
Sean Hanley and G. Anthony Svatek

UNIT 5

Energy & the changing global climate

Energy and flux

Energy flows through the natural environment, through the wind, waves, and sunlight, through the food web and the water cycle. Energy permeates human social life, enabling us to shape our environments through technological advancement, exploration, and expansion. But humans' use of energy also impacts the environment by accelerating global climate change. On Jones Beach, we can observe the results of these global dynamics at the local level, and begin to imagine a future that works in concert with natural environment forces to mitigate and adapt to the impacts of climate change.

In this Unit, students first establish their baseline knowledge about the relationship between fossil fuel consumption and the warming of the global climate system. In turn, this warming drives environmental changes (also known as indicators) that alert us to the ongoing fact of climate change, including sea level rise, drought, excess precipitation, extreme weather, and biodiversity loss. These changes are already underway, and are intensifying as time passes due to the role of feedback loops. Students come to understand the urgency of taking action to mitigate greenhouse gas emissions as soon as possible, and consider various strategies for mitigation, including reducing energy consumption; transitioning to resilient, renewable energy systems; and reinforcing plant communities that naturally remove carbon from the atmosphere.

Even as mitigation efforts increase, some present and future impacts of climate change are unavoidable. Sea level rise, warming local temperatures, extreme weather, water scarcity, and excess precipitation impact different parts of the globe to different degrees. Students discuss adaptation as the practice of altering environments and behaviors in response to these impacts, and as another way in which human energy use shapes and will continue to shape the world in which we live. Architectural and infrastructure interventions, cultural and institutional shifts, and ecosystem management are all part of successful adaptation. But for communities on the front lines of the changing climate, now and in the future, adaptation may not be enough. As human settlement becomes untenable in parts of the world affected by sea level rise, water scarcity, and extreme weather, individuals and communities face a choice of whether to migrate away from their traditional homes and lifestyles. As migrants move, first internally within their home countries, then regionally, and finally internationally, climate migration intensifies processes of urbanization and again changes built and natural environments on a global scale.

As the final chapter of *Energy & Us* draws to a close, students use their accumulated knowledge and insight to think critically and constructively about their own roles as stewards of a world continually shaped by the dynamic interplay of energy, the environment, and human life.

Objectives

Explore the relationship between anthropogenic greenhouse gas emissions, the greenhouse effect, radiative forcing, global warming, and climate feedback loops.

Define mitigation and adaptation in relation to climate change, and explain why each approach is necessary to the success of the other.

Become familiar with the landscape of policy, planning, and design interventions for climate change mitigation and adaptation.

Analyze the intersecting pressures on frontline communities and climate migrants.

Articulate a vision of global environmental justice that accounts for disparate responsibilities and experiences within ongoing global climate change.

Exercise Social and Emotional Learning skills and creative thinking to imagine life in a future world shaped by climate change.

Learning standards

The materials in this Unit correspond with the following New York State P-12 Science Learning Standards and elements of the New York State Grades 9-12 Social Studies Framework.

Science Learning Standards

ESS2-1 ESS2-2 ESS2-4 ESS2-5 ESS2-6 ESS2-7 ESS2-8 ESS3-1 ESS3-2 ESS3-3 ESS3-4 ESS3-6 ETS1-1 ETS1-2 ETS1-3 ETS1-4

Social Studies Framework

Practices | A1 A2 A3 A4 A5 A6 A7 B1 B2 B3 B4 B5 B6 B7 B8 C1 C2 C3 C4 C5 C6 D1 D2 D3 D4 D5 D6 E1 E2 E3 E4 E5 E6 F2 F3 F4 F5 F6 F7 F8

Themes | TECH ID GEO MOV TCC SOC GOV CIV ECO EXCH ID

More information:

nysed.gov/curriculum-instruction/science-learning-standards

nysed.gov/curriculum-instruction/k-12-social-studies-framework

Key terms

Energy budget

Radiative forcing

Greenhouse effect

Anthropogenic climate change

Climate change indicator

Feedback loop

Tipping point

Permafrost

Albedo

Biodiversity loss

Shared Socioeconomic Pathways (SSP)

Representative Concentration Pathway (RCP)

Mitigation

Cap and Trade

Carbon neutral

Net zero

Carbon sequestration

Carbon sink

Carbon tax

Green infrastructure

Reforestation

Rewild

Flood zone

Heat-island effect

Storm surge

Adaptation

Resiliency

Community-based

Ecosystem-based

Soft infrastructure

Rain garden

Aquifer recharge

Bioswale

Prescribed burn

De-pave

Breakaway wall

Managed retreat

Buyout

Greywater recycling

Maladaptation

Hard infrastructure

Frontline community

Small Island Developing States

Climate migrant

Climate refugee

Rural hollowing

Migration hotspot

Push-pull dynamic

Stepwise migration

Remittances

Climate debt

CORE CONCEPT 1

Energy use drives greenhouse gas emissions and warming

In the dynamic global climate system, greenhouse gas emissions from fossil fuel combustion drive global warming. Emissions and energy consumption are both targeted in efforts to mitigate climate change.

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Minimizing impacts by reducing emissions

Energy use and climate change are linked through the physical-chemical phenomenon known as the greenhouse effect. In the absence of human activity that requires the combustion of hydrocarbon fuels, greenhouse gases enter and leave the atmosphere through cycles of decomposition and sequestration, and the greenhouse effect maintains a habitable climate on Earth. Since the Industrial Revolution of the 18th century, greenhouse gases have accumulated in the atmosphere. This increases the amount of solar radiation absorbed by the planetary climate system and intensifies or distorts the production of weather and climate conditions through the water cycle. As the feedback dynamics driving climate change are better understood, taking action to reduce greenhouse gas emissions and remove existing emissions from the atmosphere appears all the more urgent. These activities, which seek to reduce the atmospheric concentration of greenhouse gases and the resulting global warming, are collectively known as mitigation.

In this Core Concept, students first delve into the processes driving radiative forcing and the understand the role of feedback loops in determining the impact of radiative forcing on climate change indicators in the environment, like global ice melt and sea level rise. Understanding the urgent need to reduce the atmospheric concentration of greenhouse gases, students explore different categories of mitigation, including carbon sequestration and renewable energy sources. Then, students examine mitigation from a policy angle, evaluating different avenues for action and considering the political and cultural forces working for and against the most effective interventions. Lastly, in a take-home research project, students take a closer look at different kinds of renewable energy. Considering different characteristics like scalability, reliability, availability, and cost, students evaluate different renewable energy sources from the perspective of transitioning to a fully renewable Energy Grid.

Coal-fired power plant in Neurath, Germany

Getting grounded with global climate change

What do I already know about the physics of the greenhouse effect?

What do I know about what causes climate change?

What do I know about the global impacts of climate change?

What do I see as my role in mitigating (minimizing as much as possible) the causes and effects of climate change?

PRIMER

Give students a few minutes to respond, either alone or in small groups. Then move into the next activity by inviting students to share their answers.

Feedback loops and climate change

Why is it important to reduce greenhouse gas emissions as soon as possible?

This is a two-part question: why does anthropogenic climate change need to be slowed or stopped, and why is time of the essence?

First, it is important to review what we know about the causes of climate change. The atmospheric concentration of greenhouse gases determines how much of the energy from solar radiation is absorbed and contained by the Earth's planetary system. Greenhouse gases are transparent to sunlight, allowing solar energy to reach the Earth's surface, where it is absorbed by land and water. But greenhouse gases absorb waves that radiate at other frequencies, including infrared, so when the absorbed energy is released from the surface as infrared radiation, the atmospheric gases prevent its release into outer space. The resulting greenhouse effect is essential for the maintenance of a habitable climate on Earth and the system maintains equilibrium through the removal of greenhouse gases from the atmosphere through plant growth and other mechanisms. But when greenhouse gases are continually added to the atmosphere at a faster rate than they are removed, the proportion of energy retained by the system increases and the proportion of energy released into space decreases, resulting in an amplified greenhouse effect and planet-wide warming.

AT THE CENTER

Groups working with the curriculum at the Jones Beach Energy & Nature Center can begin by viewing the Power of Seasons exhibit in the West Gallery, with a particular focus on the video installation.

LEARN MORE

See 1.1 for discussion of radiation, kinetic energy, atomic vibration, and heat.

See 1.3 for discussion of the greenhouse effect and the Global Warming Potential of individual greenhouse gases.

Data analysis

Use the interactive graphs to analyze the trends in greenhouse gas concentrations since the year 800,000 BCE. Consider:

> **How has the atmospheric concentration of carbon dioxide changed over time?**
>
> **What are the major inflection points? What could be the cause of this?**
>
> **What does the trend in the last three centuries indicate about the cause of increasing atmospheric carbon dioxide?**

Ice cores reflect the contents of the atmosphere at the time of freezing, and can inform us about the historical trends in the concentration of greenhouse gases. From 800,000 BCE to 1500 CE, for instance, the concentration of carbon dioxide fluctuated somewhat but remained stayed within the bounds of about 170-240 parts per million (ppm). In 2020, the global average concentration of carbon dioxide in the atmosphere was 412.5ppm. Combustion of hydrocarbons like oil and coal is a primary source of increased greenhouse gas concentrations. In addition, deforestation releases Earth-bound carbon into the atmosphere. Thus the relationship between human activity — like burning fossil fuels for industry and clearing land for agriculture or logging — and increasing greenhouse gas concentrations is very clear.

Sources

Environmental Protection Agency | Climate indicators explorer

edap.epa.gov/public/extensions/CCIDataViewer/CCIDataViewer.html#greenhouse-gases&atm-conc-ghg

Our World in Data | Global CO2 atmospheric concentrations

ourworldindata.org/grapher/global-co-concentration-ppm

BREAK OUT

For full activity materials, see:

Unit 5 Appendix Page 2


Failed crops in Mabalane District, Mozambique during drought affecting much of southern Africa, 2016
Aurélie Marrier d'Unienville via International Federation of Red Cross and Red Crescent

The energy of solar and infrared radiation can be experienced directly as heat and one indicator of the human-accelerated (or anthropogenic) greenhouse effect is gradual increase in the global average temperature. But the term "global warming" is a little misleading. Perhaps the most significant work done by all of the energy added to the global climate system is seen in the changing movement of air and water, as currents shift and the water cycle accelerates.

As water molecules charged with energy expand and move upwards, their movement creates a pressure vacuum that less charged molecules move to fill. At a macro level, this movement produces local weather phenomena like extreme storms, heat waves, and cold snaps. Meanwhile, gradual warming also makes evaporation and precipitation cycles faster and more intense, further contributing to extreme weather and heavy precipitation in some places, and droughts and ice melt in others. These phenomena, and environmental events that result from them (like wildfires, floods, droughts, and sea-level rise) are called climate change indicators. Scientists warn that the relationship between the atmospheric concentration of greenhouse gases and the on-the-ground indicators of climate change that affect our lives is not linear, so it is essential to reduce greenhouse gas emissions as soon as possible.

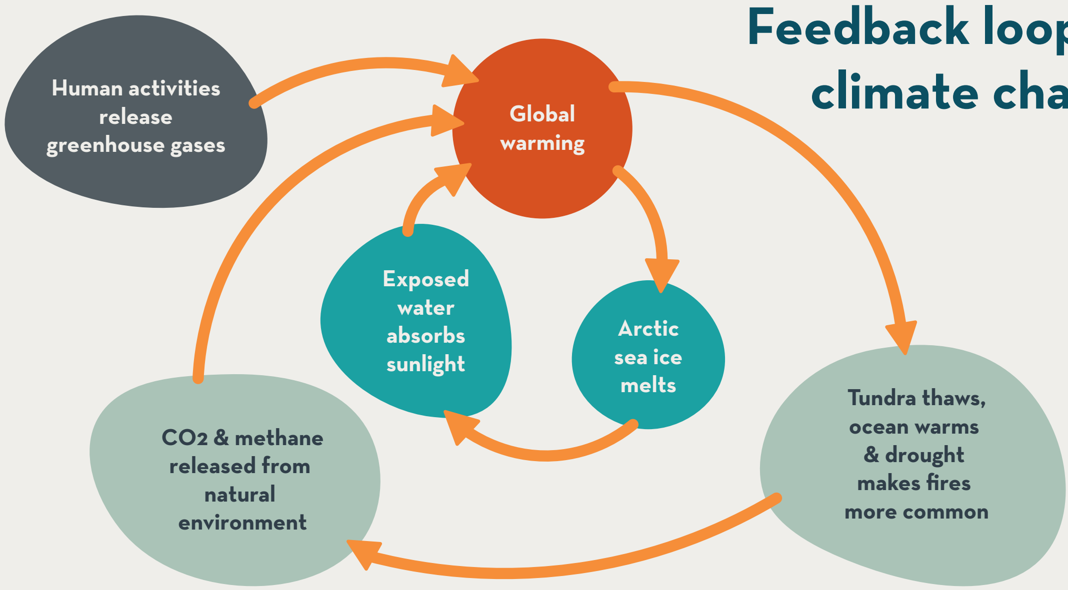
Local ecosystems and the global climate are both shaped by complex dynamics, many of which function as feedback loops. A feedback loop is a relationship where the prevalence of one variable impacts the prevalence of another. This can be a positive, or additive, feedback relationship: more of A triggers more of B, which triggers more of A, and so on. Feedback loops can also be negative: more of A triggers more of B, which suppresses A. Negative feedback loops tend to have a regulating effect, while unchecked positive feedback loops encourage exponential growth.

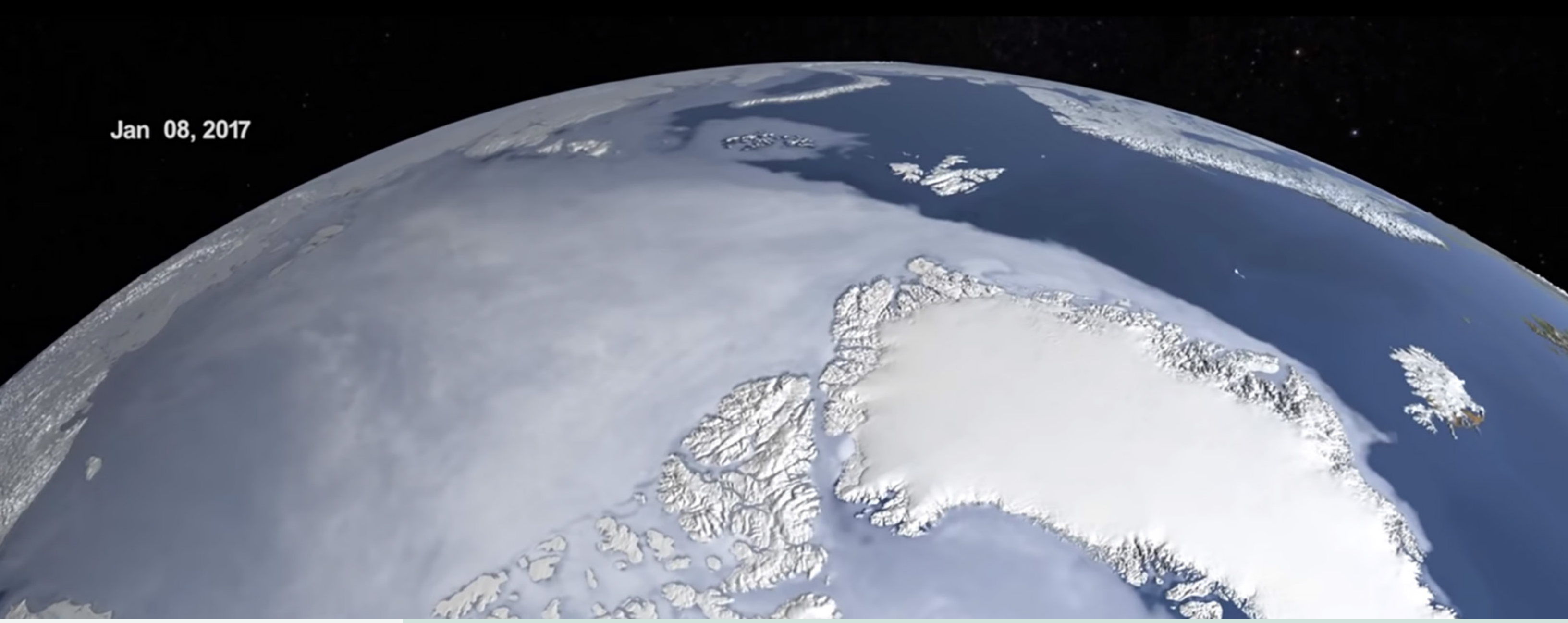
The relationship between population levels and food availability is one intuitive example of both positive and negative feedback loops in an ecosystem. On the one hand, population growth follows a positive feedback loop: the more offspring one generation has, the more offspring that second generation will have, and so on, leading to exponential increase. But on the other hand, there is a negative feedback loop between reproduction and food availability. Animals need food to survive and reproduce, but the more they reproduce, the less food is available per individual, which makes their reproductive capacity smaller. The overall effect is equilibrium, allowing ecosystems to maintain relatively steady population levels.

Like the example of food supply and reproduction in the ecosystem, in an undisturbed climate system, negative feedback loops sustain an equilibrium between different variables and actors, and regulate the system as a whole. But in the presence of anthropogenic greenhouse gas emissions, those regulatory mechanisms may be interrupted and distorted so that negative feedback loops are unable to keep positive feedback loops in check.

One example of a climate feedback loop is the cycle of warming itself. As the atmosphere warms, water evaporates from the surface of the earth and enters the atmosphere, where it acts as a greenhouse gas, absorbing more infrared radiation, warming the atmosphere further, and driving more evaporation. In an undisturbed climate system, this positive feedback loop is regulated by a simultaneously occurring negative feedback loop: as water vapor accumulates in the atmosphere, condensation and precipitation occur, removing the moisture that would otherwise continue to trap infrared radiation and drive warming. But when human activity increases the atmospheric concentration of other greenhouse gases, this regulatory effect can be overwhelmed.

Feedback loops & climate change





BREAK OUT

For full activity materials, see:

Unit 5 Appendix Page 3

Video and data analysis

View the video and graphs, based on data from NASA, that depict trends in arctic sea ice coverage since 1979.

What happens over the course of a year?

What happens over the course of the 40-year interval?

What might be causing these changes?

How might this be an example of a climate feedback loop?

Polar ice goes through a seasonal cycle of melting and refreezing, but a certain amount of ice survives the annual summertime melt. Over the 40-year interval, the extent of this old ice has shrunk, with less and less ice surviving the annual melt. Meanwhile, the extent of both new and old ice over the course of the year has also shrunk. The melting dynamics behind this trend can be intuitively understood by thinking about the melting behavior of ice cubes versus ice chips: smaller areas of ice melt faster. As the area of older ice grows smaller, it melts more easily and rapidly, creating a positive feedback loop. As more ice thaws, the rising seas melt the remaining ice faster. Meanwhile, another feedback loop is triggered: when frozen, arctic ice reflects solar radiation back into space in a process called albedo; when it melts away, it reveals darker-colored water, sea floor, and terrain that absorb more radiation. Thus, the rate of warming increases, causing the ice on land and in the ocean to melt faster. The melting permafrost also releases greenhouse gases, especially methane and carbon, which enter the atmosphere and drive further warming.

Source

NASA Climate Change | Disappearing Arctic sea ice

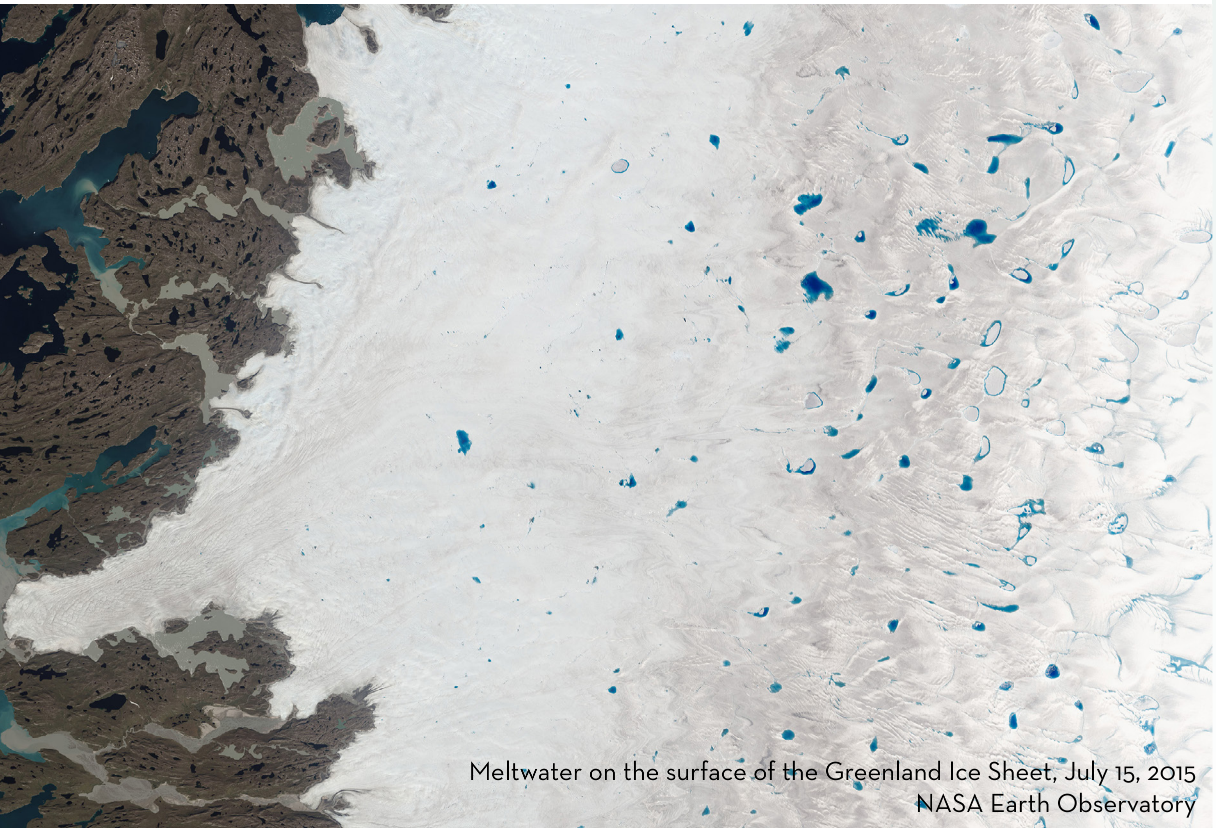
youtu.be/hlVXOC6a3ME

https://climate.nasa.gov/vital-signs/arctic-sea-ice/

Climate feedback loops are responsible for the existence of "tipping points": thresholds of warming past which certain amplified effects become irreversible even if anthropogenic greenhouse gas emissions are immediately brought to an end. Melting ice represents a significant tipping point globally, from sea ice in the Arctic, to massive ice sheets covering the land in Greenland and Antarctica, to glaciers throughout the world. If enough ice melts, further future melting becomes unavoidable due to positive feedback loops. The consequences of future melting are also, then, unavoidable. These include sea-level rise and altered ocean currents, which would in turn alter weather patterns and change the ability of various ecosystems to sustain their current biodiversity.

As an example, take the Greenland ice sheet. If the sheet were to melt completely, the global sea level would increase 7 meters. In the last three decades, thousands of tons of ice have been lost from the ice sheet. This has been one of the largest global contributors to sea level rise, but it has still only enough raised global sea levels by about half an inch. Yet in 2020, some climate scientists warned that the ice sheet is on the brink of a tipping point at which 1-2 meters of sea level rise, over the course of several centuries, could become unavoidable. This tipping point hinges on the feedback loop between elevation, air temperature, and melting. As the ice sheet melts, it shrinks in height. The surface area at the top is exposed to air at lower elevations, which is warmer. The warmer air then melts the shrinking ice sheet faster.

Feedback loops and tipping points give warming an exponential nature that means it is essential to act to reduce greenhouse gas emissions as soon as possible. If emissions are reduced sooner rather than later, it becomes less likely that these tipping points will be reached, and some positive feedback loops can be stalled or reversed.



Meltwater on the surface of the Greenland Ice Sheet, July 15, 2015
NASA Earth Observatory

LEARN MORE

The Climate Leadership and Community Protection Act (2019) established stronger emission reduction goals for New York than those of any other state. Among other goals, the Climate Act requires that that 70 percent of electricity consumed in the state be produced from renewable energy by 2030, and 100 percent zero-carbon electricity by 2040.

climate.ny.gov/Our-Mission

What is climate change mitigation?

In the range of possible responses to awareness of global climate change, mitigation is contrasted to adaptation. Adaptation accepts that some degree of anthropogenic climate change is unavoidable and that some of the effects of climate change on human communities and lifestyles cannot be averted; rather we must adapt to them. Mitigation, meanwhile, focuses on reducing the amount and impact of climate change as much as possible while reductions can still be made. Mitigation is primarily concerned with reducing the atmospheric concentration of greenhouse gases in order to interrupt the positive feedback loops that drive warming and climate change indicators. This can be achieved both by reducing anthropogenic emissions, and by removing greenhouse gases from the atmosphere.

The most effective way to reduce anthropogenic greenhouse gas emissions is to restrict the consumption of fossil fuel energy sources including petroleum, coal, and natural gas. This can be achieved by substituting renewable energy sources in their stead or by reducing energy consumption overall. Strategies for energy conservation can be structural, whether regulating the fossil fuel industry or legally limiting fossil fuel-intensive industrial practices and materials. Or, they can be behavioral, encouraging individuals and communities to consume less energy in the course of daily life by making different choices. Behavioral change can be a policy goal, too, as in the case of "carbon pricing," which seeks to discourage primary and secondary energy consumers from using fossil fuels by making the fuels themselves more expensive. More efficient energy conversion technologies — such as more complete combustion that produces less black carbon — can also have a mitigating effect without foregoing fossil fuels entirely. Changing or restricting agricultural practices and technologies responsible for methane and nitrous oxide emissions or technologies that use fluorinated gases can have a mitigating effect as well.


Landscape architect's rendering of the Jones Beach Pollinator Garden
Courtesy of Starr Whitehouse

Mitigation station

SPOTLIGHT

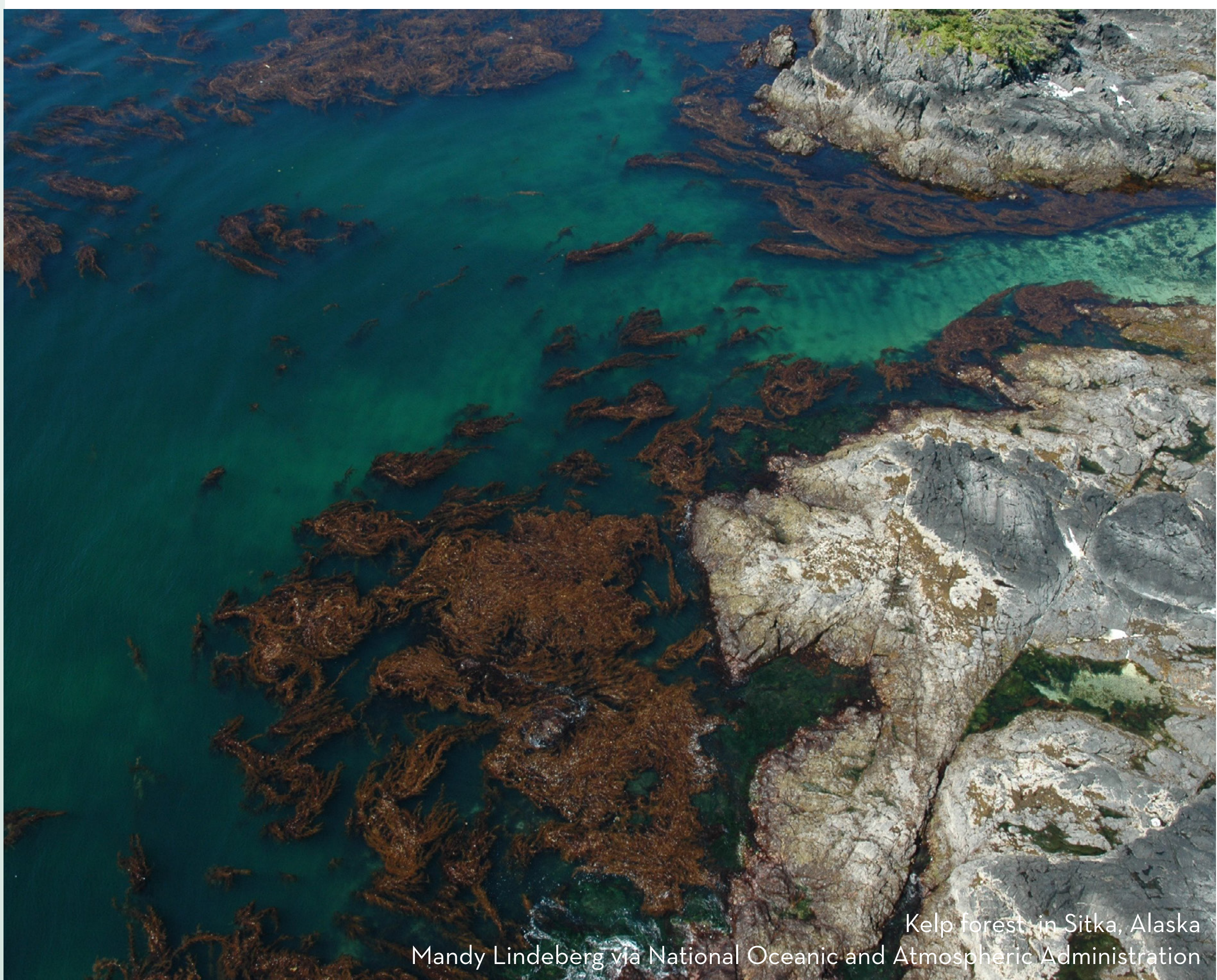
Mitigation can be accomplished at different levels. Nations, states, and cities can make policy to meet mitigation goals. But it is also possible to practice mitigation at the level of individual people, buildings, and communities. The Jones Beach Energy & Nature Center is an example of building design with mitigation in mind.

The Center building is "net-zero," which means that it produces as much emissions-free energy as the energy produced using fossil fuels that it consumes. In addition to 260 roof-mounted solar panels and a large lithium battery providing renewable electricity to the building and to the Grid, a geothermal heating and cooling system uses the consistent temperature below ground to regulate the temperature in the building, adding heat to the interior in winter and drawing heat out in summer. The building itself is also designed to maximize passive heating, cooling, and ventilation and to reduce the need for electrical lighting, making the space habitable while minimizing the use of fuel oil or fossil-fuel-produced electricity. The use of motion-sensor triggered lights and energy-efficient LED light bulbs further minimizes the building's energy usage.

Meanwhile, the landscape design contributes to carbon sequestration by replacing a 10-acre parking lot that was previously on the site with a Pollinator Garden, populated by native plant communities that are also present throughout the West End.

The other main strategy in the mitigation tool box is greenhouse gas removal: intentionally drawing carbon or other greenhouse gases out of the atmosphere and converting them into other forms that do not have a warming effect. The maintenance and expansion of natural "carbon sinks" is important in the sequestration effort. Plants remove carbon from the air through the process of photosynthesis, using it to generate chemical energy that they use to grow and reproduce. Scientists warn that the loss of the Amazon rainforest is another climate tipping point because of the key role that the rainforest plays in sequestering carbon from the atmosphere. Besides forests and soil, oceans, marshlands, seaweed beds, mangroves, and algae are also important natural carbon sinks, also known as "blue carbon." Kelp forests, for instance, collectively sequester more than 200 million tonnes of carbon each year .

Human activity can also help sequester carbon, particularly through interventions in the built environment. Reforestation and "rewilding" built landscapes, or integrating plant communities into new structures, can increase the scale and availability of carbon sequestration. Another strategy is the use of timber for building materials, as the trees used for timber sequester carbon as they grow. A building that is designed to sequester as much carbon as it consumes over its lifetime is described as "carbon neutral" or "net zero." Lastly, a number of interventions have been proposed, but not yet implemented, to literally pump carbon dioxide underground, inject it into deep waters where it would solidify, or draw it out of the air using special chemicals. However, many artificial sequestration proposals might have the potential to harm the environment in other, unknown ways.


Kelp forest in Sitka, Alaska
Mandy Lindeberg via National Oceanic and Atmospheric Administration

Mitigation mania

Climate change mitigation is a global problem that requires global solutions. To date, these solutions have mostly taken the form of international agreements that set out each country's intended greenhouse gas emission reductions, to be achieved by certain dates.

The most recent of these, the 2015 Paris Agreement, aims to make sure the global average temperature increases less than 2°C above pre-Industrial Revolution levels. More than 1°C of warming has already occurred, and scientists warn the world is on track to reach 3°C of warming by the end of the century if mitigation goals are not successfully met.

The Paris Agreement is not legally binding; countries' commitments are voluntary, national governments have total autonomy in figuring out how they will meet their commitments, and failure to do so cannot be penalized under international law. Some climate activists have argued that the agreement's commitments are insufficiently aggressive, and scientists warn that many countries are not on track to meet their promised reductions.

Scenario

You are members of a committee under the United Nations Environmental Program, tasked with exploring an update to the Paris Agreement that would attempt to reconcile the voluntary nature of the Agreement with greater oversight. Under the new framework, countries would have to provide a specific plan of measures to be taken in three areas of climate change mitigation: greenhouse gas emission reduction, renewable energy transition, and carbon sequestration. The task of the committee is to rank different proposed policies for accomplishing these goals. These rankings would then be translated into a point system used to score countries' mitigation plans. The framework is to be presented for debate and ratification at the next UN Congress Of Parties to the Agreement, the global meeting of signatories to the international climate accords.

Instructions

With your group, discuss the pros and cons of each strategy, and then rank them according to how much mitigation credit you believe a country should receive for including each strategy in their mitigation plan.

For full activity materials, see:

Unit 5 Appendix Pages 4-7

To guide the discussion, consider the following questions:

Does this strategy try to change behavior, and if so, whose behavior? Does it use positive economic incentives, values-based appeals, or legal mandates and penalties?

Does this strategy rely on private or public funding? How might this affect its likelihood of success?

What dynamics support or undermine this strategy reaching a scale that would allow it to have the desired effect?

What are the arguments for and against this strategy? Can you think of solutions to any critiques that are mentioned in these policy briefs?

On whom in society does the burden of this strategy fall? Who benefits?

After discussion, come back together as a class and present your ranking, describing what factors you considered, how you ranked each strategy, and why. Then vote as a whole class to determine the committee's overall ranking.

Materials

A groups: Regulate greenhouse gas emissions

Strategy: Carbon taxes

Carbon taxes are a "market based solution" that require owners of businesses responsible for greenhouse gas emissions — like the fossil fuel industry or manufacturers that use fossil fuels — to pay a set fee for each ton of carbon dioxide their industrial activity releases into the atmosphere. Cutting emissions reduces tax payments. The tax may increase over time in order to encourage the complete transition to renewable energy.

Critics of this strategy argue that companies may pass the cost of a carbon tax on to consumers, disproportionately impacting those who cannot opt out of high-emissions consumption patterns. For example, in countries like the US where rural populations do not have access to public transit networks, car ownership may be functionally compulsory. If, as in the US, rural populations are generally lower-income than urban populations, then a carbon tax that raised the cost of gasoline could be considered a "regressive tax," as it would primarily affect the poorest members of society.

B groups: Transition to renewable energy sources

Strategy: Corporate renewable energy development subsidies

Developers of renewable energy projects like large-scale wind farms, solar, and geothermal power plants can receive tax credits, wherein the national government forgives large portions of their tax liability. Alternately, rather than forgiving lax liability after the fact, national governments can fund renewable energy developments at the outset through grant-making or providing loans at favorable interest rates. These subsidies both lower the amount of capital necessary to develop projects, and make projects more profitable for potential investors.

Critics warn that such subsidies have not historically produced a sufficiently large increase in renewable energy production, making renewable energy sources like wind-powered electricity significantly more costly to the public than non-renewable sources. Critics also argue that configuring subsidies as tax forgiveness favors for-profit energy producers and penalizes not-for-profit producers, who do not pay taxes to national governments.

C groups: Sequester atmospheric carbon

Strategy: Carbon offsets

This "market-based" policy supports the creation and maintenance of carbon sinks in the form of forests and wetlands. Under a system of limited greenhouse gas emissions, industrial and corporate actors can fund or directly administer carbon sink restoration projects in order to "offset" their emissions. For example, if ten acres of forest can absorb one ton of carbon, then a given country that is over its carbon emissions limit by two tons can offset the overage by planting or restoring twenty acres of forest.

Critics argue that carbon offsets can be used as a "get out of jail free card" that perpetuate fundamentally unsustainable economic and environmental paradigms. Further, critics warn that the strategy could have inequitable effects, with richer countries paying poorer ones to offset their carbon emissions by maintaining natural landscapes; meanwhile, richer countries would continue to build wealth through industrial production and poorer countries would have less access to those mechanisms.

Debrief

What were the most important factors considered in ranking these mitigation strategies?

What mitigation obligations should a high-emission country have? What about lower-emission countries?

What capacities affect whether countries can implement your preferred strategies? How could your program account for unequal global distribution of wealth and other capacities?

Based on this exercise, how do you think the international community should implement mitigation agreements?

Reforestation project in Mandjou, East Cameroon
Emily Pinna via Center for International Forestry Research

Renewable energy and mitigation

The transition to a fully renewable Energy Grid is an essential piece of any mitigation effort. But how do different renewable energy sources stack up in the effort to reduce emissions? Renewables can be evaluated on several different accounts, including their technological efficiency in transforming a natural source of energy into power; their spatial and environmental impact; and their ability to meet the energy demands of contemporary life. In the effort to scale up the renewable Grid, it's important to analyze how different renewable energy sources best serve the needs of communities or industries and whether they represent the best investment of government funding and political capital.

Instructions

Using internet sources, research to compare two renewable energy sources from this list:

- **Solar**
- **Wind**
- **Hydropower**
- **Geothermal**
- **Biofuels**

Answer the following questions about each:

How does this renewable energy technology work?

What kind of energy does it produce, and how can that energy be used?

Where is this renewable energy source most available, globally? Where is it not available?

Evaluate the advantages and disadvantages of each along the following metrics:

- **Ability to scale to meet national and global energy demands**
- **Consistency and availability to meet variable energy demands**
- **Efficiency of technology at converting energy source into electricity, compared to fossil fuels**
- **Cost of technology production, installation, and maintenance**

For full activity materials, see:

Unit 5 Appendix Pages 8-9

- **Viability as part of a community-owned or public utility working towards development of an equitable renewable grid**
- **Particular strengths and weaknesses**

Then, having gathered this information, write a research memo recommending which one of the two renewable energy sources you researched should be prioritized for governmental subsidy at the national level. Consider:

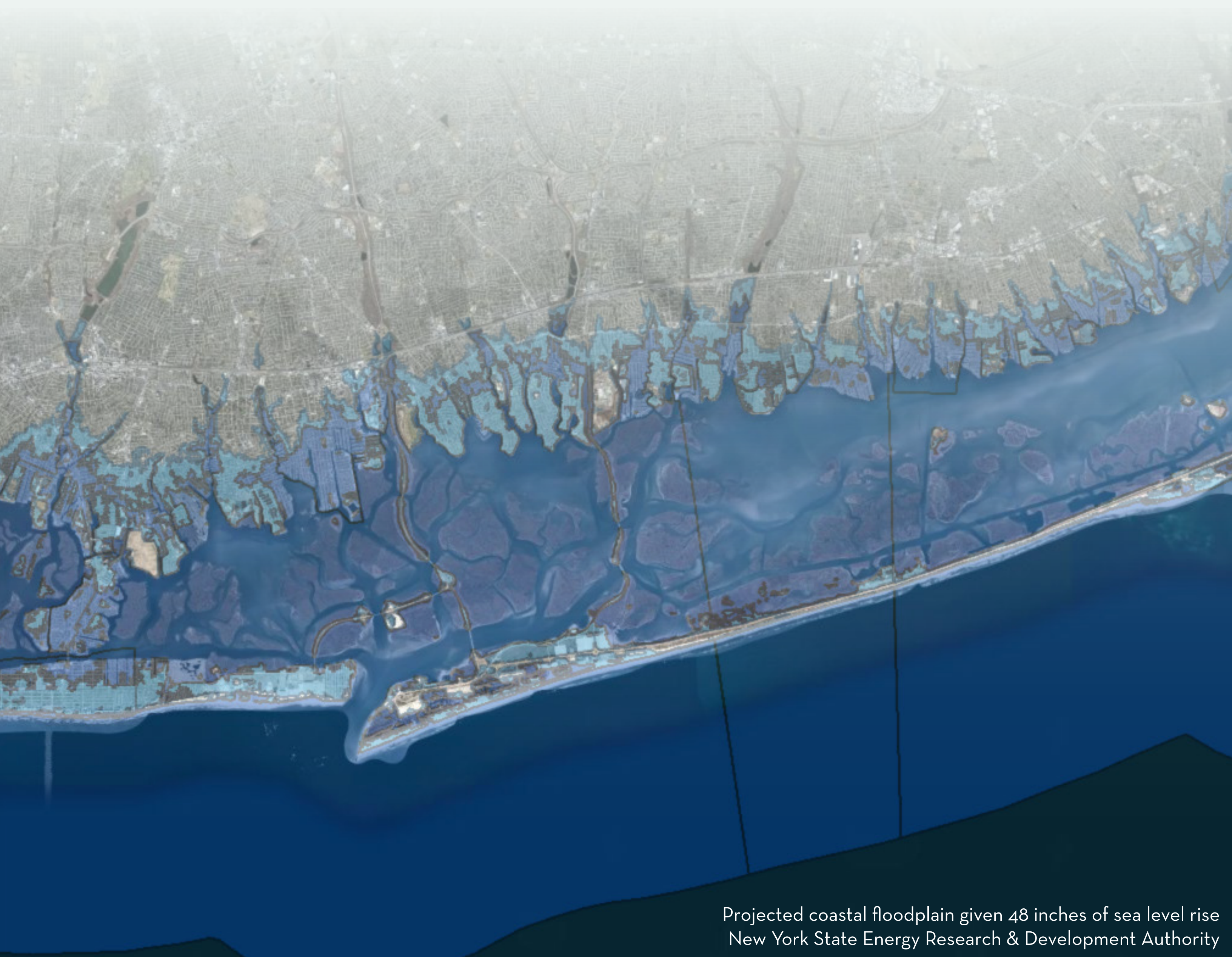
Which communities and industries will be best served by this renewable energy resource?

What are the most common points of criticism of, or resistance to this resource? How do you respond to these points?

CORE CONCEPT 2

Energy use creates a world shaped by climate change

As historical and ongoing energy use make some effects of climate change inevitable, through adaptation, natural and built environments respond to new conditions.



Projected coastal floodplain given 48 inches of sea level rise
New York State Energy Research & Development Authority

Adapting to a world remade by climate change

As the consumption of fossil fuel energy sources has made modern lifestyles possible, it has also created the conditions that will shape human life for centuries to come. To varying degrees in different locations across varying scenarios, some future impacts of climate change are unavoidable. Sea level rise, flooding, water scarcity, food insecurity, extreme weather, and biodiversity loss will change environments of human habitation all around the world. But globally, communities are already working to adapt to these changing conditions.

In this Core Concept, students first explore the range of current climate projections, and discuss how the feedback loops that make mitigation urgently necessary also introduce uncertainty about how global warming and its effects will proceed in the future. Nevertheless, it is possible to broadly project climate change's impacts on future environmental conditions in different places around the world under a range of scenarios. Still, uncertainty is a challenge for communities seeking to proactively manage their future vulnerabilities. Students explore the practice of climate adaptation at a conceptual level, discussing the goal of resilience, the strengths of community-based and ecosystem-based adaptations, and the characteristics of short-term maladaptive interventions. Then, students apply their critical framework to evaluate suites of adaptations, analyzing how different approaches reinforce or contradict one another. Lastly, students tap into Social and Emotional Learning skills to project empathetically into a future where young people like them navigate changing environmental conditions. Students undertake a multimedia narrative project that imagines a resilient, climate-adapted community in a place that is presently meaningful to them. When so much of discourse around climate change is fatalistic and stokes a negative outlook, this activity encourages students to think constructively and creatively about the future.

Shell Fire in Kern County, California, July 27, 2021
Russ Allison Loar

The global climate and the local future

How do I think climate change will impact my future and the future of my community?

How does thinking about a future shaped by climate change make me feel?

How can I work with my community to engage these feelings in myself and others?

PRIMER

Give students a few minutes to respond, either alone or in small groups.

AT THE CENTER

Groups working with the curriculum on site can begin by touring the building and making note of the adaptive building and landscape design elements.

Climate change and environmental conditions

How will climate change shape our global future?

Some effects of climate change are, at this point, inevitable. To varying degrees, different places across the planet are already experiencing sea level rise, increasing local precipitation levels, increasing local average temperatures, changing plant and animal populations, and increasing incidence of extreme weather events like storms, heat waves, and droughts. In order for human life to continue in the places where people currently live, changes will have to be made to our shelters, settlements, food supply chains, and lifestyles. Adaptation is the practice of making those necessary changes.

Adaptation can be contrasted to mitigation, which seeks to minimize the concentration of anthropogenic greenhouse gases in the atmosphere and thus limit the extent of global warming and climate change. But mitigation must always be accompanied by adaptation, and vice versa; without one, the other is likely to fail. Without mitigation, warming and its effects would intensify exponentially, overwhelming previous attempts to anticipate and adapt to changing weather patterns and water levels. Likewise, without adaptation, mitigation cannot adequately respond to the likely impacts of climate change on human communities and ecosystems — and minimizing those impacts is a primary motivation for mitigation in the first place.

In planning for adaptation, policymakers, planners, and scientists have to account for a range of different, possible climate futures, both globally and locally. "High emissions" scenarios assume "business as usual": human activity continues to add greenhouse gases to the atmosphere at a pace equal to or greater than the current rate of emissions. "Low emissions" scenarios assume the opposite: if greenhouse gas emissions can be significantly slowed or ceased entirely, the rate of warming will be reduced and the impact of climate change on ecosystems and settlements will be limited.

How do scientists project future rates of emissions and warming?

Climate scientists work continuously to create more accurate climate models. These models are essentially mathematical algorithms that incorporate the most current scientific understanding of how the greenhouse effect interacts with solar radiation and different elements of the climate system, including the oceans, atmosphere, and land surface, to predict climate change indicators like global average surface temperature, sea level rise, and ice melt. But different models offer different projections. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations Environment Program and the World Meteorological Organization to process and reconcile the individual models into an over-all picture of the climate under different future conditions. The IPCC's claims are categorized according to the degree of certainty of the conclusions and the quality of data that support them. A causal relationship or projected outcome can be rated as "likely," "very likely," "extremely likely," or "virtually certain," and a claim can be made with "very high confidence, "high confidence," "medium confidence," or "low confidence."

The IPCC includes three Working Groups, concerned with the Physical Science Basis of Climate Change (WGI); Impacts, Adaptation, and Vulnerability (WGII); and Mitigation (WGIII). The scientists in Working Group 1 compose reports that describe the current state of scientific knowledge about the causal relationships and future outcomes of climate change. In August 2021, the IPCC published Climate Change 2021: The Physical Science Basis, WGI's contribution to the Sixth Assessment Report. The report, compiled by 234 scientists from 66 countries, incorporates data from more than 14,000 different scientific studies to project the effects of climate change under six scenarios, called Shared Socioeconomic Pathways (SSPs). The SSPs broadly correspond to a previous set of scenarios developed by the IPCC, called Representative Concentration Pathways (RCPs), which described possible environmental impacts in the event of different degrees of warming in the global mean temperature. Unlike the scenarios used in earlier reports, SSPs account for geopolitics in projecting future global climate conditions. The SSPs use a "business-as-usual" baseline level of emissions and warming that represents no change from current policies and emissions rates, then layer a range of different global policy responses on top of this baseline. These different responses result in different atmospheric concentrations of greenhouse gases, which in turn will lead to different degrees of global warming and local environmental impacts.

In 2015, the globe had already warmed 1°C beyond pre-Industrial levels. The 2015 Paris Agreement sought to keep global warming to less than 1.5°C to 2°C, but by 2021, 1.5°C of warming is all but guaranteed. Many effects of climate change — sea level rise, temperature increases, more extreme weather events and water scarcity — are essentially guaranteed, due to warming that has already occurred or is on track to occur thanks to climatic feedback loops. In all scenarios, the global average sea level is projected to rise about 0.5 meters by the end of the 21st century, and up to two meters by 2300. But the difference between low emissions scenarios can be significant.

BREAK OUT

For full activity materials, see:

Unit 5 Appendix Pages 10-26

LEARN MORE

See 5.1 for discussion of international climate mitigation agreements.

Data analysis

What are the outcomes in each Shared Socioeconomic Pathway? What things influence the outcome within each pathway?

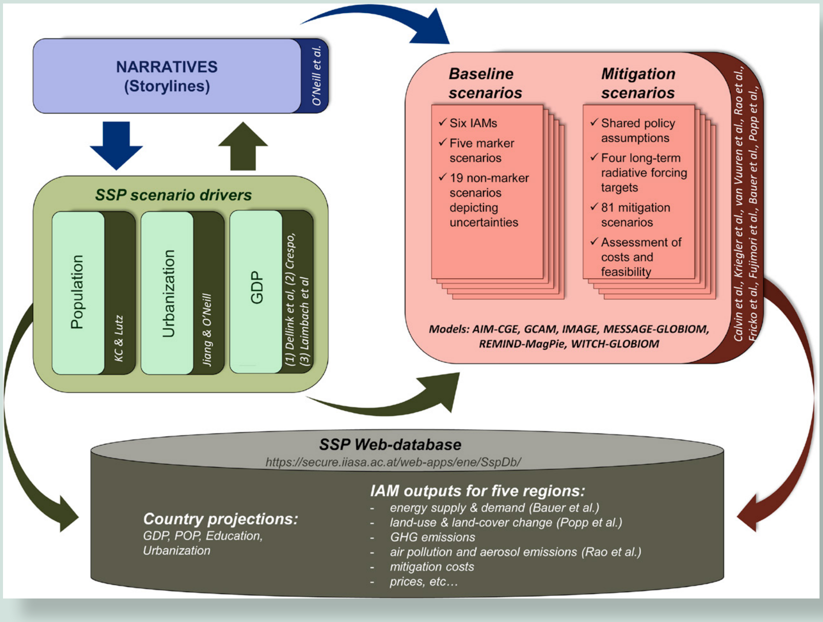
How do SSPs tell the story of climate change and its environmental impacts?

What is the impact of framing the narrative like this for our understanding of the cause and effect of climate change?

The most optimistic scenario in the report, SSP1-1.9, describes a pathway toward global sustainability and concerted, coordinated mitigation, resulting in a total global carbon dioxide emissions reduction of 25 percent by 2030 and 50 percent by 2050, in order to keep prevent the global mean temperature from rising 2°C above pre-Industrial levels in the long term (by 2100). SSP1-2.6 represents a slower uptake of adaptation and mitigation efforts, resulting in a long-term temperature increase of 1.3 to 2.4°C. SSP2-4.5, a "middle of the road" scenario, describes impacts in the event of medium challenges to mitigation and adaptation efforts due to political or economic resistance, inability to globally coordinate, failure to distribute resources for mitigation and adaptation, or other factors. This scenario would see global average temperatures increasing up to 3.5°C by 2100. The three remaining SSPs describe impacts in the event of high resistance to adaptation, mitigation, or both: a world in which global inequality, nationalist isolationism, or hunger for fossil-fueled economic growth prevent an effective global response to climate change. The result would be temperature increases of 2.8 to 5.7°C by 2100.

Source

"The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview," K. Riahi et al, Global Environmental Change 42 (2017) 153–168



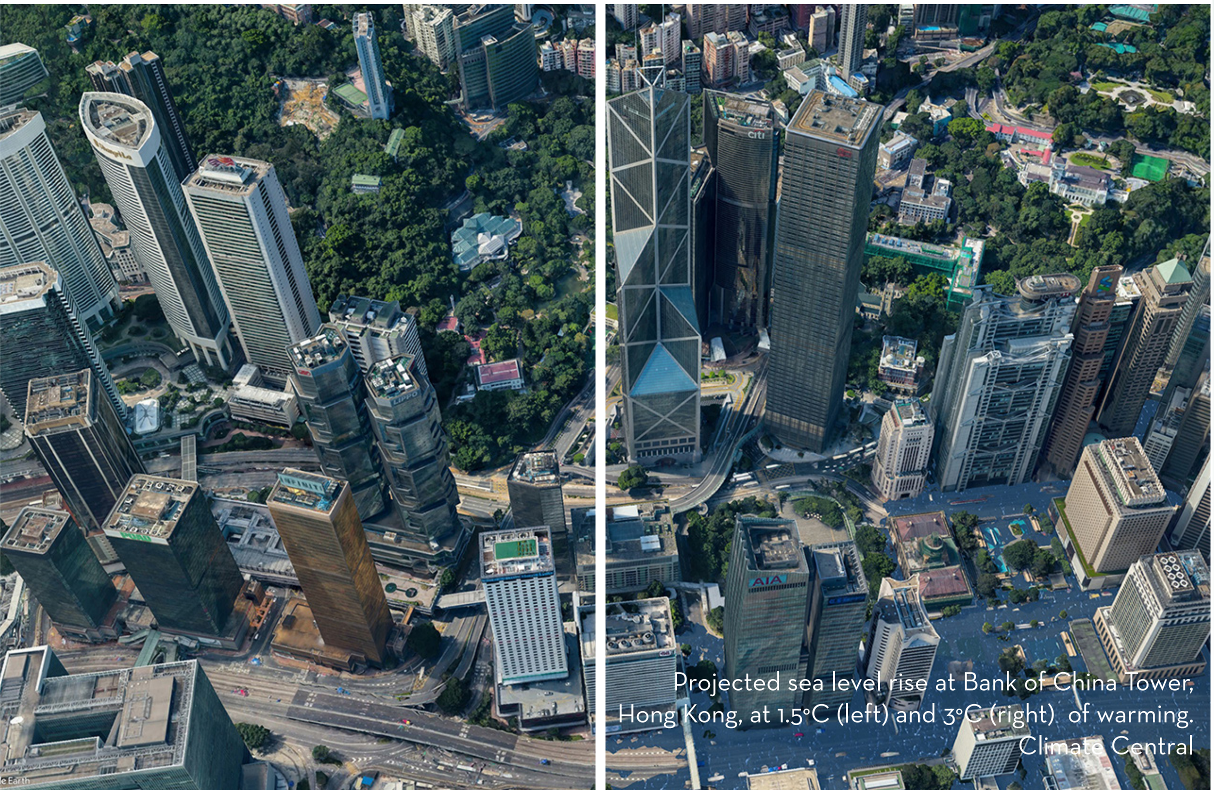
What would the future look like in the event of different amounts of warming?

Keeping warming below 2°C, as under SSP1-1.9, could be enough to avoid triggering the most catastrophic feedback loops caused by the total melting of Arctic ice and the Siberian tundra, and the loss of the Amazon rainforest. At 2°C of warming, the likelihood of extreme heat waves will double; periods of drought are projected to lengthen, increasing water and food scarcity in many parts of the world and rendering others all but uninhabitable due to extended wildfire seasons; extreme storms would become more frequent and more severe. In a scenario that assumes only weak attempts at mitigating greenhouse gas emissions — in keeping with current policies — the planet would see an average temperature increase of more than 3°C. Coastal areas currently home to 800 million people would eventually be flooded thanks to sea level rise and storm surge.

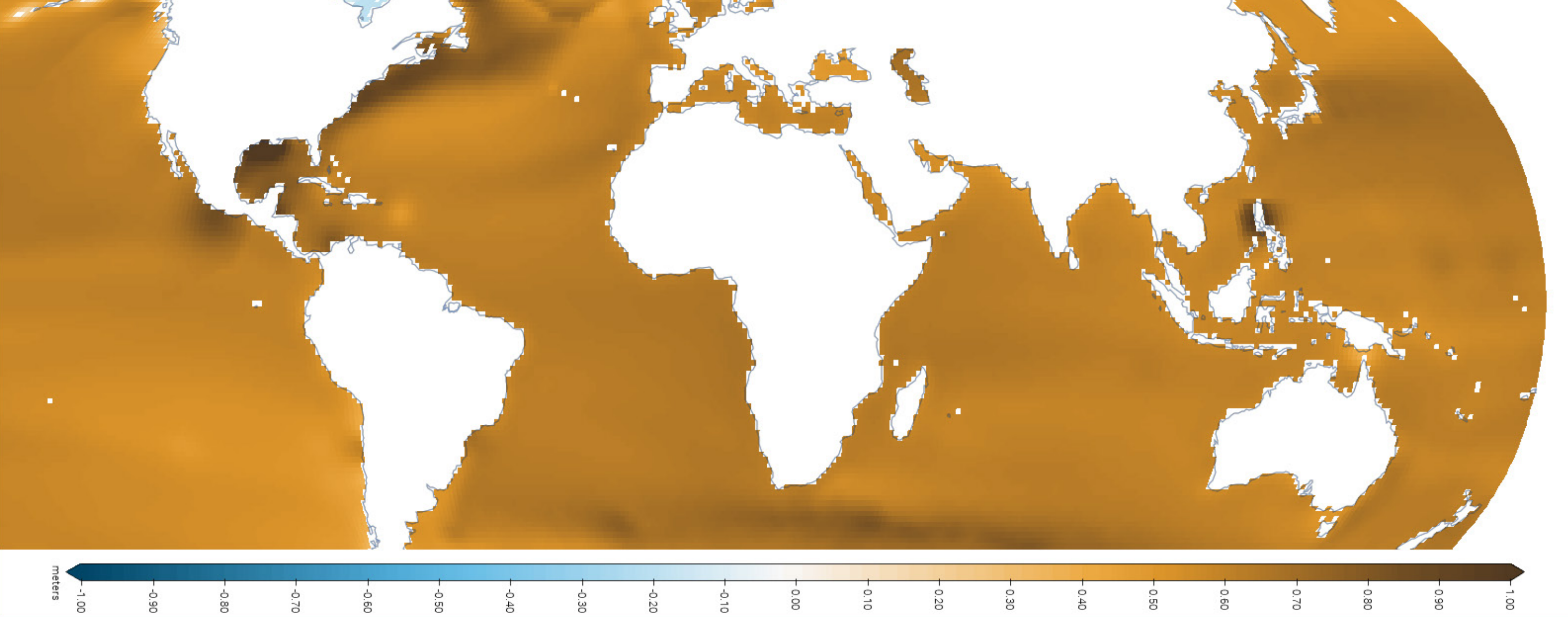
Recall that increasing global average temperatures gives rise to changing patterns of water and air circulation, as well as intensified cycles of evaporation and precipitation, that can manifest differently in different places. In tropical areas, sea level rise is expected to be 20 percent higher than average, while more northern latitudes should see lower than average sea level rise. Temperatures over land would increase 6°C or more in places like the Mediterranean, North Africa, and the Middle East, which would experience periods of extended drought and water scarcity. Other places, especially in northern latitudes, would experience heavier precipitation and intense storms.

More visualizations of sea level rise at different levels of warming can be seen online:

picturing.climatecentral.org



Projected sea level rise at Bank of China Tower, Hong Kong, at 1.5°C (left) and 3°C (right) of warming. Climate Central



BREAK OUT

For full activity materials, see:

Unit 5 Appendix
Page 27

Map analysis

The IPCC Interactive Atlas, published as part of the 2021 IPCC Sixth Assessment Report, represents projected environmental conditions in different parts of the world under different warming scenarios. The Climate Center's Surging Seas mapping tool demonstrates how different degrees of warming could impact sea level rise in different global coastal places. The U.S. Climate Resilience Toolkit Climate Explorer projects the environmental impacts of climate change in different US cities under a variety of high- and low-emissions scenarios. Use these tools to explore the projected impact of climate change on different parts of the world, including communities close to home.

How are different variables projected to change under low, medium, and high emissions scenarios?

How do these tools represent variability and uncertainty?

How would this variability affect efforts to plan for the future?

Consider:

- **Sea level**
- **Annual precipitation**
- **Maximum one-day precipitation**
- **Consecutive dry days (drought)**
- **Surface wind**

Source

International Panel on Climate Change | Interactive Atlas

interactive-atlas.ipcc.ch

What does it mean to adapt to climate change?

Affected communities adapt by changing their settlements and lifestyles to become more resilient to the effects of climate change. Resiliency refers to the ability to withstand changing weather patterns and water levels resulting from climate change, either by protecting a community from those effects or by making sure the community can bounce back from disruptions quickly and with minimal human and economic costs. Many adaptation efforts require multiple kinds of changes at once. For instance, elevating a home is a structural adaptation to sea level rise, but it also requires institutions like local or national governments to secure resources and labor and make those structural changes possible.

Locations may also experience multiple climate change indicators at once, requiring multiple simultaneous forms of adaptation. Climate change indicators are the natural events and phenomena that let us know climate change is occurring, like sea-level rise, surface and water temperature increases, precipitation increases, drought and water scarcity, and so on.

Different emissions scenarios radically change the localized projections to which adaptation planners must respond. If parts of the world become uninhabitable due to warming, those communities will have little choice but to migrate to new sites. Adaptation planning entails considering how to facilitate the relocation of some settlements and densification of others. In other scenarios and other locations, human settlement may continue with changes to the built environment, methods of transportation, agriculture and food procurement, and social and psychological approaches to life. (Note that within a mitigation-adaptation dichotomy framework, migration is considered adaptation.)

LEARN MORE

See 5.3 for discussion of climate migration.

AT THE CENTER

Groups working with the curriculum on site can view a video describing the Shinnecock Indian Nation coastal resiliency project as part of the Shaping the Shoreline exhibit in the South Gallery.

Members of Shinnecock Indian Nation install oyster reefs as part of their coastal resiliency project
Sean Hanley and G. Anthony Svatek

Breakaway wall at the Center (below line running parallel to ground)
Courtesy of nArchitects

SPOTLIGHT

Adapting Jones Beach

In the waters near Jones Beach, sea levels are rising faster than the global average. Recent storms like Hurricane Sandy, Tropical Storm Isaias, and Hurricane Ida have hit Long Island's southern coast hard, demonstrating the need to approach coastal settlements with an adaptive mindset. Even more vulnerable to storms and storm surge because of its position on a barrier island, the Jones Beach Energy & Nature Center building was designed with full awareness of how climate change is likely to impact environmental conditions in the future.

The building is elevated above the floodplain and the Battery and Transformer at the top of Energy Hill are safe from floodwaters that could disrupt the building's electrical system. A breakaway wall is designed to collapse under impact from floodwaters without affecting the structural integrity of the building, and exterior cladding materials were selected to stand up to increased precipitation. The Pollinator Garden, meanwhile, is an example of ecosystem-based adaptation. The Garden includes native plants that filter precipitation and stormwater run-off, reducing the risk of flooding. The plants also support native pollinator species, contributing to the health of the broader ecosystem.

LEARN MORE

See 2.3 for discussion of storm surge, flooding, and the changing coastline.

What makes a good climate adaptation?

Often, scientists and advocates emphasize the need for adaptations to be ecosystem-based and community-based.

Ecosystem-based strategies restore and reinforce the healthy functioning of the natural environment, while leveraging species' behaviors and relationships to accomplish the desired effect.

Community-based strategies integrate scientific information and expertise with local perspectives, including often-overlooked traditional and indigenous bodies of knowledge about the natural environment and ecological management. Community-based adaptations may make use of global insights from the experiences of analogous communities and share their findings and best practices within global networks, but the focus is always on the needs and capacities of the local adapting community and they are directed by local community leaders. The Shinnecock Nation's coastal restoration project is a good example of an adaptation that is both ecosystem- and community-based.

Climate change is a global problem, but it manifests differently in different locations. Local planners in each location impacted by climate change may be most familiar with their context and best equipped to design an adaptation response. But, as with mitigation, the cost and disruptiveness of adaptation raise ethical questions about who should bear the greatest responsibility. Those who are first or most impacted by climate change indicators are often not those who have contributed the most to global greenhouse gas emissions.

When communities facing the impacts of climate change lack resources or capacity to adapt for the long term, they may fall into the trap of maladaptation. This describes actions taken to reduce exposure to the effects of climate change in the short term that inadvertently increase vulnerability to other effects down the line or reduce the ability to respond more constructively in the future. Wealthier communities who find more robust adaptation strategies too disruptive can fall into this trap too. One example of maladaptation in response to sea-level rise is the construction of hard infrastructure. Such infrastructure may temporarily protect coastal settlements from storm surge, but they also destabilize the coastal ecosystem. If a future storm surge overwhelms a hard barrier like a levee or a sea wall, the effects on coastal settlements behind the wall will be more intense. In addition, the construction of hard infrastructure may create an appearance of protection, encouraging more people to settle or remain along coastlines that are not safe for habitation in the long-term.

LEARN MORE

See 5.3 for discussion of the challenges facing frontline communities deciding whether to migrate in response to the environmental impacts of climate change.

Adopting adaptations

When adaptation planning is done at a local level, planners can marshal deep contextual knowledge of an adapting community's needs and aspirations. Adaptations may be best implemented in conjunction with one another; no single adaptation will be sufficient to protect a given place from the long-term effects of climate change. Though every affected place is unique, localities across the globe can learn from one another and share best practices for tackling common problems. And determining which adaptations are the most promising in different situations can be an important tool for allocating resources, including energy sources and human labor.

Scenario

You are members of an advisory council at the United Nations Environmental Program, tasked with developing guidance for national governments about how to approach adaptation: which adaptations to prioritize, and how to link clusters of related or complementary adaptation strategies together. This guidance will be used alongside local knowledge and community input to design and fund adaptation plans.

Each group will consider adaptations to one of two general climate change challenges: water and warming. Water groups are review adaptations for places facing sea level rise, storms and storm surge, increased precipitation, and inland flooding. Warming groups review adaptations for places facing drought, wildfire, diminished air quality, heat waves, water scarcity, and biodiversity loss.

Instructions

For full activity materials, see:

Unit 5 Appendix
Pages 28-33

With your group, produce three model adaptation plans. Each should include between three and five adaptations from the attached list. Within each plan, rank the adaptations in terms of their scale of efficacy.

Which adaptations should receive the greatest allocation of resources and energy?

Which should be prioritized least?

Are there any adaptations that cannot be combined?

Are any "maladaptive"?

As you discuss, brainstorm ways to make the described adaptation ecosystem- or community-based.

What would the best version of the model adaptation plan look like?

Who would be involved in the planning process?

Write a short paragraph for each model plan outlining your directives.

After you discuss, come back together as a class and present your ranking, describing what factors you considered, how you ranked each strategy, and why. Then, for each adaptation category, vote as a group to determine the committee's overall ranking.

Materials

A Groups: Water adaptations

Strategy: Permeable pavers and "depaving"

Anywhere from 50 to 95 percent of the land surface in suburban and urban settlements is covered with impervious paving materials like asphalt and concrete. These both intensify warming in densely settled areas through the heat-island effect, and exacerbate flooding, as water that cannot be absorbed into the ground flows [...]

B Groups: Warming adaptations

Strategy: Cooling architecture

As well as landscape design, building design can have a cooling impact, especially in cities. Reflective roofs and light-colored ground cover can reduce the amount of solar radiation absorbed by hard surfaces. Architecture can support passive cooling through the use of ventilation, shades, awnings, and building materials [...]

Debrief

Discuss:

Did all groups come to the same conclusions? Why or why not?

What unknowns would complicate the planning process?

What type of housing is being built in your community? Is it different from the type of housing you planned to build? What might prevent the type you favored from being built?

Imagining adapted communities

Our future is guaranteed to be impacted by climate change in some way. This fact is often presented with a sense of fear, despair, or warning; indeed, collective failure to minimize the extent and effects of climate change will result in enormous, unnecessary suffering, and action must be taken to avert the most extreme effects. But it can also be important, and empowering, to think about the future shaped by climate change in more neutral and objective terms. What will be different? How will we live? What will it feel like to be alive in that moment?

For full activity materials, see:

Unit 5 Appendix Page 34

Instructions

Use the tools listed below to project future conditions in one US county — perhaps the place where you live or a place where you have connections to friends or family members — in the event of 2°C of warming. Then, using this information, design a climate-adapted settlement in this place. Combine written and visual material (use collage, drawings, or both) to compose a creative profile of this community. Consider physical, social, and institutional adaptations.

Consider the following questions:

What adaptations have been implemented in this community?

How has adaptation been planned, designed, and executed? How are decisions made?

Who lives there, and how do they live? What kind of work do they do?

What do they eat and where does their food come from?

Who do they live with? What is their home like? How do they get around?

What are their weather conditions like?

What do they worry about? What do they look forward to?

What does and doesn't change alongside the climate?

Sources

US Climate Resilience Toolkit | Climate Explorer

crt-climate-explorer.nemac.org/

US Climate Resilience Toolkit | Case studies

toolkit.climate.gov/case-studies

CORE CONCEPT 3

Energy and climate change drive global migrations

Globally, climate migrants are the people who contribute the least to greenhouse gas emissions, experience the greatest impacts of climate change, and have the most limited resources for adaption.

Sean Hanley and G. Anthony Svatek

Migrant caravan from Central America passes through Chiapas, Mexico
Javier García via En El Camino

Migration makes the world of tomorrow

Throughout history, humans have used energy to make environments habitable that otherwise would not be. But human use of energy is also changing the range and distribution of habitable environments across the planet. As the global climate system warms and the environmental impacts of this warming become more pronounced, many of the places where people currently live can no longer supply them with the energy they need to survive. This is especially true in places where people depend on subsistence or small-scale, low-technology agriculture for survival. When their ancestral homelands can no longer supply them with energy to survive, or when surviving on the land, repairing their homes after destructive storms and floods, or recovering their lost assets requires too much energy, communities on the frontlines of climate change face a difficult choice: whether and where to migrate. This decision is often made gradually, in a piecemeal fashion. But it is starkly clear that the future of the planet, and of humans living alongside natural environments, involves inevitable mass migrations due to changing climate conditions.

First, students discuss the causes and effects of climate migration. Using the example of farmers in Bangladesh displaced by rising sea levels and extreme storms, the discussion explores complex, intersecting pressures that shape the migratory experience. Then students use the story of an individual climate migrant from Central America to analyze the push-pull dynamics shaping a typical climate migrant's path, and the opportunities for and obligations of support and intervention along the way. The students then explore different perspectives on "climate debt" and "climate justice," formulating an ethical position on how burdens ought to be shared globally in a future shaped by climate change.

Departure and arrival

What is my personal relationship to migration?

Have I ever had to move away from my home? Has anyone close to me ever moved away?

What was difficult about leaving home, adjusting to a new home, or being left behind by someone who moved?

What positive things came from these experiences?

How have these experiences shaped me as a person?

Long Island, like many areas in the United States, is profoundly shaped by migration. Though an imperfect indicator, the languages that households speak at home can give a sense of their relationship to countries and communities outside of the US. Queens County, part of both New York City and Long Island, is the most ethnically and linguistically diverse urban area in the entire world, with over 200 languages spoken across 110 square miles. Kings and Nassau Counties — where Jones Beach State Park is located — are similarly diverse, with 45 percent and 30 percent of households, respectively, speaking a language other than English at home, compared to 30 percent in New York State and 22 percent in the United States as a whole. These numbers may even be lower than reality, as some people who have immigrated to the US may be fearful or reluctant to participate in official data gathering.

The reasons that people migrate are complex, as the rest of this Core Concept will explore. Nevertheless, places like Long Island that have experienced significant in-migration from Central and South America in recent years are most definitely seeing the impacts of climate change. Many newcomers to New York State and Long Island have left behind home countries where life has become untenable, especially for farmers, due to changing weather patterns and a resulting scarcity of food, water, and income.

This Core Concept may provoke challenging conversations and difficult feelings. Some students may have had personal experiences of migration, and most will have been exposed to public discourse about immigration in their home communities, or in the media. As you move through the discussion and following activities, encourage students to be mindful of their own emotional reactions and the effects that they may have on their classmates.

PRIMER

Give students a few minutes to respond, either alone or in small groups.

Groups working with the curriculum outside can explore the diversity of their area using data from the American Community Survey.

data.census.gov/cedsci/table?q=language

LEARN MORE

See 5.2 for discussion of climate change indicators and adaptation strategies.

Life on the frontlines of climate change

How does climate change affect where and how people are able to live?

Climate change indicators are the local and global natural events and phenomena that demonstrate climate change is occurring. Many of these indicators are already impacting people around the globe, and climate scientists warn that they will only intensify as warming continues.

As well as increasing global average temperatures — the most direct evidence of global warming due to the greenhouse effect and anthropogenic greenhouse gas emissions — increasing local temperatures are an important indicator. Local sea level rise that results from global ice melt is another key indicator. Sea level rise can intersect with other indicators, like increased local precipitation or more frequent extreme weather events, to produce storm surge flooding. Inland flooding and mudslides due to increased precipitation and more intense storms are also increasingly common. Weather patterns are changing in general, and periods of drought and water scarcity are longer and more common. Fires are more frequently spreading through forest and grassland ecosystems that have dried out due to drought. Both drought and excessive precipitation are impacting growing seasons and biodiversity, threatening farmers' ability to raise traditional crops — or even any crops at all — on their farmland. To some degree these indicators can be managed through the practice of adaptation: making changes to lifestyles, settlements, and foodways in response to the changing environmental conditions that follow global warming.

However, taken to an extreme, any one of these indicators can make a place uninhabitable. The escalation from manageable changes to unmanageable crisis is already underway in places around the world where the earliest and most intense effects of climate change are felt. The people who live in these places are members of "frontline communities," and they are often — but not always — the people with the least resources to spend on climate change adaptation or disaster recovery. They are often citizens of low-income countries, the economies of which often depend on agriculture and foreign capital, in the form of humanitarian aid, raw material exports, and international manufacturing. Frontline communities often also include Indigenous peoples whose traditional agricultural or cultural practices may be threatened by changing weather conditions, drought, flooding, and biodiversity loss.

What is life like on the front lines of climate change?

In many places, frontline communities are already seeing the environmental impacts of climate change. Indigenous people in the Amazon, the Arctic, and coastal North America are seeing their traditional hunting grounds and food supplies decimated by wildfires and ice-melt. In many subsistence-

From Nukunonu, Tokelau, participants in 350 Pacific's Warrior Day of Action protest against the effects of climate change on Small Island Developing Nations; via 350.org

agricultural African communities, where water scarcity has always been an intermittent and manageable fact of life, climate change threatens to take normal challenges to an unmanageable extreme. Throughout the African continent, 35 to 55 percent of the workforce are farmers; with droughts of historically unprecedented duration striking different communities at various points over the last decade, millions of people have been plunged into extreme food and water insecurity. Across the globe, so-called Small Island Developing States (SIDS) are acutely threatened by rising sea levels. Several low-lying (uninhabited) islands in the South Pacific have already completely disappeared, and other inhabited islands have lost large swaths of land, as well as homes and villages. Coastal cities, especially in East and Southeast Asia, currently suffer flooding due to sea level rise: 641 of China's 654 largest cities are already impacted by regular flooding. Tropical communities, including in Southeast Asia, the Pacific Islands, the Caribbean, Central America, and the Southern United States, are also being hit by more destructive tropical storms with stronger winds and more extensive flooding. In each of these places, even under optimistic mitigation scenarios, climate change is projected to intensify all of these indicators.

Farmers working in an inundated rice paddy, Khulna District, Bangladesh
Sonia Hoque via REACH

SPOTLIGHT

Vulnerable islands: Bangladesh

The South Asian country of Bangladesh, situated on a delta fed by numerous rivers, has long been vulnerable to flooding. People in the country's low-lying farming regions have incorporated inundation into their traditional agricultural methods. Farmers have traditionally cultivated crops on polders, temporary islands formed from silt carried by the river's current — similar in some ways barrier islands like Jones Beach Island, which build up over time from the accumulation of sand conveyed by longshore currents along the coast.

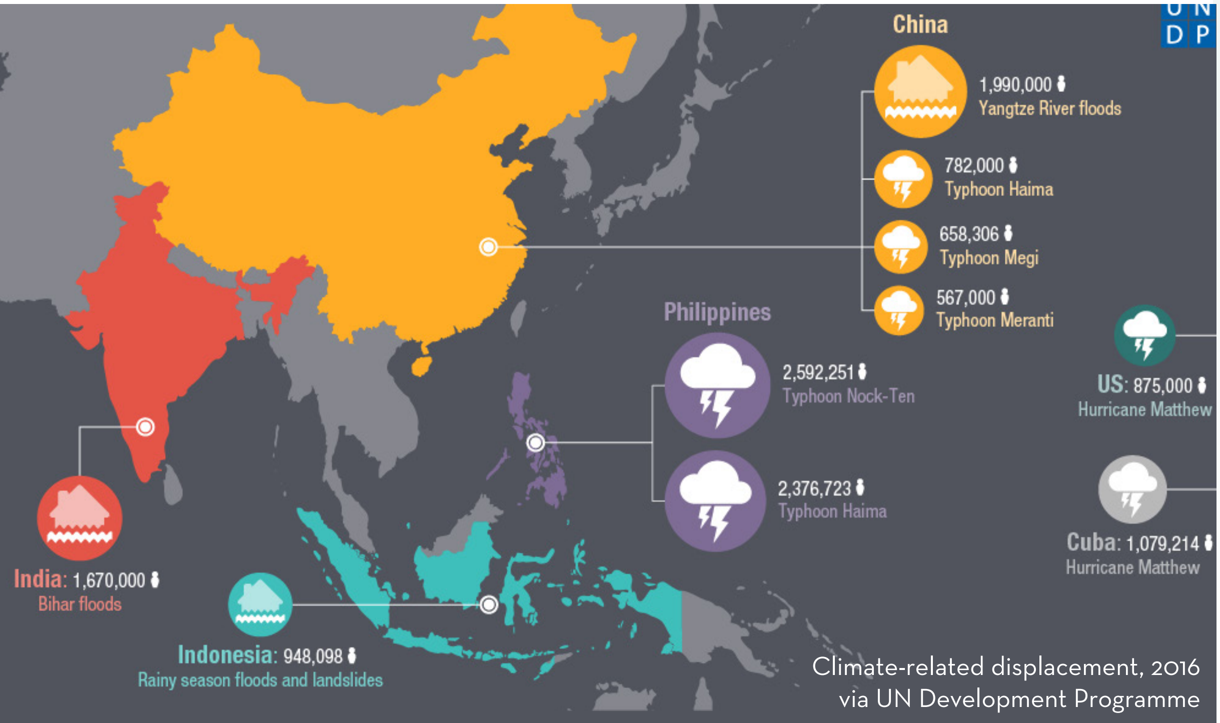
In Bangladesh, climate change is turning the familiar dynamic of intermittent, regular flooding into a constant and deadly threat. Increasing yearly floods waterlog farmlands and add salt to the groundwater. Farmers have tried to adapt by changing their farming practices — cultivating fish, shrimp, or waterfowl rather than rice, for instance, or growing vegetables in sack containers rather than the ground. But agricultural yields, even with these techniques, are much smaller and less consistent than before. Meanwhile, droughts strike the country once every five years, and severe storms like cyclones and tornadoes damage homes, decimate incomes, and claim lives. Sea levels are projected to rise almost two feet by 2050, while glaciers in the Himalayas continue to melt and permanently expand the rivers beyond their banks, covering 11 percent of the present landmass with water and displacing one in seven people in Bangladesh. Meanwhile, the farming families impacted by the increasing frequency and severity of flooding are some of the poorest in the world, with few resources to respond to these challenges in place. Bangladesh ranks 148th out of 195 countries in GDP per capita, according to the UN, and 102nd out of 152 countries on the UN's Inequality-adjusted Human Development Index, which measures the average lifespan, education level, and income of a country's citizens.

Nevertheless, people continue to live in these affected places. They may proactively adapt, with the help of their governments or communities, changing their farming methods and lifestyles. Or, they may simply survive, using whatever resources they have at their disposal to recover after each extreme weather event. The decision of whether to migrate often presents itself only when options for remaining in place have been exhausted. Migration can be thought of as the "adaptation of last resort." Communities with greater resources may be able to extend their adaptation longer. For example, in the Netherlands — a low-lying but wealthy country — cities have been able to put considerable resources into flood-prevention infrastructure and housing that is adapted to a future in which flooding is a more regular occurrence.

In the United States, coastal homeowners in places like Long Island have been able to secure aid from the government in order to elevate their homes or purchase insurance, which will enable them to remain in place longer despite the increasing risk of flooding. In countries without such resources, migration may become necessary sooner. If greenhouse gas emissions and global warming continue at their present rate, millions more people in frontline communities will have to migrate in order to survive.

How do people respond to climate change when adaptation is no longer possible?

The ripples of the first waves of climate migration are already being felt around the world. In 2017, 68.5 million people were displaced, more than at any previous point in history; of these about 22.5-24 million people were displaced by sudden natural disasters linked to climate change, like floods, forest fires, and extreme storms. Many of the remaining 46-44.5 million may have been indirectly motivated by climate change if they were displaced by the violent conflicts that develop out of growing water and food scarcity across the globe. The World Bank estimates that by 2050, 143 million people will be forced to migrate due to climate change from Latin America, sub-Saharan Africa, and Southeast Asia alone.



Climate-related displacement, 2016
via UN Development Programme

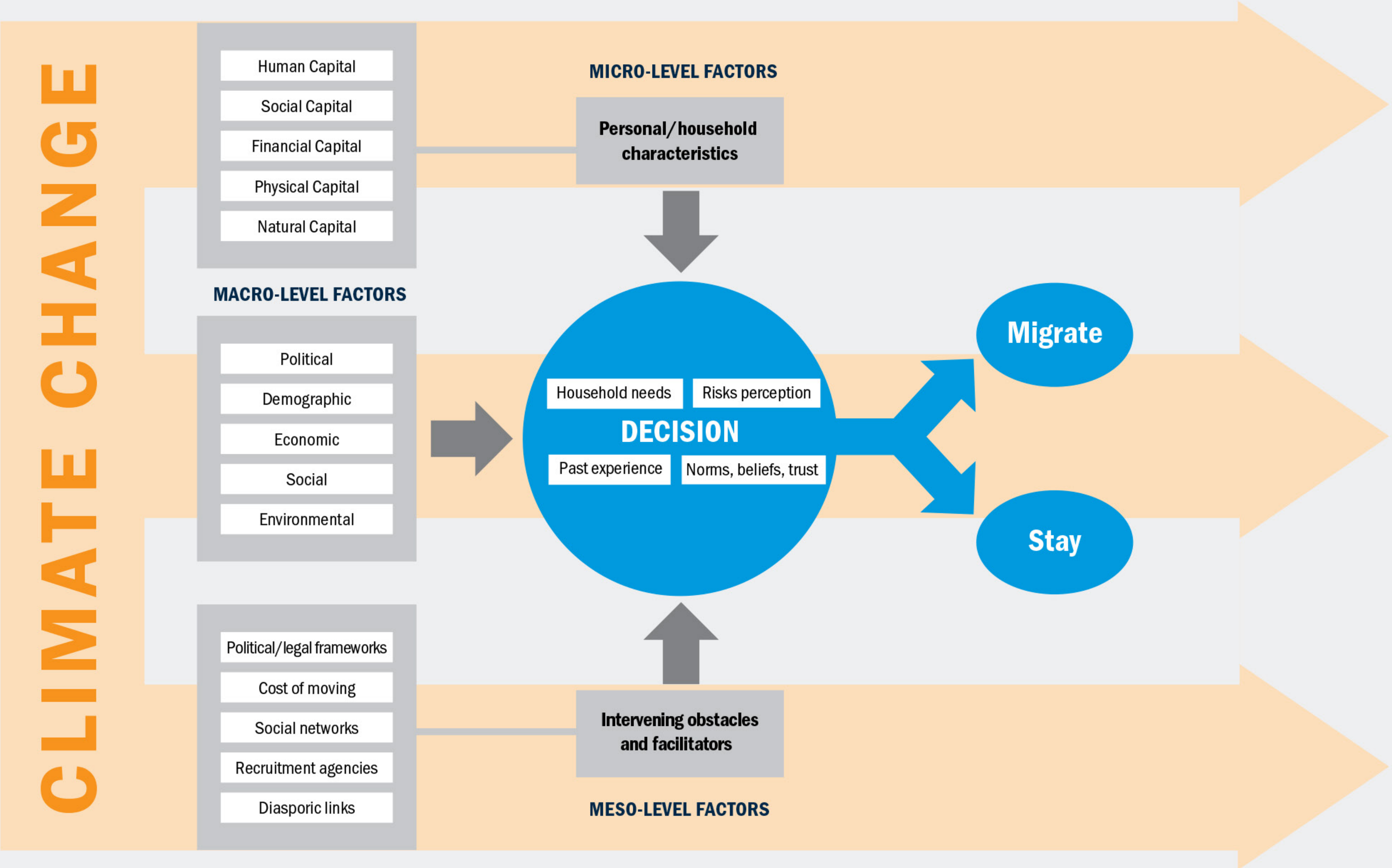
Who migrates and why?

For a long time, scholars understood migration in general (not climate-induced migration specifically) to be a product of simple cost-benefit calculations; using tools from the discipline of economics, experts theorized that people move to pursue opportunities, making simple, self-interested, rational decisions about when to leave a place and where to go. But recent research has shown that it's more complicated: migration is the product of a push-pull dynamic between the place of origin and the destination, as well as individual and cultural factors that shape the ability and inclination to migrate. Push factors can include dynamics such as poverty, lack of opportunities, and preexisting migration networks emanating from the place of origin. Pull factors like the presence of jobs, social services, family members, and social networks shape the choice of destination. Thus the unique characteristics, history, and networks of each impacted community have a strong effect on how and where members of that community migrate. People's migration choices are also shaped and limited by external factors like geography, political conditions, and cultural perceptions — people migrate to places they have access to, where they believe they will find relative safety and opportunity, but migrants do not necessarily have much choice in where they end up. Age, gender, ethnicity, and wealth of individuals also shape migration decisions and outcomes. For example, most people who migrate are young adults.

The dynamics that connect climate change and migration are complex. The term "climate refugee," while emotionally affecting, risks oversimplifying the experiences and choices of people who migrate due to climate change.

Agricultural communities are the hardest hit by climate change, but the impact is often felt gradually. Farmers and their families may undertake migration as one of several potential ways to respond to the slow depletion of their livelihoods — they may first try to adapt their farming practices, borrow money, sell off assets or land, or send family members away from home to earn money for part or all of the year. Indeed, climate-impacted farming families may not choose to migrate as a whole unit, but rather see migration of part of the family as a choice they can make in order to sustain their traditional agricultural way of life or recover from a natural disaster.

Migration, though a disruptive and often traumatic experience, is also contingent on would-be migrants having a certain amount of capital and capacity to migrate. People with access to social infrastructure (like support networks at home and away; family to stay with in potential destinations; an amount of money to make the journey; and a lack of people depending on them for direct care, like small children or elderly relatives) are more able to migrate. Both migration and the ability to receive remittances (money sent home by people who have migrated), can improve the economic prospects for individuals and families. Thus, out-migration from a climate-vulnerable area can both depend on and increase inequality within the community that remains.



Data analysis

Based on this data, how do people decide whether to migrate?

Which of these considerations do you think would matter the most, if you had to make such a decision?

Based on this graphic, what might impact whether people are able to or inclined to migrate away from areas near Jones Beach that are vulnerable to sea level rise?

Source

Graphics and tables from ***Groundswell: Preparing for Internal Climate Migration***, K. Rigaud et al, World Bank, 2018.

BREAK OUT

For full activity materials, see:

Unit 5 Appendix Pages 35-38

Where have people migrated until now, and where will they go in the future?

Rather than epic international quests, climate migrations usually take place across short distances within individual countries, or across contiguous borders within regions. Also, climate-induced migrations have so far often followed pre-existing patterns of internal migration, with people settling in "hotspots" of in-migration. Migrations may be seasonal in areas with extreme seasonal variability in their climates, but increasingly, climate migrants are staying away from home for longer periods of time. The result is called "rural hollowing": as pressure from climate change on rural frontline communities intensifies, more and more people are following those pre-established migratory paths to cities. The World Bank predicts that more than two-thirds of the world's population will live in cities by the middle of this century, up from just over half in 2020.

Meanwhile, the often informal urban infrastructure — systems of housing, sanitation, and employment — that has developed around in-migration is straining under the weight of unprecedented arrivals. Due to this strain, migrations that are a direct response to climate change may set off waves of other migrations in surrounding areas. Also partly thanks to that pressure, climate migrations are likely to occur in a "stepwise" fashion after 2050, other modelers predict. Overstretched urban centers are vulnerable to problems with public health, food access, and violence that may drive some residents away. Many of the places where climate migrants are currently settling are also under threat from climate change impacts, further down the line.

Families relocating due to flooding and landslides in a Bangladesh refugee camp
Allison Joyce via UN Women

Sujat Nagar settlement, Dhaka, Bangladesh
Dominic Chavez via World Bank

SPOTLIGHT

Internal climate migrations: Bangladesh

Rural Bangladeshis have a long tradition of migrating to cities from poor farming communities stressed by floods and storms. Already, more than 35 percent of the population in Bangladesh's six largest cities lives in informal settlements (slums), reflecting the movement of people from rural to urban areas. One group of scientists modeled the impact of people migrating from Bangladesh's agricultural areas to cities as a result of rising sea levels. They found that this initial climate change-induced migration could ultimately drive migration for 1.3 million people across all 64 of the country's districts, partly due to increased pressure on urban in-migration hotspots. In Bangladesh, many migrants from affected farming regions have moved to Dhaka, the largest city in the country, which has more economic opportunity (and makes up more than half of Bangladesh's GDP). But Dhaka is struggling with water quality issues in the wake of recent migration surges, and the low-lying delta city is also vulnerable to sea level rise. If emissions continue at their current rate, waters could rise up to 4 meters in Dhaka by 2100, and many who moved there to escape flooded rice fields will have to move again. Other migrants in South Asian region have flocked to the Ganges Valley, following another traditional migratory path, but this region will likely be uninhabitable by the end of the century due to heat waves.


Residents of Isle de Jean Charles visit the site of the future community resettlement
via Louisiana Office of Community Development

BREAK OUT

Discussion

How should we think about and plan for a future shaped by climate migration?

Should people be required to leave vulnerable places? How important is it that they have control over where they end up?

Whose responsibility is it to solve climate change migration, ultimately? How should the burden of preparing for and facilitating climate migration be shared among the peoples of the world?

Climate migration will eventually impact everyone on the planet. Already, even wealthy countries like the US are confronting a need to manage their own internal climate migrations. In 2018, 16.1 million people were displaced due to extreme weather events and disasters like floods or fires; of these, more than 1.2 million were Americans. From fires in the west to hurricanes in the east, there are plenty of examples of frontline communities in the US being displaced by climate-related events. Sometimes displacement in the wake of a weather disaster starts out temporary, and then becomes permanent, as in the case of refugees from New Orleans after Hurricane Katrina who never returned to their city. Other times, people may participate in a buyout program after a flood or other disaster, as in the case of homeowners in New Jersey, New York, and Connecticut after Hurricane Sandy, and in Texas after Hurricane Harvey. Funded by the Federal Emergency Management Agency (FEMA), state government programs purchase damaged property in order to move people out of vulnerable areas for good.

As the likelihood of future vulnerability becomes clearer thanks to updated climate modeling and flood zone maps, individuals and communities may also migrate through "managed retreat" programs that coordinate necessary migrations before a crisis occurs, allowing more intentional planning and active participation by affected individuals. Sometimes, entire communities can migrate together to a new place, as in the case of Isle de Jean Charles in southern Louisiana. Isle de Jean Charles is a low-lying strip of land in the Gulf of Mexico, 80 miles south of New Orleans, that has experienced continuous land-loss due to rising sea levels. Once 22,000 acres, Isle de Jean Charles now comprises only 320 acres, and continues to shrink, with many residents displaced by hurricanes in the last ten years.

Since 2016, community leaders have been working together with the State of Louisiana to coordinate the resettlement of remaining and former residents, the majority of whom have Native American heritage, on a "New Isle" 40 miles north of the former site.

These kinds of programs are a privilege of wealthy countries, beyond the capacity of many of the most impacted unless countries undertake a global redistribution of resources. Meanwhile, many people in climate-vulnerable areas of the US are resistant to migrating in advance, or even after sustaining damage during floods, storms, and fires. Migration is for them, also, the adaptation of last resort. But the mass movement of people around the planet in response to the effects of climate change is at this point all but guaranteed.

Members of frontline and Indigenous communities protest ahead of the Global Climate Action Summit in California, 2018
Peg Hunter

SPOTLIGHT

Hurricane Sandy and the possibility of migration

Hurricane Sandy hit New Jersey and New York in the final days of October 2012, leaving a trail of destruction in its wake. The storm caused more than $32 billion of damage in New York State and claimed the lives of 53 New Yorkers. Coastal Nassau County (the Long Island county that includes Jones Beach) was evacuated, preventing loss of life in the immediate area. More than 95,000 buildings on Long Island were damaged by the storm, including homes, businesses, and schools; 182 structures were completely destroyed, and more than 600,000 Long Islanders were left without power for two weeks after the storm.

Devastating though the storm was for Long Islanders, the barrier island system of which Jones Beach is a part largely protected homes along the southern coast from the extent of damage due to storm winds and waves seen in parts of coastal New Jersey. In New York, the storm was most damaging in areas of Staten Island, Lower Manhattan, and Brooklyn, where settlements were close to the shoreline and many residents lacked the resources to evacuate. Homes on Staten Island were damaged beyond habitability. In the small neighborhood community of Oakwood Beach, residents formed a Buyout Committee that petitioned the state government to buy out the entire neighborhood, saving costs and minimizing risks compared to a program of individual buy-outs. Out of 185 homeowners in Oakwood Beach, 180 ultimately took part in the buyout program. Their homes were demolished and the neighborhood allowed to return to its former state as a wetland buffer zone that protects inland areas from coastal storms.

Elsewhere in New York, government and communities are taking a different tack. The East Side Coastal Resiliency Project is a $1.45 billion plan for infrastructure to protect the Lower East Side of Manhattan from flooding. With more than 110,000 people living within the 100-year flood plain, this area is at high risk of damage from sea level rise and intensifying coastal storms due to climate change. Yet managed retreat has not been considered as an option for this area: buying out and demolishing buildings would be prohibitively expensive, and the majority of residents are renters, including around 28,000 residents of public housing. Instead, the city will erect flood walls and flood gates, as well as installing drainage systems and resilient electrical infrastructure.

Scientists disagree about how directly anthropogenic climate change influenced Hurricane Sandy's destructiveness. It is likely that sea level rise due to anthropogenic climate change directly affected the reach of the flood plain and the extent of the damage from flooding. Regardless, the different approaches undertaken in these two areas, and the outcomes of each approach, can be instructive for a future in which storms of such intensity are more common.

Mapping migration pathways

In “The Great Climate Migration” published by ProPublica and The New York Times with funding from the Pulitzer Center, a team of journalists and academics used existing data to project climate change migration patterns through the rest of the 21st century. The authors sought to determine where people from communities on the frontline of climate change are likely to migrate, and the impact of migration on those destinations.

Instructions

Read the first excerpt from “The Great Climate Migration”, which tells the story of Delmira de Jesús Cortez Barrera. Also review the table from the World Bank report "Groundswell: Preparing for Internal Climate Migration."

Map out Cortez’s migration pathway. What are the “push-pull” factors influencing her choices at each step?

How does climate change intersect with other pressures to influence Cortez’s decision to migrate and her pathway?

How does Cortez’s migration story reflect, or not, the dynamics described in the table?

Where in Cortez’s migration pathway are there opportunities for the Salvadoran government and the international community to help?

What kind of aid should Cortez and migrants in similar positions receive? How might aid have changed the outcome in her case?

What feelings does this story bring up for you?

Sources

“The Great Climate Migration” Abrahm Lustgarten and Meridith Kohut, July 23, 2020, co-published by ProPublica and The New York Times

pulitzercenter.org/stories/great-climate-migration

Groundswell: Preparing for Internal Climate Migration, K. Rigaud et al, World Bank, 2018.

openknowledge.worldbank.org/handle/10986/29461

For full activity materials, see:

Unit 5 Appendix Page 39-44

TAKE HOME: READ AND RESPOND

Climate debt and climate justice

One scenario in ProPublica's investigation of climate migration reflects the likely outcomes if the United States pursues a policy of closed borders and national self-interest, seeking to obstruct rather than facilitate the regional migration triggered by climate change. This projection invites us to consider: What does environmental justice mean in the context of global climate migration?

For full activity materials, see:

Unit 5 Appendix
Pages 45-65

Instructions

Read the article excerpt and the attached article from Climatic Change. Also explore the following datasets through the Our World In Data online tool.

Using these sources, and supplementing with additional research as necessary, write a persuasive essay in response to the following questions:

What is "climate debt"? How should it relate to the funding and facilitation of climate mitigation, adaptation, and migration?

What is the role of national borders in creating and maintaining environmental justice or injustice? What should the role of global entities like the United Nations be?

What needs to change to facilitate global environmental justice?

Sources

"The Great Climate Migration" Abrahm Lustgarten and Meridith Kohut, July 23, 2020, co-published by ProPublica and The New York Times

Excerpt and data visualization, available online:

features.propublica.org/climate-migration/model-how-climate-refugees-move-across-continents/

Our World in Data | Emissions by country and by sector; emissions drivers

ourworldindata.org/co2-and-other-greenhouse-gas-emissions

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