbalance by up to 2.6%.



WHAT WOULD WE HAVE TO DO?

- » Determine if the community has a recycling program, and if not, set up a recycling program.
- » Separate out recycling from other waste at home and at school/work.
- » Everyone worldwide has to recycle 68-70% of the products that could be recycled.

PROPOSED SOLUTION #10—Tropical Forest Reforestation

WHAT IS THIS SOLUTION?

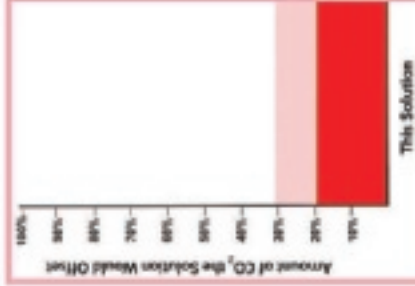
Tropical Forest Reforestation is when people plant new tropical forest plants and trees on land that has been cleared for logging and other industries. There is already a global push to start reforesting areas that were once tropical forests, but this solution only happens in tropical regions.

HOW WOULD THIS AFFECT PEOPLE?

- » Goods and products that were made on the reforested land may increase when the land is reforested.
- » Many people rely on the clearing of the land and the deforested land for jobs.
- » The land that is reforested can be turned into places for tourists to visit. This has been done in countries like Costa Rica.
- » It takes time for trees to start pulling large amounts of carbon from the atmosphere, so the carbon impact will not be immediate.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Replanting tropical forests can allow for biodiversity to return to the area.
- » Replanting trees helps to reduce erosion and the effects of floods and droughts.



Data Source: <https://www.researchgate.net/publication/351111111>

Turning at least 56% of cleared land back into tropical forests could reduce up to 1.82-2.84 gigatons of the 9.6 gigaton carbon imbalance per year. If 622,000 to 892,000 square miles of land is turned back into tropical forests, we could reduce our global carbon imbalance by 20.1-31.5%.

WHAT WOULD WE HAVE TO DO?

- » Turn 56% of cleared land back into tropical forests worldwide.
- » Donate money to groups that plant trees in these areas to create tropical forests.

PROPOSED SOLUTION #11 – Reducing Plastic Use

WHAT IS THIS SOLUTION?

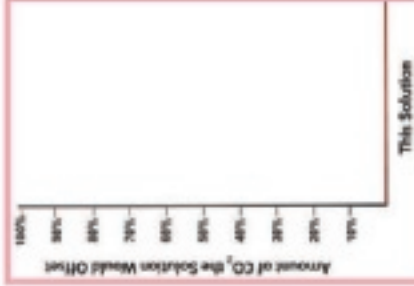
Most plastics are made from fossil fuels. It can also take energy made from fossil fuels to produce plastics. This means that fossil fuels are used in many steps of the plastic-making process. Most things we use are made of plastics, and we will most likely use 4x more plastic by 2050.

HOW WOULD THIS AFFECT PEOPLE?

- » Reducing plastic use means some people will lose manufacturing jobs initially, but shifting to recycling will create more jobs than were lost.
- » Some do not want to reduce their plastic use because plastics are easy to use.
- » Non-plastic packaging could cost more at the store.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Plastics contribute to pollution, which is bad for the environment.
- » Less waste would end up in oceans and landfills.
- » Less materials would be mined from natural resources to make plastics.



Date Source: <https://www.theguardian.com/>

Making plastics adds 1.8 gigatons of carbon dioxide to the atmosphere each year. It is believed that people will want to increase plastic use in the future, making this number even higher than 1.8 gigatons. Reducing plastic use by 68-70% worldwide could cut up to 0.36 gigatons of the 9 gigaton carbon imbalance per year.

WHAT WOULD WE HAVE TO DO?

- » Reduce all plastic usage by 20% to reduce our imbalance worldwide by 4%.
- » Use glass instead of plastic.
- » Use reusable plastic baggies.
- » Use reusable shopping bags.
- » Reuse other household plastics.

PROPOSED SOLUTION #12–Artificial Trees

WHAT IS THIS SOLUTION?

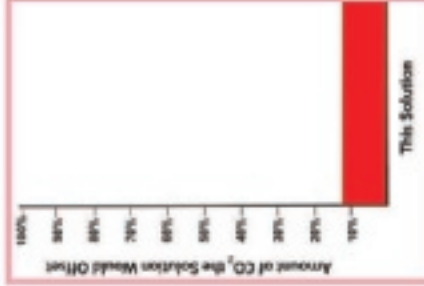
Artificial trees pull carbon dioxide out of the air 1,000 times faster than a living tree. One tree design has panels about the size of a car on top of poles. The panels hold a special kind of material that traps carbon dioxide. Another tree design has pools of electrified water and other chemicals that pull carbon dioxide from the air. As the water catches the carbon dioxide, it would also release oxygen. Currently, these trees only exist in labs and are not available for use in the real world. We also do not know how long it will take to build them or the cost.

HOW WOULD THIS AFFECT PEOPLE?

- » Jobs could be created by teaching people to build and maintain the artificial trees.
- » Some people may not like the look of artificial trees and not want them in their neighborhoods.
- » The large panels may also block some views.
- » The trees could possibly go on roadsides to capture emissions from vehicles.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » We do not know the full effect of the artificial trees on the environment or wildlife.
- » Artificial trees will probably take fossil fuels and other resources to build.
- » The trees would be able to offset any carbon that is used to build them.



Data Source: <https://www.framing.org/>

Building 10 million artificial trees could cut up to 11 gigatons of the 9 gigaton carbon imbalance per year. Artificial trees could reduce our global carbon imbalance by 12%.

WHAT WOULD WE HAVE TO DO?

- » Test and build artificial trees.
- » Invest money in creating the artificial trees.
- » Train professionals to build and take care of the artificial trees.

PROPOSED SOLUTION #13 - Alternative Cement

WHAT IS THIS SOLUTION?

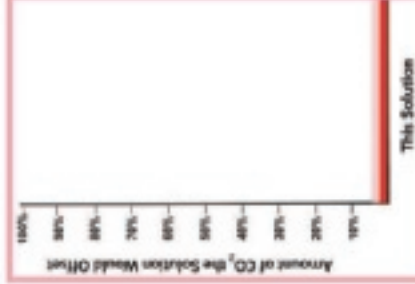
The main ingredient in regular cement is "clinker" made from heated limestone. Heating limestone and burning fossil fuels for the energy to make cement releases carbon dioxide. This is a new solution that is being tested, and emissions from power plants could possibly be used to make concrete instead of the clinker and reduce emissions by 90%.

HOW WOULD THIS AFFECT PEOPLE?

- » Using a clinker substitute appears to be cheaper than normal concrete.
- » Switching to special cement would cut jobs for those that work to make clinker, but there would also be jobs created for turning emissions into the special clinker free cement.
- » Some people like the look of the new cement that is whiter and brighter than normal cement.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Limestone used to make clinker is mined from Earth. This solution would reduce the amount of land being mined and help preserve wildlife areas.



This Solution

Data Source: <https://www.breitbart.com/>

If we reduce the amount of clinker in cement, we could reduce 0.27-0.53 gigatons of the 9 gigaton carbon imbalance per year. By changing the main ingredient from clinker to something else, carbon emissions could be reduced by 2.9-5.9%.

WHAT WOULD WE HAVE TO DO?

- » Use less clinker in cement-making materials.
- » Develop concrete that uses less clinker and make sure that it is safe to use worldwide.
- » Update building regulations so that this type of cement is allowed to be used by building companies. Most regulations do not allow for this type of cement to be used in the building of structures.

PROPOSED SOLUTION #14–Planting Trees

WHAT IS THIS SOLUTION?

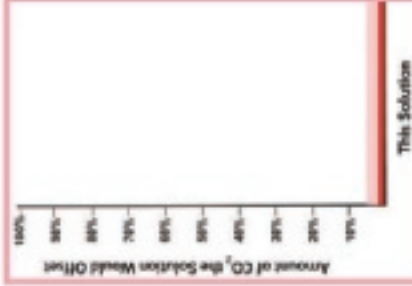
A fully grown tree can pull roughly 48 lbs of carbon dioxide out of the atmosphere a year. That is twice what a car will emit on average a year. But, this carbon does not get taken out immediately. Even after these trees have been planted, trees take a long time to grow and can take a decade to pull large amounts of carbon from the atmosphere.

HOW WOULD THIS AFFECT PEOPLE?

- » Many people like having trees in their communities.
- » Planting a seedling can cost as little as \$0.10. People would have to pay more (\$50–100) for more mature trees that pull more carbon out of the atmosphere.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » 72,000 square miles would have to be used to plant the trees – roughly the size of North Dakota.
- » Trees planted in areas like the rainforests pull carbon out of the air faster.
- » If a non-native tree is planted it can reduce biodiversity.
- » Planting trees helps with erosion, flooding, and drought controls.



Data Source: <https://www.fraunhofer.org/>

Planting one tree a person (for 7.5 billion people on the planet) could offset our emissions by 0.16–0.54 gigatons per year. If every person on the planet planted one tree, we could reduce carbon dioxide emissions by 2–6%.

WHAT WOULD WE HAVE TO DO?

- » Every person worldwide would have to plant one tree that lives to adulthood.
- » Right now, there is an effort called the "One Trillion Trees Initiative" meant to conserve and restore 1 trillion trees by 2030. So far, several countries, including the United States, are working on meeting this goal.

PROPOSED SOLUTION #15—Smart Thermostats

WHAT IS THIS SOLUTION?

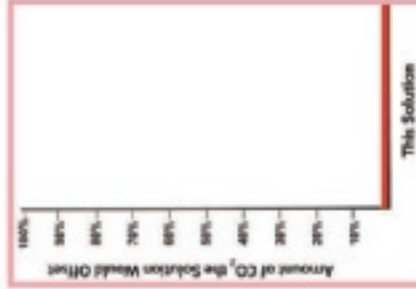
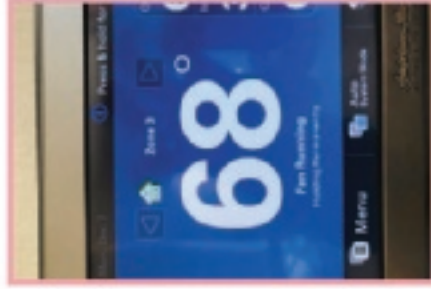
Smart thermostats learn the behaviors of their owners and adjust the temperatures to be as energy efficient as possible. When a person is away from home, the smart thermostat will adjust to save energy and money. Before the person comes home, the thermostat will automatically switch to a comfortable temperature.

HOW WOULD THIS AFFECT PEOPLE?

- » Smart thermostats cost from \$100–\$500, but can save a family \$130 a year on average in utility costs.
- » Smart thermostats require an internet connection to control, and many people in the world do not have a reliable internet connection.
- » Many homes around the world are still heated by fire, so central heat and air would have to be added to homes. This is not realistic yet in some areas and countries.
- » Eventually less fossil fuel use would be needed to heat and cool homes.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Fossil fuels and natural resources are used to create smart thermostats.
- » Over time, less fossil fuels would be needed to heat or cool homes, helping the environment.



This Solution

Data Source: <https://www.fairclimate.org/>

Using smart thermostats could cut up to 0.23–0.25 gigatons of the 9 gigaton carbon imbalance per year. If 58–63% of households worldwide use smart thermostats, this could reduce our global carbon imbalance by 1.6–2.7%.

WHAT WOULD WE HAVE TO DO?

- » Increase the use of smart thermostats from 3% of households worldwide to 58–63% of households worldwide.
- » Adjust the thermostats with apps when away from home.

PROPOSED SOLUTION #16 – Public Transportation

WHAT IS THIS SOLUTION?

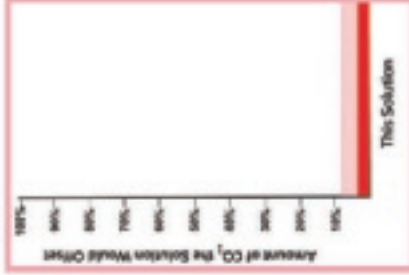
Public transportation, or public transit, moves people from place to place in larger groups. This reduces the amount of carbon dioxide being emitted by individual cars. Currently, public transit accounts for roughly 30% of urban travel. As roads improve in different countries and more people can afford vehicles, the use of public transportation is expected to decrease.

HOW WOULD THIS AFFECT PEOPLE?

- » Public transportation means less cars on the road.
- » Less traffic accidents would happen.
- » Not all areas have reliable public transit. Some areas would have to spend money to improve public transportation.
- » Some people do not want to travel in the same vehicle as other people or wait on public transit.
- » Using public transit costs less than the cost to own and maintain a personal vehicle.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Less cars means that there would be less emissions, so air quality would improve.
- » Less cars on the road would lead to less accidents with animals.



This Solution

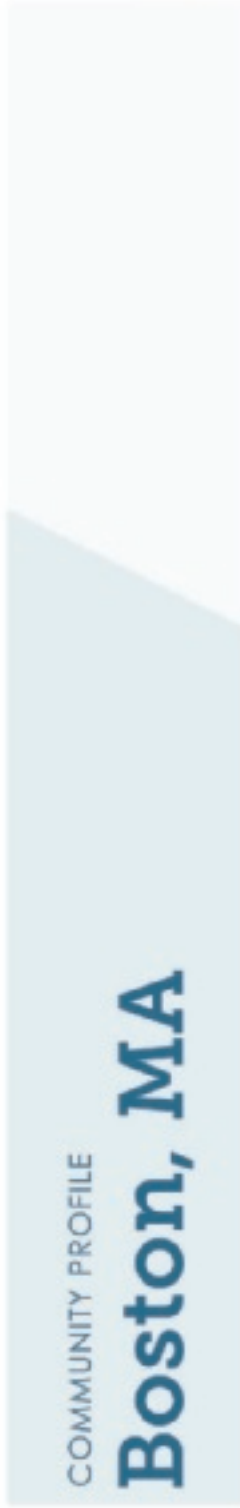
Data Source: <https://www.ourworldindata.org/>

Keeping the use of public transportation above 22%, preferably higher, by 2050 would cut up to 0.25 gigatons of the 9 gigaton carbon imbalance per year, and 0.76 gigatons if we can increase the usage to 30% worldwide by 2050. This could reduce our global carbon imbalance by 2.6%–8.7%.

WHAT WOULD WE HAVE TO DO?

- » Take public transportation (bus, metro, trains) instead of driving individual cars.
- » Keep the use of public transit to at least 22% by 2050, preferably increasing use to 35% worldwide.
- » Convince others to not switch to cars and invest in public transportation.

Boston: Community Resilience Plan



Boston, Massachusetts is one of the largest urban centers in the US with a population of almost 700,000 residents within the city itself (excluding all the outlying towns and suburbs). It is a coastal city located on the Atlantic Ocean. Boston has identified their greatest expected climate change impacts as:

- Warmer winters and more extreme heat days
- Heavier precipitation and more frequent storms
- Stormwater and sea level rise flooding



Source: City of Boston. (2021). Preparing for climate change. Retrieved from: <https://www.boston.gov/departments/environment/preparing-climate-change>

Buildings and Energy Efficiency

SOLUTIONS

1. Building codes for all new structures that require no use of fossil fuels for energy.
2. Improved energy efficiency of existing structures to reduce the amount of energy needed.
3. Elevated heating, cooling, and electrical systems to prevent damage during floods.

ACTIONS

-  Residents can improve energy efficiency of old homes or opt to support renewable energy sources.
-  Communities provide home services to residents to help them identify ways to improve energy efficiency.
-  Businesses design and build buildings with improved energy efficiency, renewable energy sources, and elevated electrical and heating/cooling systems.
-  Local government develops new building guidelines.

Transportation and Energy Options

SOLUTIONS

1. Smaller microgrid electricity systems (smaller electrical grids for communities) to help maintain power during storms.
2. Increased solar panels on city buildings to generate renewable energy.

ACTIONS

-  Individuals and communities can participate in funded solar or wind programs to obtain renewable energy.
-  Businesses install solar panels on roofs to generate energy.
-  Work with utility providers to develop and implement microgrid energy systems.

Water and Land Use Planning

SOLUTIONS

1. New stormwater systems to accommodate larger rain events and prevent damage to homes and buildings.
2. Maintain existing greenspaces and build new spaces to help take up carbon and provide shade and cooler temperatures during heat events, and better absorption of flood water during storms.

ACTIONS

-  Residents can be sure to report blocked stormwater systems and plant native plants or trees.
-  Communities can reserve space for parks, increased numbers of trees, or other green spaces.
-  Businesses can install green roofs and walls (roofs/walls with plants) to provide protection in flood and heat events.
-  Local government enforces new zoning and building codes.

Other Solutions

SOLUTIONS

1. Coastal flood protection barriers and stormwater parks to protect the city against sea level rise and storm surge.
2. Educate residents on the climate hazards that Boston will experience so they are prepared and resilient.

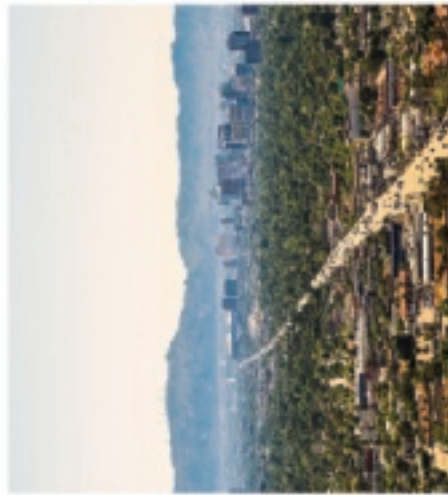
ACTIONS

-  Learn about the local hazards and city plans to help families.
-  Outreach and education campaigns by local government and business.
-  Large-scale building of levees and flood parks along the coast.
-  New zoning plans to make space available for coastal protection.

COMMUNITY PROFILE

Phoenix, Arizona is located in the southwestern portion of the US and is home to 1.7 million people. Phoenix is located in a very dry region known as Valley of the Sun and is near the Sonoran Desert. Phoenix has identified its climate change impacts as:

- Extreme heat events that can cause a public health risk
- Droughts and water shortages



Source: City of Phoenix. [2021]. Climate action plan. Retrieved from: <https://www.phoenix.gov/cepsite/Documents/2021ClimateActionPlanEnglish.pdf>

Buildings and Energy Efficiency

SOLUTIONS

1. Building codes for all new structures that require no use of fossil fuels for energy.
2. Replace all city lighting (100,000 bulbs) with efficient LEDs.
3. Upgrade existing cooling air conditioning systems to use less water, but maintain cooling efficiency.

ACTIONS

-  Residents and communities can replace all lighting with LED, choose reflective roof and paint materials and energy efficient appliances.
-  Businesses can choose energy-efficient and reflective building materials to reduce electricity load and reduce urban heat effects.
-  Provide incentive programs for residents to use more energy-efficient materials and appliances.

Water and Land Use Planning

SOLUTIONS

1. Build 100 cool corridors (trees canopies for shade; cool pavement) to provide heat relief.
2. Develop and maintain a 100-year water supply through water banking in the central Arizona aquifer system.
3. Expanded programs to install water efficient appliances and irrigation systems in existing homes.

ACTIONS

-  Reduce water use and use shade corridors on high heat days.
-  Monitor and reduce water use in high use buildings and spaces; switch to water efficient cooling systems when possible. Plant trees and provide greenspaces.
-  Provide incentive programs to change homes and buildings to more water efficient appliances; continue to bank water in the aquifer system.

Transportation and Energy Options

SOLUTIONS

1. Institute large-scale public or shared transportation options (light rail; rapid bus transit) so that 90% of residents live within half of a mile of public transit.
2. Increased solar energy projects to take advantage of 300+ days of sunshine each year.
3. Large expansion of electric vehicle charging stations.

ACTIONS

-  Residents can ride-share or use public transportation; limit unnecessary driving.
-  Businesses provide electric vehicle charging stations.
-  Plans for the development of a new light rail and shared public transportation options.

Other Solutions

SOLUTIONS

1. Attract businesses whose focus is on energy efficiency or waste reduction.
2. Educate residents on the climate hazards that Phoenix will experience so they are prepared and resilient.

ACTIONS

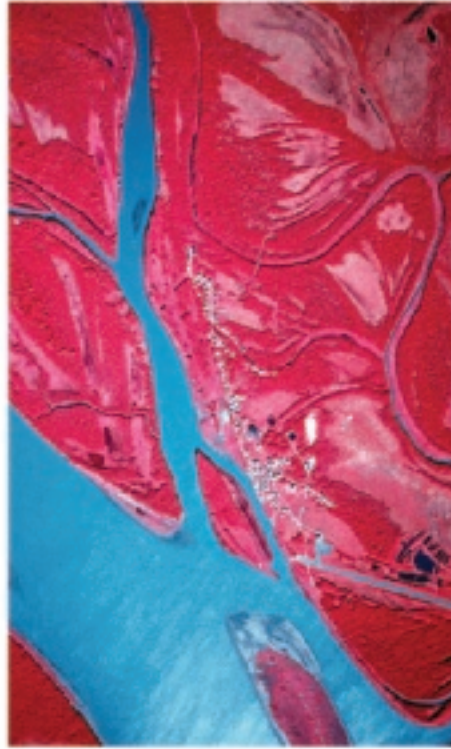
-  Use businesses that are focused on reducing waste and water use, and using carbon-neutral energy sources.
-  Provide incentives and educate community members on climate hazards and how to be more resilient.
-  Work with new businesses that are implementing solutions to reduce carbon emissions or water use.

Oscarville: Community Resilience Plan



Oscarville, Alaska is a small, remote Yup'ik subsistence community with 70 residents who primarily obtain their food from the sea, the land, and the air. There are no roads, running water, or in-home sanitation in Oscarville, and families live off less than \$20,000 per year. The residents of Oscarville rely upon traditional Yup'ik practices and a subsistence way of life. Oscarville has identified its climate change impacts as:

- Sea level rise and retreating sea ice
- Warmer winters and melting permafrost (which causes buildings to shift and sea ice to break)
- Extreme weather events and more frequent flooding and erosion
- Changes to harvests, hunting seasons, and fishing grounds



US Government Accountability Office

Source: Oscarville Traditional Village (no date). Pelttay'nahta = We are resilient; Oscarville Tribal climate adaptation plan. Retrieved from: http://oahvc.org/media/Oscarville_Adaptation_Plan.pdf

Buildings and Energy Efficiency

SOLUTIONS

1. Reinforce structures, such as houses, boardwalks, and community spaces with foundations that provide stability on the new terrain.
2. As temperatures warm, monitor buildings for mold, moisture, or leaks.

ACTIONS

1. Educating community members on identifying structural problems for buildings, or issues around moisture and mold.
2. Provide needed materials and equipment in a remote region of the state in order to fortify structures.

Water and Land Use Planning

SOLUTIONS

1. Build up river banks to prevent river flooding: move or secure docks.
2. Install in-home water tanks with clean water to provide steady access to water.
3. Create a Food Resource Plan to monitor how food sources are changing to ensure access to food year round.

ACTIONS

1. Identify seasonal shifts in food availability; introduce new appliances (e.g. freezers, in-home water) to help protect against food and water loss.
2. Consider how to change hunting, fishing, and harvesting policies and time periods to adjust to changing plant and animal populations.

Transportation and Energy Options

SOLUTIONS

1. New energy sources and electrical lines to run freezers to keep food frozen for year-round access.
2. Form a safety partnership with neighboring communities to help monitor travel of residents as ice is thinning and travel is more dangerous.

ACTIONS

1. Develop a shared network of safety reporting for community members travel over ice or ground to prevent accidents.
2. Provide infrastructure and power lines to service appliances in the community designed to preserve food or provide heat during the year.

Other Solutions

SOLUTIONS

1. Public health officials are preparing for viruses and bacteria that have been "dormant" in the permafrost that may pose a risk to people.
2. Educate residents on the climate hazards that Oscarville will experience so they are prepared and resilient.

ACTIONS

1. Community members can work together and with neighboring communities to share information and resources that help the communities adapt to changes.
2. Fund research on new viruses or bacteria trapped in the melting permafrost to better understand possible threats to human health.

COMMUNITY PROFILE

Yakima Basin, WA

The Yakima Basin is a large river basin region of Eastern Washington and is home to the territories of the Yakama Nation, along with the city of Yakima and the outlying farming communities in the area. The Yakima Basin region has identified its climate change impacts as:

- Drier summers with more frequent droughts
- Warmer winters with less snow and more rain; and peak streamflow earlier in the spring
- Warmer river water causes more fish to die from temperature and disease-related conditions



Source: Yakima Nation: Confederated Tribes and Bands, (2016). Climate Adaptation Plan for the Territories of the Yakama Nation. Retrieved from: <http://www.cattle.org/rep-content/uploads/2016/05/Yakima-Nation-Climate-Adaptation-Plan.pdf>

US Climate Resilience Toolkit, (2017), in the agricultural heartland of the Northwest Pacific, a water plan that protects people and nature. Retrieved from: <https://www.climate.gov/news-features/climate-case-studies/yakima-water-resilience>

City of Yakima Planning Division, et al. (2017). We are Yakima: Comprehensive plan 2040. https://www.yakima.gov/services/planning/files/2018/03/Yakima-Comprehensive-Plan-2017_0612-FINAL.pdf

Buildings and Energy Efficiency

SOLUTIONS

1. Provide cooling centers to community members without air conditioning on extreme heat days.
2. Evaluate and rebuild or update housing to better stand up to extreme heat and precipitation.
3. Develop new government and business structures following energy efficient design and materials.

ACTIONS

-  Residents can look for cooler places during extreme heat events; communities can provide public cooling centers for residents.
-  Use energy efficient designs and materials when building new structures or remodeling existing ones.
-  Build in policies that ensure buildings are well insulated and can withstand extreme heat and storm events.

Transportation and Energy Options

SOLUTIONS

1. Enlarge road crossings and culverts to prepare for flood events and clean and remove debris more often.
2. Take advantage of the large amounts of sun and wind in the Yakima basin to develop solar and wind energy.
3. Offer different modes of safe transportation and ensure the city is walkable.

ACTIONS

-  Choose to walk or ride-share when possible; report debris in culverts/ditches.
-  Government can invest in solar and wind projects to generate carbon-neutral energy for the region; provide for sidewalks and walking and biking corridors to allow for safe alternative transportation options.

Water and Land Use Planning

SOLUTIONS

1. Develop wetlands and river ecosystem protection plans to ensure healthy plant and animal populations.
2. Install stations to monitor weather and seasonal water flow and adjust flow as needed for crops, livestock, and fish.
3. Use water conservation practices to reduce water use in homes and for agricultural irrigation.

ACTIONS

-  Residents can plant native plants that need less water; irrigate less; use water efficient appliances.
-  Community and local government can develop plans for water storage and monitoring; create policies to protect the ecosystems to ensure healthy fish, animal, and plant populations.
-  Farmers and businesses can implement more efficient water and irrigation technologies, or rainwater collections, to reduce water use during drought.

Other Solutions

SOLUTIONS

1. Develop back-up communication and electrical systems in case there is a disruption during a storm event.
2. Educate residents on the climate hazards that the Yakima Basin will experience so they are prepared and resilient.

ACTIONS

-  The community residents can educate each other on climate hazards and how to be more resilient.
-  Businesses and local government can install back-up communication systems to warn people during a hazard.

Project Options

Different presentation options for your climate resilience plan are below. This list is meant to help you think of ways to present your information, and you also may think of a way that is NOT on this list. Check with your teacher if you would like to explore a project option that is not listed below. If you choose a digital option, make sure that you can access at least 1 digital resource on your device that can help you assemble your project.

Project options	Project details	Materials for a paper-based project	Materials and apps for a digital project
Poster	Create a poster to be displayed in a public place in your school or community.	chart paper, poster board, or regular copy paper	Computer Apps to consider: • Google Slides • Google Docs • Google Draw • Microsoft Word • Microsoft OneNote • Microsoft Powerpoint • Keynote • Notability • Piktochart • Adobe Spark or other Adobe software • Animaker For a Website: Google Sites For a Commercial, Newscast, Podcast: • phone or computer to record video or audio • editing software (optional) • additional apps: iMovie, Flipgrid, Clips, GarageBand, Anchor, Quicktime There may also be free templates and printables you can edit, download, and use from the web.
Infographic or brochure	Create an infographic or brochure to be passed out or shared with others.	pencils	
School or community newspaper article	Write a newspaper article about the carbon solution and why it is needed.	colored pencils or markers	
Website	Create an informative website for people to get more information.	make drawings or print/cutout photographs	
Community resilience app	Design an app to educate and prepare others with your plan.		
Series of tweets	Craft a series of informative tweets others would read to learn more about the plan.		
Presentation to a target audience	Prepare a presentation with talking points and graphics for a group at your school, the school board, or a community group.		
Commercial or newscast	Film a commercial to air during a popular TV show or a newscast.	No paper option available	
Podcast	Record an informative podcast.		

WATER SOLUTION #1—Stormwater Parks

HOW DOES THIS SOLUTION WORK?

Stormwater parks are built in places that are designed to flood with minimal damage. The park is mostly made of green spaces with native plants. These parks allow water to slowly absorb into the ground. The difference between a stormwater park and a wetland is that a stormwater park provide spaces for activities and recreation.

HOW WOULD THIS AFFECT PEOPLE?

- » Provide space for people to enjoy nature or outdoor activities.
- » Reduce flooding in vulnerable areas of the community.
- » Increased trees and plants improve air quality.
- » Green spaces improve property values of homes.
- » Reduce heating in urban areas by providing shade.
- » Expensive to build initially, but save money later on by reducing damage.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Native plants and animals have part of their native habitat restored.
- » More green spaces support greater biodiversity.
- » Plants pull carbon dioxide from the atmosphere.



The city of Arlington, Washington turned a section of wetlands into a stormwater park. The park has walking trails, a dog park, an area for wildlife viewing, and picnic tables. The park cleans stormwater, filters the water, and helps to control local flooding. This is a similar wetland.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » What areas are more likely to flood.
- » Spaces in that area that can be turned into a park, such as an old parking lot or a vacant lot.
- » If the community wants to transform the land into a park.
- » How to raise money to build the park.
- » The best native plants for the area to help control flooding.
- » How to engage the community in designing and building the park.

Source: Puget Sound Regional Council (2021). Stormwater parks for water quality and human health central puget sound stormwater parks — summary of interviews. Retrieved from: <https://www.psrc.org/sites/default/files/stormwater-parks-interviews-summary.pdf>

WATER SOLUTION #2–Rain Gardens

HOW DOES THIS SOLUTION WORK?

Every time it rains, the rain runs across roofs, driveways, roads, and other areas that can be covered in pollution. Rain also has nowhere to go if it is only landing on concrete, causing flooding. If rain runs off into streams or ponds, it can carry the pollutants with it.

Rain gardens are gardens planted at the bottom of slopes in yards or other areas that are designed hold rainwater when it falls. The gardens allow rainwater to soak into the ground. The rainwater is filtered as it passes through the soil. Compared to lawns, rain gardens allow 30% more water to filter into the ground.

HOW WOULD THIS AFFECT PEOPLE?

- » Rain gardens can reduce flooding in yards and other properties.
- » Rain gardens do not need a lot of maintenance, and reduce the area that needs to be mowed and watered.
- » While some people like the look of native plants, others do not.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Plants help to pull carbon dioxide from the atmosphere.
- » Rain gardens would help to filter the water and keep groundwater clean.

Source: United States Environmental Protection Agency (2021). Soak up the rain: rain gardens. Retrieved from: <https://www.epa.gov/soakuptherain/soak-rain-rain-gardens>



This photo shows a rain garden after a storm.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » Where the land naturally slopes.
- » If any spaces at the bottom of that area can be turned a rain garden.
- » Replace the area with 6-12 inches of sand and compost to allow more water to filter into the ground, and plant native plants in that area.

WATER SOLUTION #3 – Rainwater Harvesting

HOW DOES THIS SOLUTION WORK?

Rainwater harvesting catches the rain running off of roofs and stores it in tanks or rain barrels. This water can be used later for things like flushing toilets, laundry, or watering plants and gardens. If the water is cleaned, it can be used for other purposes as well.

HOW WOULD THIS AFFECT PEOPLE?

- » Rainwater harvesting can reduce flooding in yards and other properties.
- » Rainwater harvesting can reduce the money spent on water.
- » In areas of extreme drought, rainwater harvesting can help people have water to use for basic things, like flushing toilets, when water is scarce.
- » People would have to plan ahead and create rainwater harvesting systems on their buildings.
- » Some people do not like the look of tanks or barrels on the sides of their buildings.
- » Rain barrels cost money and take time to install.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Rainwater harvesting helps to reduce flooding around buildings.
- » Rainwater harvesting can provide water that can be used for plants when it has not rained recently.

Source: Office of Energy Efficiency and Renewable Energy (2021). Water-efficient technology opportunity: rainwater harvesting systems. Retrieved from: <https://www.eere.energy.gov/eere/energy/water-efficient-technology-opportunity-rainwater-harvesting-systems>



Image credit: USDA NRCS South Dakota. CC BY-SA 2.0

This rain barrel is attached to a house near Lowry, South Dakota. The water can be used for many purposes.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » Where to add rain barrels to buildings. Areas that have periods of rain and drought may need bigger or more barrels to collect water to last through the drought season.
- » How to add gutter covers to keep out large leaves and other items that can block the barrels.

WATER SOLUTION #4 –Green Roofs

HOW DOES THIS SOLUTION WORK?

Rooftops are covered with soil and small plants. When it rains, the roof absorbs part of the water. That absorbed water does not leave the roof, which reduces water runoff around the building.

HOW WOULD THIS AFFECT PEOPLE?

- » Green roofs reduce building heating and cooling bills.
- » Adding greenery on roofs instead of regular roofing materials reduces the temperature around the building, making the area less hot in the summer.
- » Green roofs reduce regular flooding around buildings.
- » Installing a green roof requires a very sturdy roof. Building or fixing a roof to be a green roof can be expensive.
- » A green roof requires regular maintenance.
- » Green roofs can also filter extra water through the soil, and this can be collected in rain barrels to use later.
- » Many people like the addition of green spaces in urban areas.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Temperatures in cities are higher than other areas in the summer. Adding green roofs helps to limit the increase in temperatures.
- » Plants on green roofs pull carbon dioxide from the atmosphere.

Source: United States Environmental Protection Agency (2018). Estimating the environmental effects of green roofs a case study in Kansas City, Missouri. Retrieved from https://www.epa.gov/sites/default/files/2018-09/documents/greenroofs_casestudy_kansascity.pdf



The building above is an example of a green roof. This green roof has an area for people to walk and enjoy the landscaping.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » What buildings have roofs that could support a green roof, or what roofs could be upgraded to support a green roof.
- » Green roofs can be expensive to build. We would have to find someone to pay for this expensive project.
- » After a green roof has been built, we would have to develop a maintenance plan.

WATER SOLUTION #5-Tree Canopy

HOW DOES THIS SOLUTION WORK?

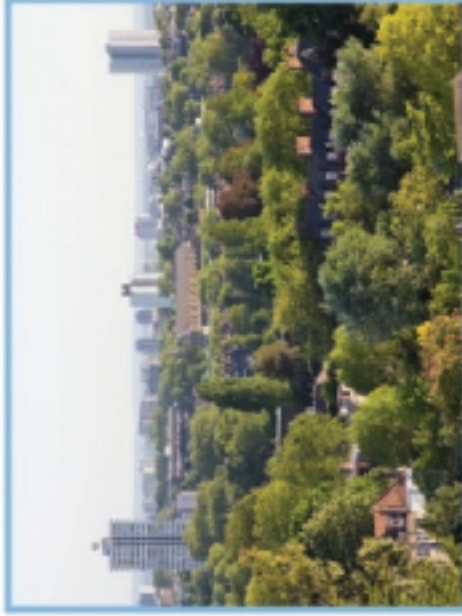
Trees are planted in areas that are generally covered with concrete. When it rains, the trees catch and use some of the rainwater, and also help the unpaved ground absorb the water instead of letting the water runoff and flood other concrete areas.

HOW WOULD THIS AFFECT PEOPLE?

- » Reduce flooding in vulnerable areas of the community.
- » Increased trees and plants improve air quality.
- » Green spaces improve property values of homes.
- » Reduce heating in urban areas by providing shade.
- » Trees can be inexpensive to plant from seedlings, but it would take time to see the changes trees cause in water absorption and temperatures.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Native plants and animals have part of their native habitat restored.
- » More green spaces support greater biodiversity.
- » Plants pull carbon dioxide from the atmosphere.



This image shows an urban tree canopy from above.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » Where trees could be planted that are also at risk of regular flooding.
- » Whether the community wants to add trees.
- » How to get city approval to plant trees on city land.
- » How to raise money to plant the trees.
- » The best native trees for the area to help control flooding.
- » How to engage the community in planting the trees.

Source: Center for Watershed Protection (2015). Urban tree canopy. Retrieved from: <https://www.cwcp.org/urban-tree-canopy/>
United States Environmental Protection Agency (2021). What is green infrastructure? Retrieved from: <https://www.epa.gov/green-infrastructure/what-green-infrastructure#UrbanTreeCanopy>

WATER SOLUTION #6—Reduce Our Everyday Water Use

HOW DOES THIS SOLUTION WORK?

We use water everyday, and sometimes that water is wasted. Water can be conserved by being aware of your use and making small changes to reduce the amount of water used each day. Common activities are adding motion sensing or automatic shutoff devices to faucets, switching to low-flow showerheads and other low-flow water saving devices, adjusting ice machines to make less ice, checking plumbing for leaks, and watering lawns less often.

HOW WOULD THIS AFFECT PEOPLE?

- Some activities require money to implement, but would save money and water in the long run.
- Some people do not want to reduce their water use.
- Conserving water allows for more water to be available during a drought.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- Less water use leaves more water for plants and animals.
- Non-native lawns and other non-native plants that are not used to the environment may die or go dormant.

Source: Chesapeake Bay Program (2017). Water conservation strategies. Retrieved from: <https://www.baydelpark.com/action-projects/school-water-conservation-strategies/water-conservation-strategies>



For every minute a sink runs, roughly 3 gallons of water is used. This means washing dishes by hand can cause a lot of water to be wasted if the water is running constantly. We can reduce our water usage by only running water while rinsing dishes or using dishwashers, which only use roughly 6 gallons a load.

WHAT WOULD WE HAVE TO FIGURE OUT?

- The ways we use water and the devices that use water around us daily.
- Where water may be wasted in our daily lives.
- What type of changes people are willing to make in their water use.
- How to communicate these changes to conserve water and how to get the community involved.
- Who will fund any new devices, such as automatic shutoffs.

WATER SOLUTION #7 –Coastal Wetlands

HOW DOES THIS SOLUTION WORK?

Coastal wetlands are natural areas near the ocean. These natural spaces almost always have water present and are filled with native plants and animals. The area provides a natural buffer zone and also helps to prevent coastal erosion while filtering the water. Some common names for these wetlands are bogs, marshes, swamps, and mangrove forests.

HOW WOULD THIS AFFECT PEOPLE?

- » Reduce flooding in vulnerable areas of the community.
- » Increased native plants improve air quality and biodiversity.
- » Expensive to build initially, but save money later on by reducing damage.
- » Some people may have to find new places to live or give up land for the wetlands to be put into place.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Native plants and animals have part of their native habitat restored.
- » More green spaces support greater biodiversity.
- » Plants pull carbon dioxide from the atmosphere.
- » Cleans water of pollutants as it filters through the wetlands.

Source: National Park Service (Accessed 2028). Restoring wetlands. Retrieved from: <https://www.nps.gov/subjects/wetlands/restoring-wetlands.htm>



Image credit: NPS

This image is of a bulldozer taking out man-made drainage ditches at the Palo Alto Battlefield National Historical Park in Texas. The United States National Parks Service also removed levees and stock ponds in 2017 to help bring back the wetland and prairie landscape that was once found at this site.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » What areas are naturally supposed to be wetland areas (this may include places that have housing and other businesses on them).
- » How to get the land that may be owned by someone, or convince that person or community to turn the area into a wetland.
- » What requirements the city has for land.
- » Who would be responsible for maintaining the wetland.

WATER SOLUTION #8–Native Plants

HOW DOES THIS SOLUTION WORK?

Every area of the USA has plants that naturally grow in that region. Those plants are well adapted to changes that occur in its particular climate. Native plants have life cycles and root systems that are meant to withstand the areas natural drought and flood conditions better than non-native plants.

HOW WOULD THIS AFFECT PEOPLE?

- » Native plants require less water and care than non-native plants.
- » Native plants help to reduce erosion.
- » Some native plants can cost more than non-native plants to buy and plant.
- » Some people do not like the look of native plants in their area.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » More spaces filled with native plants support greater biodiversity.
- » More shelter and food for native insects and animals.
- » Plants pull carbon dioxide from the atmosphere.
- » Less erosion would occur.
- » Water would more easily filter into the ground or out to the local waterway.

Source: United States Department of Agriculture, US Forest Service (Accessed 2019) Native gardening. Retrieved from: https://www.fs.fed.us/wildflowers/native_plant_materials/native_gardening/index.shtml



This home in California is landscaped with native plants.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » What places currently have non-native plants (yards, gardens, parks, etc.)
- » What native plants could take the place of those non-native plants.
- » Who is responsible for caring for and owning that land.
- » How to raise money or convince others to change the plants to native plants in the area.

WATER SOLUTION #9–Cool Roofs

HOW DOES THIS SOLUTION WORK?

Cool roofs are made of a material that is meant to help reflect heat away from a building. Reflecting this heat away from the building means there is less energy absorbed by the building. This keeps the building cooler. Some cool roofs can be 50-60 degrees cooler in peak summer when compared to traditional roofs.

HOW WOULD THIS AFFECT PEOPLE?

- » Cool roofs can reduce the overall temperature of a roof, and the air around a cool roof can be much cooler than the air around a regular roof. Cooler roofs can help keep temperatures in urban areas lower than with regular roofs.
- » Cool roofs can reduce the amount needed to cool a building in the summer. This type of roof does reflect some heat during the winter, but the savings in the summer are greater than the losses in the winter.
- » Green roofs can be more expensive than traditional roofs to install.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Cool roofs help to keep temperatures lower when compared to a regular roof.



The roofs to the right are all lighter colored and reflect light. This keeps the building temperature and the temperature of the surrounding air cooler than a traditional roof.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » What roofs absorb more energy in the summer and would benefit from being replaced with a cool roof.

Source: US Department of Energy (Accessed 2023). Cool roofs. Retrieved from: <https://www.energy.gov/energy-saver/cool-roofs>

WATER SOLUTION #10 – Drought Resistant Crops

HOW DOES THIS SOLUTION WORK?

Some crops grow better under different conditions. Crops like sorghum and sweet potato can grow better than other crops where it is generally drier. Over time, crops like corn, wheat, and rice have been bred to be more drought tolerant. Planting crops that have growing needs that are similar to the land they are planted on tend to grow better and continue to produce food even in drought conditions.

HOW WOULD THIS AFFECT PEOPLE?

- Drought resistant crops reduce the amount of watering that has to occur.
- Crops that are more native to the areas can help to maintain soil quality.
- Some crops that can grow in drought conditions may produce less money from year to year, but make up for any money lost during a year when a different crop would have failed.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- Drought resistant crops reduce the amount of water being channeled from different areas, saving water for other plants and animals.

Source: Esther Ngumbi, Inter Press Service News Agency (2019). Becoming drought resilient: why African farmers must consider drought tolerant crops. Retrieved from: <http://www.ipnews.net/2019/03/becoming-drought-resilient-why-african-farmers-must-consider-drought-tolerant-crops/> Date: 7/10/2020, source: rssdubm_medium-rssdubm_com/poign-becoming-drought-resilient-why-african-farmers-must-consider-drought-tolerant-crops

Good, Keith. University of Illinois (2019). Drought-tolerant corn in the U.S.: new report from USDAs Economic Research Service. Retrieved from: <https://farmpolicynews.illinois.edu/2019/01/drought-tolerant-corn-in-the-u-s-new-report-from-usdas-economic-research-service/>

Held, Elizabeth. Food Insight (2016). Bioeth: benefits, drought- and salinity-resistant crops. Retrieved from: <https://foodinsight.org/bioeth-benefits-drought-and-salinity-resistant-crops/>

Percent of each state's corn acreage planted with drought-tolerant (DT) hybrids, 2018



Note: In 2018, U.S. DT corn acreage totaled 16.6 million acres.
Source: USDA, Economic Research Service and National Agricultural Statistics Service, 2018 Agricultural Resources Management Survey

Image credit: USDA Economic Research Service and National Agricultural Statistics Service

Areas that more frequently experience drought are starting to grow drought resistant corn, as seen in the graph above.

WHAT WOULD WE HAVE TO FIGURE OUT?

- What conditions are like in different fields (droughts, floods, etc.).
- What crops work well in those conditions.
- Specific needs for each crop and the suitability of the crop to the temperatures in the area.
- What the requirements are to grow each crop and harvest it, along with the costs.

WATER SOLUTION #11–Prairie Strips

HOW DOES THIS SOLUTION WORK?

Prairie strips are strips of land where native plants are planted within crops. These strips are generally planted in rows throughout the field and take up no more than 25% of the field. The rows are between 30–120 ft wide.

Native plants have root systems that help to reduce erosion and also help to absorb water into the ground better than non-native crops during minor flooding events. Native prairie plants also require less water than most crops, and can help with reducing the amount of water needed during droughts.

HOW WOULD THIS AFFECT PEOPLE?

- » This solution helps maintain soil quality.
- » Just planting prairie plants on 10–20% of land with crops can reduce runoff by over 90%, including the loss of nitrates and phosphorus.
- » Takes roughly 3 years for prairie plants seed to root and produce benefits.
- » Could be balled into hay at the end of the season.
- » Reduces losses of land during flooding events.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Native plants and animals have part of their native habitat restored.
- » Plants pull carbon dioxide from the atmosphere.
- » Less runoff into the water results in cleaner water.
- » Can help restore pollinator populations.
- » Plants pull carbon dioxide from the atmosphere.

Source: Iowa State University (2020). USDA Farm Service Agency supports evaluation of prairie strips. Retrieved from: <https://www.iastate.edu/news/STWPS/fields-farm-service-agency-supports-evaluation-prairie-strips>
United States Department of Agriculture Farm Service Agency Conservation Reserve Program (2019). Clean Lakes, Estuaries and Rivers (CLEER) initiative prairie strip practice (CP-43). Retrieved from <https://www.nrm.iastate.edu/news/STWPS/fields-farm-service-agency-supports-evaluation-prairie-strips>
United States Department of Agriculture–Natural Resources Conservation Service Iowa (Accessed 2020). Iowa farmer fields new conservation practice. Retrieved from <https://www.nrcs.usda.gov/hq/pdp/portal/lands/fields/newsroom/features/STWPS/PR201843050/>



The image above shows a prairie strip blooming in the middle of a crop.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » Fields where prairie strips could be added.
- » Funding for the prairie strips. Contact your local branch of the NRCS or the USDA service center near you for more information.
- » The best native plants for the area to help control flooding.
- » Mowing schedule for the first few years to keep weeds down and native plants growing in the strips.

WATER SOLUTION #12—Cover Cropping

HOW DOES THIS SOLUTION WORK?

Cash crops, or crops that farmers grow for money, are planted according to growing seasons. In between cash crops, sometimes fields are empty. With cover cropping, the fields are planted with other plants in between the growing of cash crops.

HOW WOULD THIS AFFECT PEOPLE?

- » Reduces erosion and increases the fertility of the soil, increasing future crop yields.
- » Helps the ground absorb more water during large rains or flooding events.
- » Can break disease and insect cycles.
- » Money will need to be spent upfront on seed, fuel, and planting costs, which can make this expensive to implement. Over time, the cover crop will pay for itself with soil and crop yield benefits.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Plants pull carbon dioxide from the atmosphere.
- » Reduced erosion on farmland helps to keep water clean.



Image credit: USDA NRCS South Dakota. CC BY-SA 2.0

This picture shows a field that has cereal rye planted with the corn as a winter cover crop.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » What times of the year the fields lay fallow and what can grow during that time.
- » What the specific needs of the soil are and what cover crop to plant can help (ex. beans/legumes can help to provide new nitrogen). Contact your local extension office for more information over what crops work best for your area.
- » How to manage the cover crop so that it does not go to seed and become a weed.

Source: U.S. Department of Agriculture Northeast Climate Hub (Accessed 2021). Cover cropping to improve climate resilience. Retrieved from: https://www.climatehubs.usda.gov/sites/default/files/CoverCropsFactSheet_Feb2019_web508.pdf

WATER SOLUTION #13 – Water Banking

HOW DOES THIS SOLUTION WORK?

During a drought, surface water is can be hard to find and use. Many people use water that comes from underground. Unfortunately, in some places during droughts, the amount of water from underground is being used too fast to be replenished by natural rains and floods. Water banking is the process of taking extra surface water and sending it underground for use when it is needed.

Think of this solution as water being money and the ground being a big bank. You can save extra money (water) in a bank (underground). You can then take out your extra money (water) when you need it.

HOW WOULD THIS AFFECT PEOPLE?

- » Selling water to the water bank can provide extra income for people.
- » Increase water availability when other sources of water are low.
- » Less water being pulled from rivers and areas that are dammed during a drought could mean that hydroelectric power could still be easily produced.
- » Floodwaters could be redirected to sites where the water can be stored underground, reducing the size and timescale of a flood.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » More groundwater creates more stable environments.
- » Decreases impacts of droughts on local plants and animals.

Source: Colorado River District (2020). Water banking option. Retrieved from: <https://www.coloradodistrict.org/water-banking/>
Gins, Erica. Yale Environment 360 (2015). Water in the bank: one solution for drought-stricken California. Retrieved from: https://e360.yale.edu/features/water_in_the_bank_one_solution_for_drought-stricken_california
Horvath, Michelle. Stanford Water in the West (2021). Using floodwaters to weather droughts. Retrieved from: <https://waterinthewest.stanford.edu/news-events/news-insights/using-floodwaters-weather-droughts>



This image shows a hydrogeologist who is checking water levels at a percolation pond. Percolation ponds are places where water can naturally seep into the ground over time.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » What areas are more likely to have excess surface water or flood, and if they can be used to take water from.
- » Where canals or pipelines could be added to send extra surface water to places where the water can easily soak into the ground.
- » Who is responsible for building and maintaining the water bank (water agencies, community, local government, state government, conservation groups, etc.).

WATER SOLUTION #15–Dirty Cars

HOW DOES THIS SOLUTION WORK?

Car washes use a lot of water when washing your car. Some car washes are becoming more efficient and recycle that water from car to car, but still use more than washing your car with a bucket or not washing the car at all. By not washing your car you are cutting down on water usage.

HOW WOULD THIS AFFECT PEOPLE?

- » People would have dirty cars.
- » Some people would be disappointed because their cars are dirty on the outside.

HOW WOULD THIS AFFECT THE ENVIRONMENT?

- » Less soap would run off into the wastewater system and into areas where it could potentially affect plants and animals.
- » If you hand-wash your car, you would have to make sure that all soap and runoff does not go down a storm drain, causing the water to become polluted.



If you have to wash your car during a drought, try to only use one bucket of soapy water.

WHAT WOULD WE HAVE TO FIGURE OUT?

- » If people would be willing to not wash their cars.
- » If a vehicle absolutely needs to be washed, a bucket of soapy water would have to be used instead of going to the carwash. Use the sprayer only when absolutely needed.
- » How to engage the community in this solution.

Source: Seaman, Greg. *Earth Easy* (2012). The 5 best ways to save water during a drought. Retrieved from <https://thameswater.co.uk/article/5-best-ways-to-save-water-during-a-drought/>

Water Solution Cards Sources

The table below shows the sources used to compile information for the *Water Solution Cards*.

Card	Source(s)
Water Solution #1 - Stormwater Parks	Puget Sound Regional Council (2021). Stormwater parks for water quality and human health central puget sound stormwater parks - summary of interviews. Retrieved from: https://www.psrc.org/sites/default/files/stormwater-parks-interviews-summary.pdf
Water Solution #2 - Rain Gardens	United States Environmental Protection Agency (2021). Soak up the rain: rain gardens. Retrieved from: https://www.epa.gov/soakuptherain/soak-rain-rain-gardens
Water Solution #3 - Rainwater Harvesting	Office of Energy Efficiency and Renewable Energy (2021). Water-efficient technology opportunity: rainwater harvesting systems. Retrieved from: https://www.energy.gov/eere/femp/water-efficient-technology-opportunity-rainwater-harvesting-systems
Water Solution #4 - Green Roofs	United States Environmental Protection Agency (2018). Estimating the environmental effects of green roofs a case study in Kansas City, Missouri. Retrieved from: https://www.epa.gov/sites/default/files/2018-09/documents/greenroofs_casestudy_kansascity.pdf
Water Solution #5 - Tree Canopy	Center for Watershed Protection (2015). Urban tree canopy. Retrieved from: https://www.cwp.org/urban-tree-canopy/ United States Environmental Protection Agency (2021). What is green infrastructure? Retrieved from: https://www.epa.gov/green-infrastructure/what-green-infrastructure#Urbantreecanopy
Water Solution #6 - Reduce Our Everyday Water Use	Chesapeake Bay Program (2021). Water conservation strategies. Retrieved from: https://www.baybackpack.com/action-projects/school-water-conservation-strategies/water-conservation-strategies
Water Solution #7 - Coastal Wetlands	National Park Service (Accessed 2021). Restoring wetlands. Retrieved from: https://www.nps.gov/subjects/wetlands/restoring-wetlands.htm

Card	Source(s)
Water Solution #8 - Native Plants	United States Department of Agriculture, US Forest Service (Accessed 2021) Native gardening. Retrieved from: https://www.fs.fed.us/wildflowers/Native_Plant_Materials/Native_Gardening/index.shtml
Water Solution #9 - Cool Roofs	US Department of Energy (Accessed 2021). Cool roofs. Retrieved from: https://www.energy.gov/energysaver/cool-roofs
Water Solution #10 - Drought Resistant Crops	Esther Ngumbi, Inter Press Service News Agency (2019). Becoming drought resilient: why African farmers must consider drought tolerant crops. Retrieved from: http://www.ipsnews.net/2019/03/becoming-drought-resilient-why-african-farmers-must-consider-drought-tolerant-crops/?utm_source=rss&utm_medium=rss&utm_campaign=becoming-drought-resilient-why-african-farmers-must-consider-drought-tolerant-crops Good, Keith. University of Illinois (2019). Drought-tolerant corn in the U.S., new report from USDA's Economic Research Service. Retrieved from: https://farmpolicynews.illinois.edu/2019/01/drought-tolerant-corn-in-the-u-s-new-report-from-usdas-economic-research-service/ Held, Elizabeth. Food Insight (2016). Biotech benefits: drought- and salinity-resistant crops. Retrieved from: https://foodinsight.org/biotech-benefits-drought-and-salinity-resistant-crops/
Water Solution #11 - Prairie Strips	Iowa State University (2021). USDA Farm Service Agency supports evaluation of prairie strips. Retrieved from: https://www.nrem.iastate.edu/research/STRIPS/usda-farm-service-agency-supports-evaluation-prairie-strips United States Department of Agriculture Farm Service Agency Conservation Reserve Program (2019). Clean Lakes, Estuaries and Rivers (CLEAR) initiative prairie strip practice (CP-43). Retrieved from https://www.nrem.iastate.edu/research/STRIPS/usda-farm-service-agency-supports-evaluation-prairie-strips United States Department of Agriculture - Natural Resources Conservation Service Iowa (Accessed 2021). Iowa farmer tests new conservation practice. Retrieved from: https://www.nrcs.usda.gov/wps/portal/nrcs/ia/newsroom/features/STELPRDB1143858/

Card	Source(s)
Water Solution #12 - Cover Cropping	U.S. Department of Agriculture Northeast Climate Hub (Accessed 2021). Cover cropping to improve climate resilience. Retrieved from: https://www.climatehubs.usda.gov/sites/default/files/CoverCropsFactsheet_Feb2019_web508.pdf
Water Solution #13 - Water Banking	Colorado River District (2021). Water banking option. Retrieved from: https://www.coloradoriverdistrict.org/water-banking/ Gies, Erica. Yale Environment 360 (2015). Water in the bank: one solution for drought-stricken California. Retrieved from: https://e360.yale.edu/features/water_in_the_bank_one_solution_for_drought-stricken_california Horton, Michelle. Stanford Water in the West (2021). Using floodwaters to weather droughts. Retrieved from: https://waterinthewest.stanford.edu/news-events/news-insights/using-floodwaters-weather-droughts
Water Solution #14 - Improved Stormwater Systems	Chicago Metropolitan Agency for Planning (Accessed 2021). Stormwater and flooding. Retrieved from: https://www.cmap.illinois.gov/programs/water/stormwater Metropolitan Planning Council (2021). Steady streams establishing dedicated funding for stormwater management. Retrieved from: https://www.metroplanning.org/steadystreams/default.aspx?utm_source=%2Fsteadystreams&utm_medium=web&utm_campaign=redirect
Water Solution #15 - Dirty Cars	Seaman, Greg. Earth Easy (2012). The 5 best ways to save water during a drought. Retrieved from: https://learn.eartheasy.com/articles/the-5-best-ways-to-save-water-during-a-drought/

Reading: Changes to Groundwater

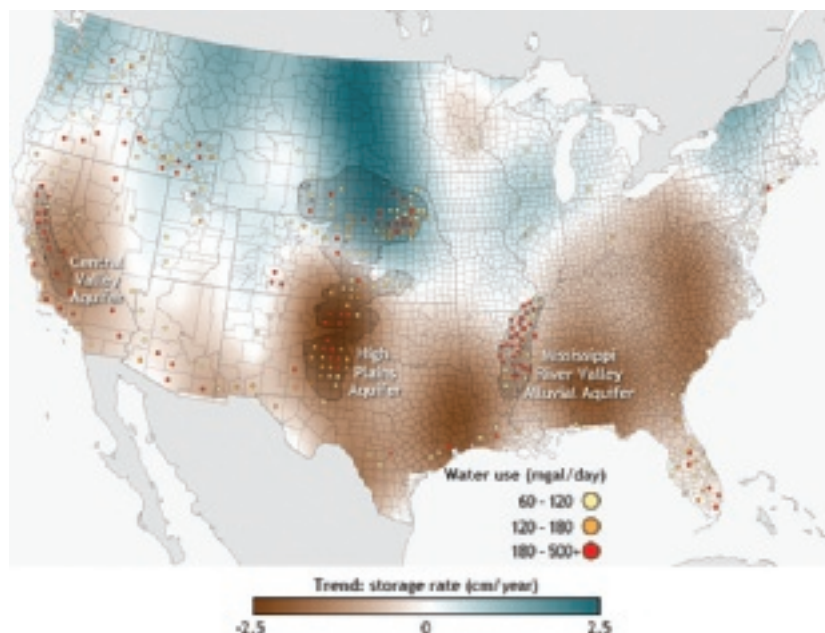
The water cycle describes how water moves above, on, and through the Earth. But, in fact, much more water is “in storage” at any one time than is actually moving through the cycle. By storage, we mean water that is locked up in its present state for a relatively long period of time. Short-term storage might be days or weeks for water in a lake, but it could be thousands of years for deep groundwater storage or even longer for water stored in an ice cap or glacier. In the grand scheme of things, this water is still part of the water cycle.

Groundwater is a very important source of freshwater for human communities. Groundwater contains over 1,000 times more freshwater than rivers and lakes combined.

Changes to Groundwater

In simplest terms **groundwater** is what its name implies: water in the ground that fully saturates pores or cracks in soils and rocks. Water underlies the Earth’s surface almost everywhere – beneath oceans, hills, valleys, mountains, lakes, and deserts. It is not always easy to get to or clean enough for use without treatment, but it exists essentially everywhere if you dig deep enough. Groundwater may occur close to the surface or it may lie many hundreds of feet below. And not all groundwater is the same age. Water at very shallow depths could be just a few hours old, whereas water at great depth may have been there for several thousands years.

The map shows a satellite-based estimate of the change in the amount of water stored in aquifers per year across the United States from 2003-2012. Areas where the storage rate increased are shades of blue while areas where the water storage decreased are shades of brown. The dots indicate water use by people. Increases and decreases in the amount of water stored in U.S. aquifers is influenced both by the rate of recharge from snowmelt and rainfall as well as demand from pumping and natural draws.



Climate.gov

The water stored in the ground can be compared to money kept in a bank account. If you withdraw money at a faster rate than you deposit new money you will eventually start having account-supply problems. Pumping water out of the ground faster than it is replenished over the long-term causes similar problems. The volume of groundwater in storage is decreasing in many areas of the United States in response to pumping. Groundwater depletion is primarily caused by sustained groundwater pumping.

Questions for Discussion

- How is the amount of groundwater changing? What are different reasons for why it might be changing?
- Think about how groundwater refills. Based on what you read, what problems are happening between how groundwater refills compared to how people use it?

Text adapted from the following sources:

USGS Water Science School:

- Groundwater Basics: <https://www.usgs.gov/mission-areas/water-resources/science/groundwater-basics>
- Groundwater decline and depletion: <https://www.usgs.gov/special-topics/water-science-school/science/groundwater-decline-and-depletion>

NOAA

- Groundwater declines across US South over past decade: <https://www.climate.gov/news-features/featured-images/groundwater-declines-across-us-south-over-past-decade>

Reading: What Is Air?

The air around us is a mixture of different types of gases. The molecules that make up those gases are too small for us to see. But there are other pieces of matter in the air that are bigger than a single molecule. These include things like dust, ash, spores, pollen, and pollution.

Most of the gas in the air is either oxygen or nitrogen. A smaller amount of it is carbon dioxide, water, and argon. Water in gas form is often called *water vapor*. The amount of water vapor in the air is referred to as *humidity*.

Humidity probes can help us measure changes in the amount of water vapor in the air. They often report the amount of water vapor in the air as something called *relative humidity*. Relative humidity is reported as a percentage from 0 to 100 percent. A relative humidity reading of 100 percent means the air has reached the maximum amount of water vapor it can hold. It doesn't mean that the air is only made of water vapor molecules.

The humidity probe to the right is shown measuring a relative humidity of 39 percent in air that is 19.5°C. This shows that the water vapor in the air is about halfway between the minimum and maximum amounts that air can possibly hold at this temperature.

Substance	Gas by volume
Nitrogen	Around 78%
Oxygen	Around 21%
Argon	About 1%
Carbon dioxide	Less than 1%
Water	From 0% to around 6%
Other substances	Less than 1%



Reading: Glaciers and Water Supply

Changes to Glaciers

Even though you've maybe never seen a glacier or massive extents of ice, they are a big item when we talk about the world's water supply. Almost 10 percent of the world's land mass is currently covered with glaciers and ice caps, mostly in places like Greenland and Antarctica. Glaciers contain 70 percent of the world's freshwater, too. Glaciers are important features in Earth's water cycle and affect the volume, variability, and water quality of runoff in areas where they occur. Glacial ice can be very old—in some Canadian Arctic ice caps, ice at the base is over 100,000 years old.



In a way, glaciers are just frozen rivers of ice flowing downhill. Glaciers begin life as snowflakes. When the snowfall in an area far exceeds the melting that occurs during summer, glaciers start to form. The weight of the snow compresses the fallen snow into ice. These “rivers” of ice are tremendously heavy, and if they are on land that has a downhill slope, the whole ice patch starts to slowly grind its way downhill. These glaciers can vary greatly in size, from a football-field sized patch to an ice patch a hundred miles (161 kilometers) long.

Temperature and precipitation determine how much snow a glacier receives and how fast it melts. Glaciers tend to gain more snow and ice during the winters. Glaciers lose more ice than they gain in summers. During a cool year with lots of precipitation glaciers gain more snow than they lose. During warm years without precipitation, glaciers lose more snow and ice to melting than they receive.

In some parts of the world, like the Himalayan mountains in Asia, people depend greatly on freshwater that melts from glaciers. It is estimated that 1.5 billion people depend on this source of water for drinking and household use, for farming, and for generating electricity for their communities.

Glaciers exist today in the United States, too. Tens of thousands of them are in Alaska. During the current warmer climate today, glaciers are shrinking at a rate we can easily measure on a yearly scale.

Questions for Discussion

- How is the amount of glacier water changing as temperatures warm up?
- Think about what you've learned about changes to glaciers. How might these changes affect water supplies for people?

Text adapted from the following sources:

USGS Water Science School:

- Ice, Snow, and Glaciers and the Water Cycle: <https://www.usgs.gov/special-topics/water-science-school/science/ice-snow-and-glaciers-and-water-cycle>
- Glaciers and Ice caps: <https://www.usgs.gov/special-topics/water-science-school/science/glaciers-and-icecaps>

Reading: Gases that Vibrate

Many years ago, Eunice Foote was trying to answer some of the same questions you have been asking. She was curious about the gases in the atmosphere and their role in the temperature of the atmosphere. Foote used glass cylinders filled with different gases and placed the cylinders in the sunlight and recorded the temperature. She discovered that some of the cylinders of gas warmed up more than others. Can you guess which ones?



Foote reported the following in 1856: “The highest effect of the sun’s rays I have found to be in carbonic acid gas.” Carbonic acid gas is what we know now as carbon dioxide. She was the first to conclude that “An atmosphere of that gas would give to our earth a high temperature. . . .” Eunice Foote’s contribution often goes unnoticed. As a woman, she was not allowed to present her work at science conferences or publish like male scientists. It was a few years later that John Tyndall published a paper identifying the gases responsible for warming our atmosphere. He is often given credit for this discovery, even though Eunice Foote was first to make these claims.

Eunice Foote concluded that carbon dioxide causes our atmosphere to warm. How does carbon dioxide do that? What makes carbon dioxide so special? Water vapor and methane also cause the air to warm. Gases like these absorb energy. The atoms in the molecules of these gases can move within the molecule—they vibrate. Because of their structure, these gases vibrate when energy is transferred to the molecule. Once they start to vibrate, they release that energy back into the atmosphere in all directions. Most of the energy from Earth’s warmed surface goes into space, but the energy released from these gases causes the atmosphere to warm because they send some energy back to Earth. This process is called the **greenhouse effect**.

Gases that absorb and release energy in the atmosphere are called **greenhouse gases** (GHGs). Three of the most important greenhouse gases include water vapor (H_2O), carbon dioxide (CO_2), and methane (CH_4). We would not be able to survive on Earth if we didn’t have greenhouse gases—it would be too cold! These gases help to warm our planet. So, they are not bad gases—they are necessary for life on Earth!

A very important GHG is water vapor. Have you ever thought about why we are not worried about water vapor building up in the atmosphere? The amount



Original science experiments by Eunice Foote, American Journal of Science (1857)

of water vapor in the atmosphere stays about the same, though it's going up a little as the temperatures get warmer. If the amount of water gets too high, the water cycle takes care of it. Water condenses and falls as precipitation. However, we know that some GHGs are increasing in our atmosphere—carbon dioxide and methane, for example. They cannot fall out of the atmosphere as precipitation like water vapor can.

Reading: Powering our World

What was happening in the world when CO₂ started going up again?

1600s and earlier

Before the 1700s, people mostly used trees to build homes and provide heat and fuel for everyday life, like cooking. But people used coal for this purpose, too. There is evidence that coal was used in China 3,000 years ago, by Romans in Europe 2,000 years ago, and by the Hopi tribe in North America 1,000 years ago. By the late 1600s, wood from forests was used up in many places, and people started to use coal as a major energy source for daily life.

1700s

In the 1700s, the world's energy use began to drastically change. Coal is a hard black rock formed from the leftover carbon from ancient trees and animals that have been buried in the ground for millions of years. It is known as a "fossil fuel" because it is the remains of ancient living things that can be used as a fuel for heat and light. Early on, coal could be easily extracted from the ground in shallow mines.

In 1712, in England, Thomas Newcomen invented an engine that could run off of steam produced by burning coal and heating water. In the late 1700s, an improved version of the steam engine was patented by James Watts. When burned, coal gives off heat, but also gases (including CO₂).

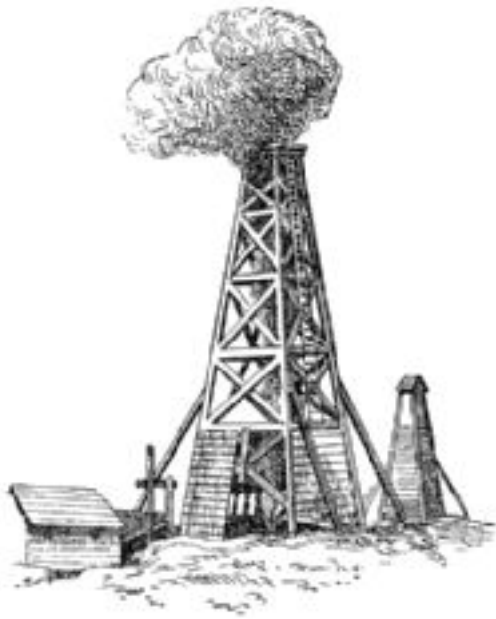
1800s

The steam engine began to transform the world. It powered ships, railroads, and factories. The use of the steam engine began in England but quickly spread to the rest of Europe and North America in the early 1800s. Coal continued to be the main fuel source for these engines for most of the 1800s. Coal also became the main fuel to produce electricity to homes.

Oil and natural gas were also used in the mid-1800s to make kerosene for lamps. Eventually, oil was refined into gasoline, too. Oil and natural gas come from the same source as coal—the remains of living things that died and were buried for millions of years.

1900s

In the early 1900s, cars were produced on large scales. In 1900, there were only about 8,000 cars in the US. By 1920, there were millions of cars on the road! Cars were quickly adopted in the US because of the ease and speed of traveling long distances. Initial car designs ran on steam and electricity, but eventually, gasoline became the most used fuel. Today there are about 275 million cars in the US alone and almost all use gasoline. Since 1950, oil and natural gas have been the energy sources for powering transportation, heating homes, and producing electricity.



Discontinued and changing dates will be in accord with the time required for ready to print and deliver at all possible times.

6000 TONS



COAL

OF THE BEST QUALITY.

AT LOWEST PRICES.

Bacon & Hucksins,
KENTUCKY BURNS AND FIRST ST.

LOST,

A BLACK JAY BARNER and is sold to the Kentucky State of Kentucky. Bacon and Hucksins' agent. The dealer will be holding up money by having to be in the office.

COAL.



OWN THIS BEST QUALITY

Lehigh & White Ash Coal,

at my Tackle, which will be sold

AT LOWEST PRICES.

T. G. STICKNEY,
OFFICE, 1000 N. 1, Lehigh & Ash

Mr. E. PARRY BECKETT
State of Kansas, now member of LEHIGH CO.

ARROW COAL

DRIVE IN SERVICE.
INSTANT LOADING.
PROMPT HOME DELIVERY.

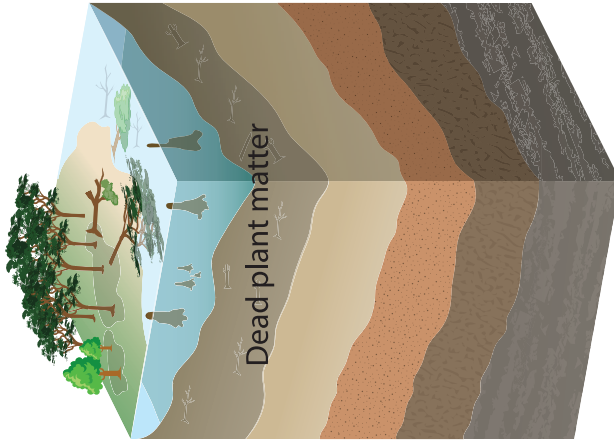
505 EIGHTEENTH ST.

Phone **191**

ASK ABOUT OUR PLAN OF CO-OPERATIVE CUSTOMER OWNERSHIP TO SAVE YOU MONEY

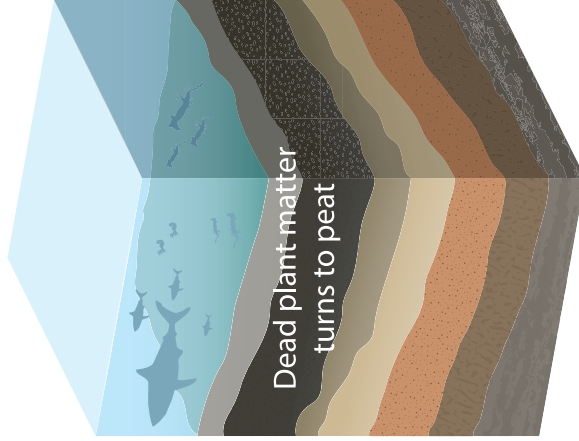
Coal Formation

Dead plant matter sank to the bottom of swampy waters. A thick layer forms on the bottom.



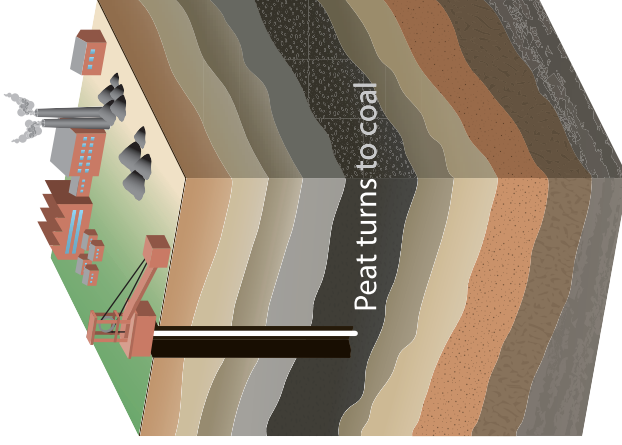
70–400 million years ago

Over millions of years new layers of sediment form on top of the plant matter, which is now called peat. These new layers create pressure and heat on the peat.



50–100 million years ago

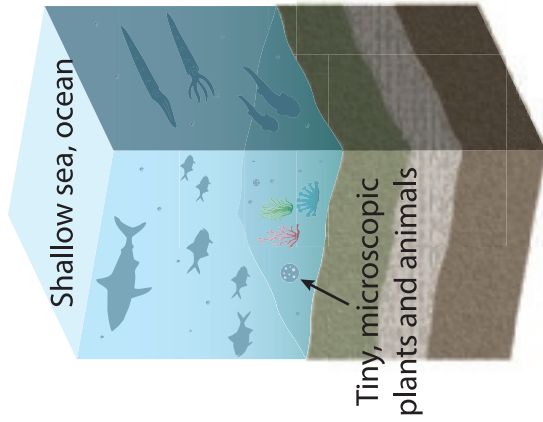
After millions of years of heat and pressure, the peat turns into different kinds of coal. Coal can be mined from deep underground or at the surface, as shown in this picture.



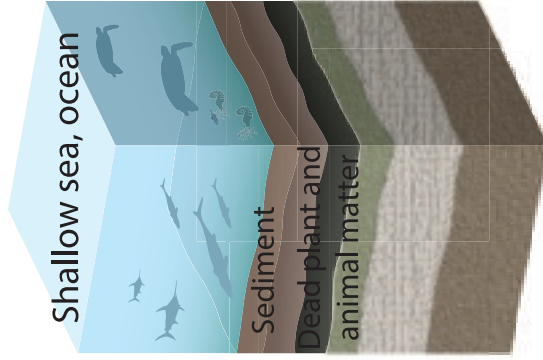
Today

Oil and Natural Gas Formation

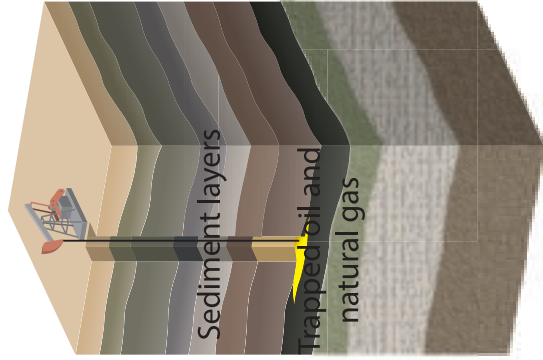
Tiny marine plants and animals dies and their remains sunk to the ocean floor. Eventually the remains were buried.



The dead plants and animals were buried deeper by more layers of sediment.



Millions of years of heat and pressure turned the dead plant and animal matter into oil (or petroleum) and natural gas. Oil is drilled deep underground. It can be drilled on land or just off the coast using drilling platforms.



100+ Millions of years ago → 60 Millions of years ago → Today

Coal Long Ago and Today

Coal mining in the Appalachian Mountains fueled the American economy into the mid-20th century. At one point in time, the coal industry in this region employed hundreds of thousands of workers. Coal is still an important industry in this region, and a major fuel source for the US energy system. However, most coal now comes from mines in the Powder River Basin in Wyoming and Montana. The two most productive coal mines are located in this region. The Black Thunder Mine in Wyoming is the largest coal producing mine in the US today.

Where is coal found in the US?

Coal is mainly found in three regions: the Appalachian coal region, the Interior coal region, and the Western coal region (including the Powder River Basin).



Coal production by region in million short tons and regional share of total U.S. production, 2019



Note: Excludes refuse recovery coal. Sum of shares may not equal 100% because of independent rounding.
Source: U.S. Energy Information Administration, Annual Coal Report, October 2020



U.S Energy Information Administration (2020)

Why is coal found in some places and not others?

We have to go back 300 million years to answer that question!

The Appalachian region today is a forested and hilly terrain. Three hundred million years ago this area looked very different. Great expanses of swampland and coastal wetlands covered the region. The Appalachian coalfields were formed from those swamps, when over time, the dead plant and animal matter from the wetlands was buried, then the land was thrust upward by tectonic forces forming a large plateau. Coal miners in Appalachia find coal near the surface and deep underground in different layers.

The coal found in Wyoming is much younger than the coal in Appalachia. This coal started to form 60 million years ago. This area was once a shallow sea. When tectonic forces started to push the land up, the sea grew smaller and the area slowly turned into wetlands, swamps, and marshes with lots of plants. Over time, these swamp and wetlands were buried as sand, dirt, and sediment from rivers washed over them.

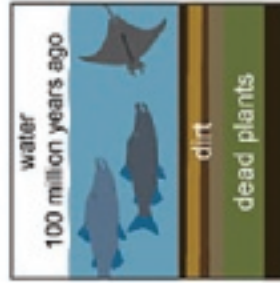
Coal is classified as a nonrenewable energy source because it takes millions of years to form. Coal contains the energy stored by plants that lived hundreds of millions of years ago in swampy forests. Layers of dirt and rock covered the plants over millions of years. The resulting pressure and heat turned the plants into the substance we call coal.

How coal was formed

Before the dinosaurs, many giant plants died in swamps.



Over millions of years, the plants were buried under water and dirt.



Heat and pressure turned the dead plants into coal.



Source: Adapted from National Energy Education Development Project (public domain)

National Energy Education Development Project

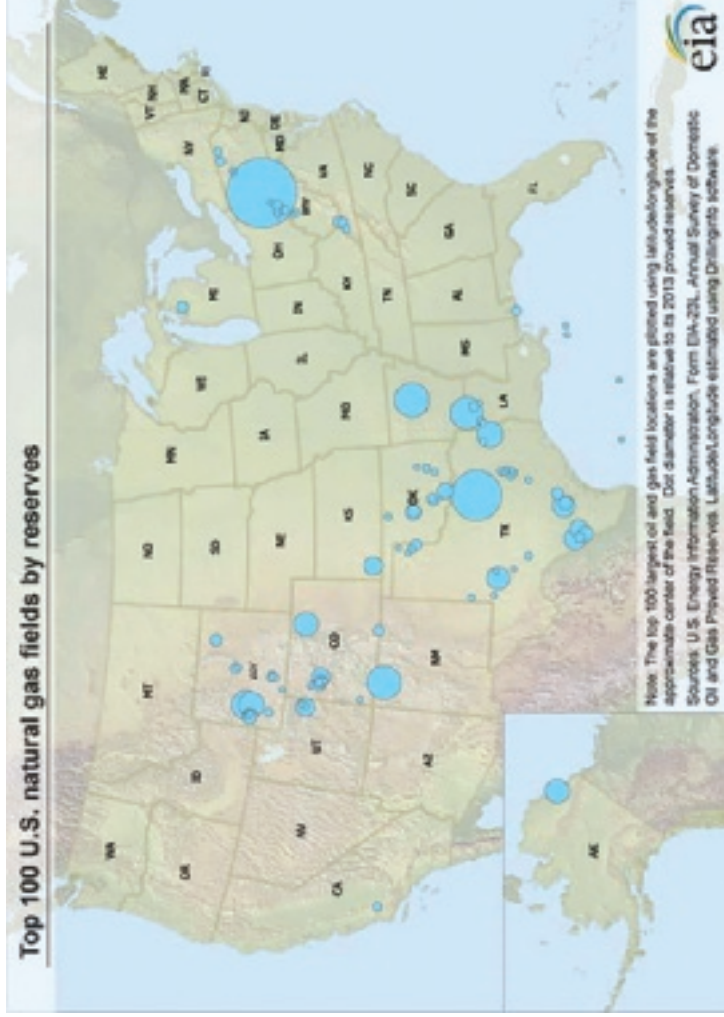
Source: Adapted from U.S. Energy Administration. *Coal explained*. Retrieved from: <https://www.eia.gov/energyexplained/coal/>

Natural Gas Long Ago and Today

Natural gas is a fossil energy source that formed deep beneath the earth's surface. There are booming natural gas industries throughout the western U.S., but the top states producing natural gas include Texas, Pennsylvania, Oklahoma, Louisiana, and West Virginia. Natural gas contains many different molecules. Methane is one very important component of natural gas. Methane is a molecule with one carbon atom and four hydrogen atoms (CH_4). Natural gas fields are often characterized by "flare stacks" where excess gas is burned for safety reasons.

Where is natural gas found in the US?

Natural gas is found throughout the US, but the most productive natural gas fields are located in Texas and Pennsylvania.



U.S. Energy Information Administration (2020)

Why is oil found in some locations and not others?

We call oil a *fossil fuel* because oil is mixtures of hydrocarbons that formed from the remains of animals and plants that lived millions of years ago in a marine environment before the existence of dinosaurs.

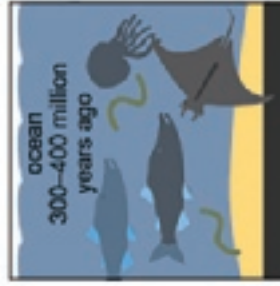
Texas is the single largest producer of oil for the US. Most of this oil comes from a region called the Permian Basin. This area is called a “basin” because it was a low lying area for millions of years, kind of like a bowl. This area was part of a shallow sea at one point in time and a wetland at another point in time. Over hundreds of millions of years, the remains of plants and tiny sea animals built up in thick layers on the floor of the shallow sea. This plant and animal matter mixed with sand, silt, and calcium carbonate (e.g., shells and corals). Over time, these layers were buried under sand, silt, and rock. Pressure and heat changed some of this material into natural gas, oil, or coal.

The Gulf of Mexico is another place with rich oil resources. The Gulf of Mexico was also a basin. Over hundreds of millions of years this area was covered in wetlands and a shallow sea. Algae and tiny sea creatures lived and died here, sinking to the ocean floor. The remains of these animals and plants were covered by layers of sand, silt, and rock. Heat and pressure from these layers turned the remains into what we now call oil.

Oil and other hydrocarbons exist in liquid or gaseous form in underground pools or reservoirs, in tiny spaces within sedimentary rocks, and near the earth’s surface in tar (or oil) sands.

Petroleum and natural gas formation

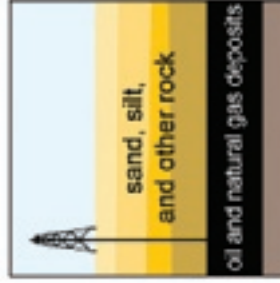
Tiny marine plants and animals died and were buried on the ocean floor. Over time, the marine plants and animals were covered by layers of silt and sand.



Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned the remains into oil and natural gas.



Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and natural gas deposits.



Source: Adapted from National Energy Education Development Project (public domain)

U.S. Energy Information Administration (2020)

Source: Adapted from U.S. Energy Information Administration. *Oil and petroleum products explained*. Retrieved from: <https://www.eia.gov/energyexplained/oil-and-petroleum-products/>

Oil Long Ago and Today

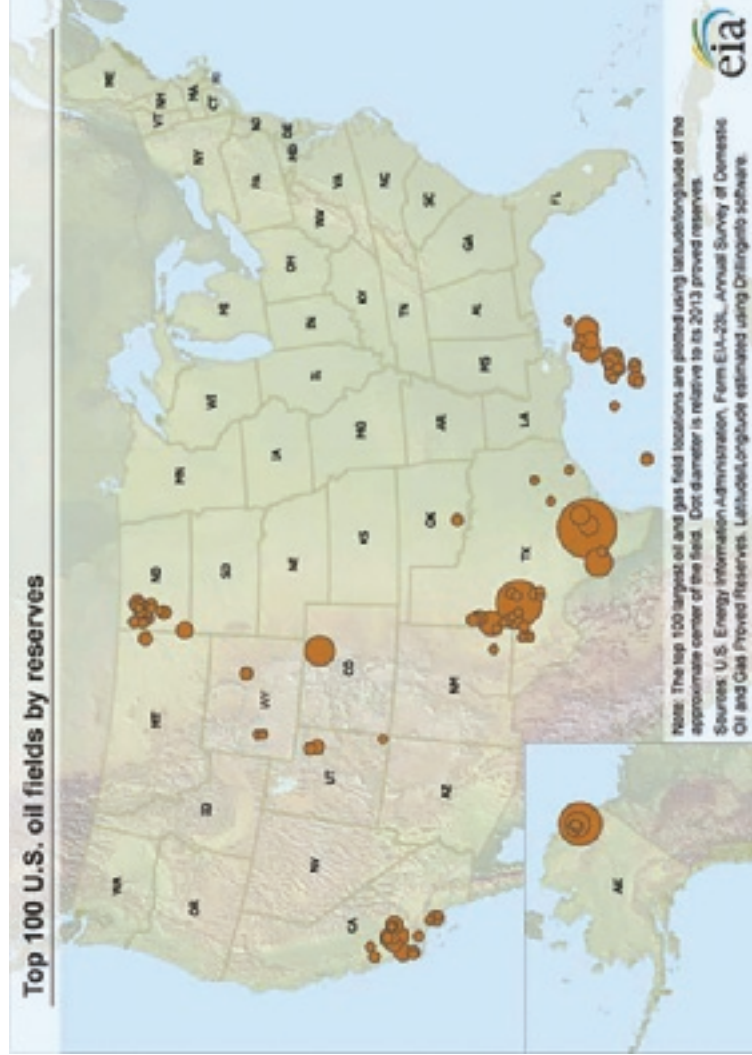
Before European colonizers arrived in North America, Indigenous peoples in Texas had discovered oil seeping from the soils. It wasn't until the 1900s that oil began to define much of modern Texas history. In 1901, oil gushed from the Lucas well at Spindletop. Oil spewed 100 feet high for 9 days before they were able to cap the well. Today, Texas accounts for about 40% of the oil production in the US. The Gulf of Mexico offshore oil drilling is another productive oil area in the US.

Where is oil found in the US?

Oil is found throughout the US, but the most productive oil fields are located in Texas, New Mexico, North Dakota, Oklahoma, Colorado, Alaska, and California.



Oil derrick at Spindletop in Texas.



U.S. Energy Information Administration (2020)



CKSci™
Core Knowledge **SCIENCE™**

Editorial Director
Daniel H. Franck

Source Material Attribution

The development of the original material in this unit (Copyright © 2022 OpenSciEd) was supported by the Bill & Melinda Gates Foundation, Carnegie Corporation of New York, Charles and Lynn Schusterman Family Foundation, and William and Flora Hewlett Foundation.

The OpenSciEd name is subject to the Creative Commons license and may not be used without the prior and express written consent of OpenSciEd.

This curriculum includes images that are public domain, openly licensed, or used by explicit agreement with their owners. See the attribution information with each image for ownership details and any restrictions on its use. Unless otherwise noted in the image attribution information, all images are licensed for distribution under the terms of the Creative Commons Attribution License (CC BY 4.0) by OpenSciEd or by their respective owners, or they are in the public domain.

Unit Development Team

Audrey Mohan, Unit Lead, BSCS Science Learning
Whitney Smith, Unit Lead, BSCS Science Learning
Lindsey Mohan, Unit Lead, BSCS Science Learning
Renee Affolter, Writer, Reviewer, & PD Design, Boston College
Tommy Clayton, Writer and Pilot Teacher, Columbia Middle School, Berkeley Heights, NJ
Candice Guy-Gaytán, Writer, BSCS Science Learning
Dawn Novak, Writer, BSCS Science Learning
Guy Ollison, Writer, BSCS Science Learning
Betty Stennett, Writer, BSCS Science Learning
Charles Hickey, Pilot Teacher, Weymouth Public Schools, Weymouth, MA
Chris Newlan, Pilot Teacher, David Wooster Middle School, Stratford, CT
Katie Van Horne, Assessment Specialist
Charles Anderson, Unit Advisory Chair, Michigan State University
Tonya Brainsky, Teacher Advisor, Taunton High School, Taunton, MA
Melissa Johnson, Teacher Advisor, Saint Albert Schools, Council Bluffs, IA

Consultants

Beth Covitt, University of Montana
Elizabeth de los Santos, University of Nevada, Reno
KC Busch, North Carolina State University
Dwanna McKay, Colorado College
Michael Mendez, University of California, Irvine
Frank Niepold, NOAA
Heidi Roop, University of Minnesota
Daniel Shephardson, Purdue University

Production Team

BSCS Science Learning
Maria Gonzales, Copyeditor, Independent Contractor
Stacey Luce, Editorial Production Lead
Valerie Maltese, Communications and Advancement

Manager
Renee DeVaul, Project Manager
Chris Moraine, Multimedia Graphic Designer
Kate Chambers, Multimedia Graphic Designer

OpenSciEd

James Ryan, Executive Director
Sarah Delaney, Curriculum Director

Developers Consortium Leadership

Daniel C. Edelson, Director
Audrey Mohan, Associate Director
Professional Learning Center at Boston College
Katherine McNeill, Director
Renee Affolter, Associate Director
Instructional Materials Center at BSCS Science Learning
Daniel C. Edelson, Director
Audrey Mohan, Senior Research Scientist
Field Test Implementation and Evaluation Center at Charles A. Dana Center, The University of Texas at Austin
Carolyn Landel, Director
Sara Spiegel, Assoc. Director, Implementation
Carol Pazera, Assoc. Director, Evaluation
Field Test Evaluation Center at Digital Promise
Andrew Krumm, Director
William Penuel, University of Colorado, Boulder, Co-Director
Instructional Materials Center at Northwestern University
Brian Reiser, Director
Michael Novak, Assoc. Director

State Steering Committee

California	New Jersey
Kathy DiRanna	Michael Heinz
Phil Lafontaine	New Mexico
Iowa	Yanira Vazquez
Kris Kilibarda	Shafiq Chaudhary
Tami Plein	Oklahoma
Louisiana	Tiffany Neill
Jill Cowart	Megan Cannon
Lydia Hill	Rhode Island
Breigh Rhodes	Phyllis Lynch
Massachusetts	Kate Schulz
Erin Hashimoto-Martell	Washington
Nicole Scola	Ellen Ebert
Michigan	
Mary Starr	

Field Test Teachers

California

Diana Campos
Zoe Carpenter
Kathryn Ducharme
Bruce Hansen
Michel Perez
Robert Sherriff

Iowa

Kari Etherington

Louisiana

Taylor Garrett
Emily Hurst
Belinda Mire
Silvia Pouwels

Massachusetts

Maria Citrin
Jenna Decker
Alice Elbakian
Charles (Chuck) Hickey
Mary Holland
Johanna Mendillo
Jamie Mitchell
Jennifer Nissley

Michigan

Krista Brady
Patsy Curnell
Cheryl Czarnik
Stephani Dzubak

Jeremy Giles
Al Schwehofer

New Jersey

Thomas Clayton
Ryan Jendrek
James McGinn
David Parke
Allison Wiesel

New Mexico

Theresa Armijo
Sandra Beaudet
Lillian Montoya
Kim Orphal

Oklahoma

Toni Humphrey

Natalie Kimbrell
Jennifer Stevens
Laura Vaughn
Jimmie Wheat

Rhode Island

Mary Colannino
Emily King
Marissa Kitchen
Jackie Zahm

Washington

Kyndra Eide
Fa Fairbank
Gregory Glascock
Katie James
Kristi Young

Illustrations and Photo Credits

agefotostock / Alamy Stock Photo: 135a, 142a

AICC/Alaska Fire Service: 73b, 75a

Alaska Interagency Coordination Center: 73c, 75b

Alpha Stock / Alamy Stock Photo: 135c

American Journal of Science (1857): 132b

Bob Daemrich / Alamy Stock Photo: 140a

Climate.gov: 29a, 64, 127

Design Pics Inc / Alamy Stock Photo: 130

Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC): 29b

inga spence / Alamy Stock Photo: 61

Jim Havey / Alamy Stock Photo: 138a

National Energy Education Development Project: 139

NOAA/National Centers for Environmental Information: 76a-b, 77b

NOAA: 57, 58b, 59, 60b

Old Paper Studios / Alamy Stock Photo: 135b

Our World in Data: 30

Peter Horree / Alamy Stock Photo: Cover, i

The Protected Art Archive / Alamy Stock Photo: 135d

The World Bank: 43

U.S. Energy Information Administration (2020): 138b, 140b, 141, 142b

U.S. Geological Survey: 69

UCAR: 22

US EPA using data sources CSIRO (2017) and NOAA (2021): 68

US EPA using US Geological Survey data source: 70a-b

USDA Natural Resources Conservation Service: 62

USFWS: 67

USGS: 58a, 60a

Walter Meier National Snow and Ice Data Center: 77a

Within this publication, the Core Knowledge Foundation has provided hyperlinks to independently owned and operated sites whose content supports the unit instruction. At the time of publication, all links were valid and operational, and the content accessed by the links provided additional information that supported the Core Knowledge curricular content and/or lessons. Please note that we do not monitor the links or the content of such sites on an ongoing basis and both may be constantly changing. We have no control over the links, the content, or the policies, information-gathering or otherwise, of such linked sites.

By accessing these third-party sites and the content provided therein, you acknowledge and agree that the Core Knowledge Foundation makes no claims, promises, or guarantees about the accuracy, completeness, or adequacy of the content of such third-party websites and expressly disclaims liability for errors and omissions in either the links themselves or the contents of such sites. If you experience any difficulties when attempting to access one of the linked resources found within these materials, please contact the Core Knowledge Foundation:

www.coreknowledge.org/contact-us/

Core Knowledge Foundation

801 E. High St.

Charlottesville, VA 22902

CKSci™ Core Knowledge SCIENCE™

A comprehensive program in science, integrating topics from Earth and Space, Life, and Physical Sciences with concepts specified in the **Core Knowledge Sequence** (content and skill guidelines for Grades K–8).

Core Knowledge SCIENCE™

units at this level include:

Chemical Reactions and Matter
Chemical Reactions and Energy
Metabolic Reactions
Matter Cycling and Photosynthesis
Ecosystem Dynamics
Earth's Resources and Human Impact

www.coreknowledge.org

ISBN: 978-1-68380-733-9

Core Knowledge Curriculum Series™