Celebrate 50 years of Earth Day by exploring human impact on the environment. How can we take action against climate change? How can we be sustainable even as our population grows?

Readings:
**An All-Consuming Challenge** – What is an ecological footprint and what are the impacts of using (and disposing of) so much stuff? Read about how personal consumption decisions impact our environment and society.

**Disappearing Islands: A Climate Change Wake-Up Call** – This case study profiles Kiribati, a nation of islands in the Central Pacific. Learn about the effects of a changing climate on the land and people, and what Kiribati’s leaders are doing about it.

Lesson Plans:
**Cap and Trade Game** (science, social studies) – Students play a game that simulates a cap and trade system, and analyze its successes and weaknesses as a policy to reduce emissions of pollutants and greenhouse gases.

**Code Blue: Endangered Oceans** (science, social studies, ELA) – As the instructor reads a story about the history of the world’s oceans, students act as characters adding and removing items based on real-world events.

**Earth: Apple of Our Eye** (science, social studies, math) – A visual demonstration of the limited farmland available on Earth, followed by an analysis of arable land per capita over time.

**Secret Life of Tees** (science, social studies) – Students use guided research to perform a five-stage life cycle analysis on a t-shirt and brainstorm ways to reduce the garment’s social and environmental impact.

*For more great resources, visit us at [www.PopulationEducation.org](http://www.PopulationEducation.org)!*
"The best things in life aren't things." — Art Buchwald

With world population approaching 8 billion and headed toward a projected 11 billion by the end of this century, one might ask “how many people can the Earth support?” We know that resources are finite, so it would seem that there are definite limits to the growth and consumption of the human population. Data on our use of biologically productive land and water, extraction of natural resources and the pollution these processes generate suggest that these limits are in sight. Our species currently uses more of these resources each year than can be replenished – 68 percent more as of 2013.¹ Yet, resource use is not only tied to the size of our population but also to the rate at which our population consumes. Growing affluence around the globe has led to a level of consumerism that intensifies our resource use, which in turn, imperils our ecosystems – the life-support systems on which we all depend.

History of consumerism

Consumer spending is a central part of our national and global economy with 70 percent of U.S. gross domestic product (GDP) coming from consumer spending.² Consumer demand for new houses, cars and electronics fuels economic growth, raises tax revenues and creates more jobs so that more people can afford to consume more. There is a non-ending cycle of buying, using and discarding goods. The engine of this economic train got moving during the Industrial Revolution. With mechanization, we were able to produce more goods quicker than ever. In the early 20th century, an abundance of fossil fuels enabled a dramatic increase in the rate and scope of resource extraction. Once assembly lines got rolling, manufacturers were able to produce a great variety of consumer products, actually leading to a problem of overproduction. Production between 1860 and 1920 increased by 12-14 times in the U.S. while the population only increased three times.³ Manufacturers had to find ways to increase demand for the abundance of goods they were producing.

Industrialists found their solution in advertising. The advertising industry created a demand for items that went well beyond the necessities. In the wake of the Great Depression, the National Association of Manufacturers enlisted a team of advertisers, marketers and psychologists to create a massive campaign to equate consumerism with “The American Way.” Buying items was now about more than satisfying needs and desires; it was one’s
patriotic duty. Advertisers also promoted new goods as a way of gaining social status, boosting the desire to have the newest models of cars and appliances or the latest fashions. Economist Victor Lebow writing in the Journal of Retailing in 1955, described how consumerism had taken hold of the American psyche: “Our enormously productive economy demands that we make consumption our way of life, that we convert the buying and use of goods into rituals, that we seek our spiritual satisfaction and our ego satisfaction in consumption. We need things consumed, burned up, worn out, replaced, and discarded at an ever increasing rate.”

Consumer spending was also promoted by offering credit. Before the advent of automobiles, people were accustomed to paying cash for their purchases. But since most people couldn’t afford to pay for cars outright, automobile companies established a system of credit, enabling purchasers to pay for their cars over time. Credit soon expanded to store charge cards and credit cards by the mid-20th century. Today, Americans carry over $900 billion in credit card debt (about $7,000 per household).

Consumerism is far from an American phenomenon. The entire global economy is based on the consumption of an ever-increasing amount of goods. With incomes rising around the world, there is a rapidly expanding population of consumers who want to follow America’s lead. Growing GDPs in large economies such as China and India are increasing demand for luxuries, including automobiles and air travel. In fact, the number of cars worldwide is expected to double (to 2 billion) by 2040.

Tons of raw materials

Even as consumerism continues to rise, most ecologists agree that this trend will be physically impossible to maintain. According to a report from the United Nations, the amount of the planet’s natural resources extracted for human use has tripled in the past 40 years and may double again by 2050. That includes nearly 90 billion metric tons of fossil fuels, biomass, minerals and metals extracted annually. “The alarming rate at which materials are now being extracted is already having a severe impact on human health and people's quality of life,” says Alicia Barcena Ibarra, co-chair of the U.N.’s International Resource Panel. The process of extracting resources, as well as the subsequent processing and transporting of these materials has a number of negative impacts on the environment. These include water resource depletion, soil erosion, biodiversity loss and pollution through agrochemicals, mine tailings and oil spills. The use of these resources, especially fossil fuels, contribute to sharp rises in greenhouse gas emissions and ocean acidification.
Every year the world extracts, processes and throws away over a half-trillion tons of “stuff.” Less than one percent of these materials become a product that remains a product six months after its sale. Countless policymakers, designers, engineers, marketers and distributors are involved in producing an item. By the time most things are designed – but before they are built – 80 to 90 percent of that thing’s economic and ecological costs have already become inevitable. In other words, when you purchase a product, it’s in the last 10 percent of its life cycle, and odds are, a lot of environmental damage has already been done.

The human footprint

A team of international researchers developed a set of metrics to measure countries’ **material footprints (MF)**, the amount of raw materials extracted per person each year in order to produce the demanded goods and energy. The top three raw materials used are metal ores (e.g. iron, copper), fossil fuels for energy, and construction materials (e.g. concrete). Australia leads the world with the highest per capita material footprint of 35 metric tons. The United States, Japan, United Kingdom and Chile follow with MFs of 25 metric tons per capita. That’s the weight of about 20 cars. On average, the richest countries consume 10 times as much of the average available resources as the poorest countries, and twice as much as the world average. An increase in materials extraction and use suggest growing environmental pressures and impacts ahead.

The extent of our **ecological footprint** goes beyond just the extraction of raw materials. The ecological footprint was created as a tool to quantify all human demand on nature, and nature’s capacity to meet those demands. It measures how fast we consume resources and generate waste compared to how fast nature can absorb our waste and generate new resources. **Biocapacity**, or resource supply, is what nature provides and can absorb. It varies every year with ecosystem management, agricultural practices (such as fertilizer use and irrigation), ecosystem degradation and weather. When demand (ecological footprint) is greater than the supply (biocapacity), the Earth finds itself in an ecological deficit, overshooting or exploiting an ecosystem faster than it can be renewed and leading to a build-up of waste and a depletion of natural resources.

How many Earths do we need if the world’s population lived like…

<table>
<thead>
<tr>
<th>Country</th>
<th>Footprint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>5.2</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>5.0</td>
</tr>
<tr>
<td>South Korea</td>
<td>3.4</td>
</tr>
<tr>
<td>Russia</td>
<td>3.4</td>
</tr>
<tr>
<td>Germany</td>
<td>3.2</td>
</tr>
<tr>
<td>Switzerland</td>
<td>3.1</td>
</tr>
<tr>
<td>France</td>
<td>3.0</td>
</tr>
<tr>
<td>U.K.</td>
<td>3.0</td>
</tr>
<tr>
<td>Japan</td>
<td>2.9</td>
</tr>
<tr>
<td>Italy</td>
<td>2.6</td>
</tr>
<tr>
<td>Spain</td>
<td>2.4</td>
</tr>
<tr>
<td>China</td>
<td>2.1</td>
</tr>
<tr>
<td>Brazil</td>
<td>1.8</td>
</tr>
<tr>
<td>India</td>
<td>0.6</td>
</tr>
<tr>
<td>World</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Source: Global Footprint Network National Footprint Accounts 2017
Currently, humanity’s ecological footprint is 68 percent larger than what the planet can regenerate and humans have been overshooting Earth’s available resources in this way every year since 1970. It now takes 1.68 years to regenerate what we use over the course of one year.\textsuperscript{14} Expressed another way, it would take 1.68 Earths to meet the demands of our ecological footprint. By 2030, it is expected that we will require two Earths worth of resources.\textsuperscript{15}

The United States has one of the world’s largest ecological footprints at 8.6 global hectares (gha) per capita (1 gha = 2.47 acres). This footprint is 35 percent larger than Germany’s (5.5 gha) and twice as large as Greece’s (4.2 gha). Consider that the average American consumes 50,000 pounds of raw materials annually, or 137 pounds per day.\textsuperscript{16} The Global Footprint Network calculates that if all global citizens consumed at the rate of the average North American, we’d need five Earths worth of resources to meet the demand. At the other end of the scale are the world’s least developed countries, such as Mozambique, Haiti and Eritrea. Millions in these countries have footprints of less than 1 gha and, unless the amount they can consume actually increases, it is unlikely they’ll be able to meet their basic needs.\textsuperscript{17}

Why is there so much disparity in the size of average ecological footprints around the globe? Our individual use of resources varies depending on our lifestyles – our diets, modes of transportation, size and energy use of our homes, consumer choices and waste disposal. Even among the most developed countries, there are significant differences in resource use. The United States consumes nearly five times as much gasoline and drives nearly twice as far as other advanced democracies. Only 15 percent of Americans use public transportation compared to 32 percent in Germany and 35 percent in the United Kingdom. In a global survey of thousands of consumers in 20 countries, 61 percent of Argentinians responded that they consume beef daily or several times per week but only 32 percent in Spain said the same. Over half of Germans surveyed indicated that they always recycle their electronics, yet two-thirds drink bottled water on a daily basis.\textsuperscript{18}

**Measures of progress**

There are tools available to help us each assess our individual ecological footprints with suggestions on how to shrink its size and contribute to a more sustainable future. Small changes can add up if enough people reduce wasteful consumption and support environmentally-friendly products and transportation. Though given the global economy’s dependence on using ever more natural resources, many may find changing consumption habits seems like swimming against the tide.

---

\textsuperscript{14} The World’s Growing Ecological Deficit

![The World’s Growing Ecological Deficit](image)
Since the mid-20th century, GDP (Gross Domestic Product) has been the most common measure of a nation’s economic growth and general welfare. GDP is defined as the total value of all goods and services bought and sold in a given year. But using GDP measures has several shortcomings, especially when it comes to accounting for resource use and environmental sustainability because there is no distinction between “good” and “bad” spending. For example, pollution increases GDP not once, but twice – first when calculating the sale of products from factories that produce pollution, and second when calculating the money spent to clean up the pollution. In other words, according to GDP measures, pollution is good for the economy.

GDP measures also ignore resource depletion, counting the sale of resources as the only income. The result is that the sole economic value placed on a forest is for the harvested timber. Economic services that nature provides for people, such as clean air and water, fertile soil, habitat for wildlife and support of our recreational activities, are not accounted for under this economic measurement. Traditional economics state that if people use natural resources and convert them into man-made things, like cars or buildings, the world will be just as well off, or better off, than it was before. The new things, or physical capital, that are produced replace the value of the natural capital that was lost. An economy is sustainable as long as it does not deplete the total amount of capital. It does not matter what form the capital is in.

An alternate way of viewing the economy’s relationship to the environment is through ecological economics. Ecological economics argues that because our natural capital is scarce, it needs to be treated as a special case. Man-made products, or physical capital, cannot fully replace the loss of our natural capital. The ecological economists claim that benefits gained from new roads or malls cannot match or outweigh the costs of pollution and resource depletion. Therefore, in order to have a sustainable economy, natural capital must remain intact. This does not purport no natural resources can be used, only that they must not be used faster than they are replaced.

Robert Costanza, Professor of Public Policy at Australian National University, puts it this way: “Standard economists don’t seem to understand exponential growth. Ecological economics recognizes that the economy, like any other subsystem on the planet, cannot grow forever. And if you think of an organism as an analogy, organisms grow for a period and then they stop growing. They can still continue to improve and develop, but without physically growing, because if organisms did that you’d end up with nine-billion-ton hamsters.”

It is thus arguable that traditional economic indicators like GDP only provide a glimpse into the well-being of a nation and its people. Human well-being is multi-dimensional and includes more than material living standards. It encompasses health, education, meaningful work, political voice and governance, social connections and
relationships, security and a healthy environment. Some organizations have developed new sets of indicators to measure a society’s progress and give a broader picture of human development. The United Nations Statistical Division has been using the **Human Development Index** which ranks countries based on a series of quality of life indicators including life expectancy, literacy, education and child welfare. The Organization for Economic Cooperation and Development measures countries using its **Better Life Index**, which includes 24 indicators of well-being including housing, jobs, civic engagement, health, safety, education, work-life balance and environmental quality.²⁰

**Living more sustainably**

It may seem that we are locked into a system that encourages overconsumption, from our relentless exposure to advertising to the seemingly endless variety of goods that await us online and in stores. Even so, unsustainable consumption need not go hand-in-hand with growing global affluence. There is an emerging movement in affluent countries to simplify our lives by owning less stuff. In urban areas, this has taken the form of shared resources like cars and bikes – people pay a subscription fee to use these vehicles when they’re needed rather than owning their own. Networks such as Freecycle enable neighbors to give away all sorts of personally unwanted goods that would otherwise end up in a landfill. Books on “decluttering” top the best-seller list as people seek fulfillment in ways other than accumulating things. These trends find success in offering people more than just eco-conscious behaviors by appealing to other needs, such as creating more time for enjoyable pursuits and saving money.

While conscious consumerism is important, it may not be enough to significantly shrink the human ecological footprint to a sustainable size. Buying and wasting less stuff will help but so will our efforts as conscientious citizens. Reducing our material and ecological footprint as a global society will require major shifts in how energy, food and consumer goods are produced. Donating time and money to organizations and political candidates that work to protect the environment and plan for a sustainable future can help multiply individual efforts. Population stabilization is also part of securing a sustainable future. Reducing resource consumption with nearly 8 billion people is challenge enough, let alone planning for a world of 11 billion. The question worth answering is not how many people the Earth can support, but how can we create a future that promotes human well-being in a way that can be sustained indefinitely by Earth’s resources.

---


The headlines were startling: “Sea Level Swallows 5 Whole Pacific Islands.”¹ “Sea Level Rise Is Here, And Is Gobbling Up Islands.”² “Five Pacific Islands Lost to Rising Seas as Climate Change Hits.”³

The islands in question were part of the Solomon archipelago, a collection of over 1,000 low-lying reef islands in the central Pacific Ocean, home to some 560,000 people. An Australian team of researchers had used aerial and satellite images from 1947 to 2014, together with on-the-ground surveys, to come to their stark conclusion: five vegetated islands, ranging in area from three to twelve acres, had disappeared in recent decades. Six additional islands were losing ground to severe erosion. Villages at two locations had relocated because of encroaching seas, and one provincial capital was slated to follow.⁴

The reason for the islands’ disappearance is, of course, more complicated than the headlines suggest. Coral atolls shrink and grow depending on the health of the living reefs and the surrounding environmental conditions. But plant life on the islands had existed for at least 300 years. And now it is all under water. A combination of sea level rise, more powerful waves, and the building of seawalls and other “inappropriate development” all are thought to play a role.⁵

Seas are rising almost three times faster in that part of the Pacific than in most of the world’s oceans, up by an average 11 millimeters each year from 1993 to 2009, an increase from the 3 millimeter average annual rise experienced between 1950 and 2009.⁶ The researchers write: “These higher rates are in line with what we can expect across much of the Pacific in the second half of this century as a result of human-induced sea-level rise. Many areas will experience long-term rates of sea-level rise similar to that already experienced in Solomon Islands in all but the very lowest-emission scenarios.”⁷

The science of sea level

Over the last century as greenhouse gas emissions increased and the global temperature climbed, the average sea level rose by 4 to 8 inches (10 to 20 centimeters). The mechanisms for this are a matter of physics. For one, warmer water takes up more space than colder water. About half of the past rise is linked to this thermal expansion. The other contributors to higher seas are melting glaciers and melting on the ice caps of Greenland and Antarctica.⁸

Scientists tell us that we’ve barely seen a preview of sea level rise. Ice melting has accelerated in recent decades, and glaciers and ice sheets are expected to lose more water to the oceans in years to come. With projected warming, the average global sea level could be six feet higher than the present day before the end of this century.⁹
The case of Kiribati

Such projections are worrying to coastal communities around the world, but to low-lying island nations, they are an existential threat. Consider Kiribati. This former British colony of 110,000 people, pronounced “Keer-re-bahs,” is made up of 33 islands in the central Pacific. The capital is situated on the equator, about midway between Hawaii and Australia. The ocean area dotted by the archipelago’s coral atolls is vast, covering an expanse roughly half the size of the continental United States, but the actual land area is just 310 square miles, about the size of Oklahoma City. The islands’ average height is about 6.5 feet above sea level.

Kiribati is threatened by a confluence of population growth and overcrowding, environmental contamination, and sea level rise. Rather than too much water, in many parts of the republic the pressing issue is too little. Clean drinking water is scarce. Groundwater is over pumped. In some places, seawater inundates freshwater wells; in others, water supplies are polluted by human waste. Pollution also harms the corals that are the islands’ structural base. On the island that is home to the capital and half the country’s population, many residents live in shantytowns. They rely on rainwater tanks for drinking water, leaving them vulnerable to drought.

Former Kiribati president Anote Tong made his country a poster child for the perils of sea level rise over his 13 years of leadership, which ended in 2016. Tong is a strong advocate for international funding to help small islands cope with climate change. He favors “migration with dignity” rather than having islanders wait in harm’s way until they had no choice but to flee as “climate refugees.”

Relocating a nation

In 2014 Tong announced that the government purchased almost 6,000 acres of land in Fiji for close to $8.8 million. It would serve as a higher elevation destination for the Kiribati population to relocate or to grow food, never mind international immigration concerns or the fact that the island was at least a three-hour flight away. Though the Fijian mountains reach as high as 4,000 feet above current sea level, the country also suffers from freshwater shortages and the impacts of stronger storms.

Additionally, in somewhat of an ironic twist, the land that Kiribati purchased from the Anglican Church was already inhabited, according to news reports, by descendants of plantation workers who had come to Fiji from the Solomon Islands, well before some of those islands were submerged. All together, these factors draw the feasibility of relocation into question.

Kiribati is not the first country to look for safe haven overseas. The government of the Maldives, a chain of some of the world’s lowest-lying islands in the Indian Ocean, has examined options for resettlement in India, Sri Lanka, and Australia. In 2009 then-president Mohamed Nasheed garnered international attention for holding an underwater cabinet meeting to illustrate the state of affairs if climate change were to continue unchecked. Ahead of a major international climate change negotiation he warned that “If scientists are not able to save the Maldives, then they won’t be able to save the world.”
Not just the tropics

It is true that the threat of sea level rise does not just apply to tropical islands. Low-elevation river deltas, which are home to millions and also major food producers, are also at risk. The World Bank estimates that 40 percent of Bangladesh’s farmland would be lost with a 2-foot rise in seas. Much of Vietnam’s highly productive rice paddies would similarly be covered with seawater.\(^\text{16}\)

Cold areas are in trouble, too. Climate change has shrunk and thinned Arctic sea ice. The melting of floating ice does not directly change sea level (picture ice cubes in a glass of water), but without the sea ice buffer, storms and extreme waves more easily erode coastlines. The lack of reflective sea ice also accelerates regional warming. Dark open water absorbs more heat than snow and ice, creating a positive feedback cycle of additional warming and melting. Permafrost thaws. The result: homes sliding into the sea.\(^\text{17}\)

In August 2016, the village of Shishmaref on an island off the northwest coast of Alaska voted to move their community to a site on the mainland about five miles away. It is one of at least a dozen native Alaskan villages intending to relocate because of severe erosion or flooding. This was not the first time Shishmaref’s residents voted to relocate. The discussion dates back at least as far as the 1970s, before conditions became so precarious. But without funding to make the move possible, the population grew and built a schoolhouse and an airport. Just between 2005 and 2009, over $27 million was spent on coastal protection that is only anticipated to last 15 years. But the cost to move the 600 villagers could add up to $180 million. Who will pay?\(^\text{18}\)

Costly consequences

There’s the rub. The people immediately at risk from sea level rise are some of the least culpable for warming the planet. Their carbon emissions are typically very low. And often their economic capacity is limited.

In what some consider the first federally-assisted climate migration, the U.S. Department of Housing and Urban Development announced in January 2016 that it would pay for the relocation of a community on Isle de Jean Charles in Louisiana—a state hit by the triple threat of sea level rise, storm surge, and subsidence (sinking of the land, due in part to groundwater pumping and a reduction of sediment flow down the Mississippi River because of the damming and channelization). The grant is part of a $1 billion allocation to communities in 13 states for "disaster resilience."\(^\text{19}\)

Like most of the populations being displaced by climate change, this community is relatively small, though if you count the tens of thousands who fled during Hurricane Katrina in 2005 and never returned home, the Gulf coast region has already seen a major flow of climate refugees.\(^\text{20}\)
Looking forward, many of the world’s largest cities are also located on coasts. The major financial centers of New York, Tokyo, and Shanghai, are among the megacities vulnerable to the higher seas and more powerful storms and storm surges that accompany global warming. If climate migrant flows grow to the hundreds of thousands, as some studies project, the planet’s social and economic systems will be strained.²¹

Author: Janet Larsen

---

CAP AND TRADE GAME

introduction

While the scientific community has reached consensus that humans are causing climate change through greenhouse gas emissions, there is no single policy answer to solve this problem. Even countries that have agreed to reduce their emissions have implemented different strategies to do so, with varying degrees of success. One possible solution is a carbon tax, where companies or consumers pay extra based on the amount of emissions produced by their activities. Because a price or monetary value is placed on the damage to the environment and economic forces are used to reduce pollution, it’s called a market-based solution.

Another market-based solution is the “cap and trade” or emissions trading approach, in which companies that pollute are provided yearly allowances of pollutants by a government or other regulatory body. Those that pollute beyond their allowed amounts are fined. Polluters also have the option to buy the leftover allowances of other companies that reduced their own emissions. Over time, the number of allowance permits distributed decreases, and thus their value on the market increases. Ultimately, polluting becomes more and more costly, while reducing emissions becomes more and more profitable. Companies invest in upgrades because eventually, that is less expensive than continuing to pollute and pay the fine.

This cap and trade approach found great success in the United States when it was used to target sulfur dioxide and nitrous oxide emissions, the major contributors to acid rain. Monitoring data from the EPA shows that by 2014, acid rain sources reduced emissions by 80 percent (12.6 million tons) from 1990 levels.\(^1\) This system has been applied to the issue of climate change, too. The European Union’s Emissions Trading System is the largest climate market in the world and expects to see a 21 percent emissions reduction in the participating business sectors from 2005 to 2020.\(^2\) In July 2017, the state legislature of California renewed its commitment to a statewide cap and trade program through 2030, and it will play a large role in the state’s goals of reducing emissions by 40 percent in that time.\(^3\)

It is essential that we consider the potential benefits and challenges of policies designed to reduce greenhouse gas emissions, especially as energy needs continue to grow rapidly with population and increasing affluence.

---

**concept**

A cap and trade policy can be used to reduce emissions of air pollution and greenhouse gases, using market forces to encourage companies to invest in cleaner energy and more efficient technologies.

**objectives**

Students will be able to:
- Record data, track financial transactions, and make strategic decisions during a multi-round cap and trade simulation.
- Explain the concept of cap and trade in their own words.
- Identify advantages and disadvantages of cap and trade policies designed to reduce emissions.

**subjects**

Environmental Science (General and AP), Government, Economics, AP Human Geography, Geography

**skills**

Analyzing costs and benefits, recording data, strategizing with teammates

**method**

Students play a game that simulates a cap and trade system, and analyze its successes and weaknesses as a policy to reduce emissions of pollutants and greenhouse gases.
**Vocabulary:** cap and trade, carbon tax, climate change, emissions trading, greenhouse effect, greenhouse gas, market-based solution

**materials**

- Rules of the Game (provided)
- Game Chart (provided)
- Play Money (provided)
- 2 dice

For each group:
- Upgrade Cards (provided)
- 75 poker chips

**procedure**

**Note:** This lesson does not explicitly teach the greenhouse effect or the in-depth science and data behind climate change. Before starting this lesson, students should have a basic understanding of how humans’ greenhouse gas emissions cause climate change, as well as some of the social and environmental costs of a warming world.

1. Display the graph to the right.

2. Ask students to identify the largest single source of greenhouse gases (GHG) in the United States. *(Answer: Electricity).* Explain to students that all electricity production, for any purpose, is included in this category, so it includes the emissions from electricity used in homes, schools, and businesses. Given this fact, ask students to brainstorm steps that individual citizens can take to reduce their GHG emissions due to electricity.

   Answers may include: turning off and unplugging appliances when not in use, decreasing the use of hot water in your home, air-drying laundry, installing solar panels on your property, using the air conditioner or heater slightly less often, asking your power company to use more alternative energy sources, buying fewer new consumer items, recycling or upcycling whenever possible.

3. Explain to students that while individual actions are powerful, policy decisions can work on a larger scale to change the way that companies provide power to
consumers. Ask students to brainstorm what governments and companies can do to reduce the GHG emitted by generating electricity in the United States.

Answers may include: government investments in clean energy like wind and solar, providing tax breaks for people who install solar panels, fining the power companies that pollute the most, shutting down some companies or power plants, rewarding companies that reduce pollution with money or special “green” status.

4. Ask students to turn to a neighbor, choose one of the brainstormed strategies, and identify pros and cons.

For example, for “government shutting down some polluting companies or power plants,” answers may include:

Pros – reduces pollution immediately, stops pollution more quickly than other strategies, sends a strong message about clean air and climate change, allows those power plant companies to do something new instead such as clean energy-related products.

Cons – people who worked there will lose their jobs, not fair to choose some power companies to close over others, the company loses money, the consumers must pay more for energy, the remaining fossil fuel-burning power plants or companies may actually pollute more to meet increased demand.

5. Explain to students that one major way to reduce pollution emissions is called “cap and trade” or “emissions trading.” The United States used this strategy with great success in reducing the sulfur dioxide and nitrous oxides that cause acid rain. This strategy is also currently being used by the European Union, the state of California, and a coalition of Northeastern states to address the GHG emissions that cause climate change. Students will be playing a game to see how this system works and to identify some of the pros and cons of it as a method for decreasing GHG emissions.

6. Divide the class into groups of 5-7 students. Assign one student within each group to be the Banker during the game (he or she can still play). Each group needs one set of Upgrade Cards (one printed page, cut out) and 75 poker chips. Each student needs two dice, $1,000,000 play money (one printed page, cut out), one Rules of the Game sheet, and one Game Chart.

7. Following the directions on the Rules of the Game sheet, students will play a game in small groups as if each person is a power company with fossil fuel-burning plants that emit the greenhouse gases causing climate change. The teacher will play the role of the regulatory agency for all groups, distributing a decreasing number of allowances each year and monitoring the buying/selling of allowances amongst the companies.

Note: It would be helpful to play a practice round by modeling the process with a few student volunteers, so the whole class can see how the game is set up.

• At the start of each new round, distribute a specific number of new allowances (poker chips) to each student according to amount listed on the Game Chart.
• During the buying and selling period, monitor student transactions within their groups.
• The student who is the Banker will handle the upgrades purchases.
• Announce the time for the dice roll. After the dice are rolled, collect allowances (poker chips) from the players and levy fines if they rolled a higher number than their available allowances (poker chips). Students may earn money during dice rolls if they have purchased certain upgrades; the Banker in each group should provide that money.
discussion questions

1. What was your overall strategy? Did it work?

   Answers will vary. Ask a person from each group to share. Aim to have at least one person who won in their group and one person who came in last place in their group share.

2. Why do you think the winning person’s strategy worked for them?

   Answers will vary. If students mention luck in rolling the dice, point out that this is part of it, but it is also very important what the person did with their extra allowances and funds. If he or she simply hoarded allowances to avoid fines, that person likely had trouble in the final rounds without any risk-reducing upgrades.

3. Who had the most allowances at the end? Is it better to have money or allowances?

   Answers will vary, but students may identify that the allowances are worth money on the market, so it’s comparable. Other students may note that the value of the allowances changes over time, and may be more or less depending on the round and what other companies are doing. Ultimately, as the teacher you should emphasize that more allowances still means more potential pollution, and so having more of them means more impact on the environment. Having money means a company could ideally find more ways to reduce pollution.

4. Did your group reduce the total amount of pollution by the end of the game? If so, how?

   Answers will vary, but most likely, yes, as students would play to win and avoid the fines that come from polluting over the amount allotted. The upgrades allow students to earn money for future rolls (investing in clean energy), or lets them reduce their pollution through rerolling and/or rolling only a single die instead of both.

5. Did the price of an allowance change over the course of the game? What happened to it and why?

   If students are unsure, ask for a volunteer to share how much they paid for an allowance early on, and another volunteer to share how much they paid late in the game. Most likely, the price of the allowances on the market went up. If it went down in some groups, discuss with students why this may have happened—for example, everyone had invested in upgrades so the demand for allowances (and thus total pollution) was low.

6. Explain the term “cap and trade” in your own words, using examples from the game as needed.

   The government (teacher) capped the total amount of emissions for each person. Students then traded with the existing allowances and invested in upgrades. As the total number of allowances decreased, the price of a single allowance went up in trade. This allowed teams who had invested in clean energy or upgrades for their plants to make more money by selling their allowances. Overall, pollution was decreased.

7. What are at least two pros and two cons of a cap and trade strategy for reducing pollution?

   Pros – reduces emissions over time, gives companies choice, allows them to make money to invest in clean energy or other upgrades. Cons – difficult to decide who gets many allowances, it takes time to reduce the emissions, some companies ran out of money, some companies just paid the fine at first instead of trying to reduce their emissions, so they may pass the cost of upgrades on to their consumers.
8. Do you think this is a worthwhile strategy? Do the pros outweigh the cons?

*Answers will vary. Ask students to defend their answers with evidence from the simulation.*

9. What are some challenges of applying this strategy on a global level as a means of fighting climate change?

*Many people, even some political leaders, do not believe climate change is a threat, or reject the scientific consensus that it is anthropogenic. Many or all countries would have to agree and stick to their agreement in order to implement cap and trade on a global scale. If some countries defected and didn’t limit their allowances or pollution, they may have a comparative advantage in terms of trade. In addition, consumers may not be happy to pay more for products, and technology may not always advance quickly enough for companies or power plants to improve their efficiency.*

**assessment**

Student contributions to discussion can be assessed for comprehension and connections made from the simulation to the real world policy.

**follow-up activities**

1. Students explain how they would alter or edit the gameplay to make it more realistic, or design a game to represent carbon taxes or other ways of reducing pollution.

2. Have students research current implementations of carbon emissions trading (such as California’s or the EU’s) to identify how they are effective and how they can be improved.

---

1 United States Environmental Protection Agency. (January 2017). *Clean Air Markets, Progress Report.* Retrieved from [https://www3.epa.gov/airmarkets/progress/reports/emissions_reductions_so2.html#figure3](https://www3.epa.gov/airmarkets/progress/reports/emissions_reductions_so2.html#figure3)


rules of the game

You are a power company that owns several fossil fuel-burning power plants to make electricity for the citizens of your region. The government has implemented a new policy called “cap and trade.” Your goal is to be the company with the most money (not the most poker chips) at the end of the game.

1. Each player starts with $1,000,000, 8 poker chips (representing 8 allowances, or units of pollution they are allowed to emit), and two dice.

2. To begin the first year of gameplay, all players in the group roll their two dice. The number rolled represents how many units of pollution the player emitted that year. The teacher will come around and take away one allowance (poker chip) for each unit of pollution. (Example: if you rolled a 7, the teacher will take away 7 poker chips.) If you have any extra allowances (poker chips) left over, save them for now.

3. Any player who pollutes more than his or her current number of allowances (poker chips) will be fined $100,000 per unit above the limit. (Example: if you only have 8 poker chips and you roll an 11, you will be fined 3 units x $100,000 each = $300,000 total.) You can’t go into debt, but you can have zero dollars.

4. To start the next year, the teacher will give each person their new allowances (poker chips). Notice that each year of gameplay, you receive one less new allowance (chip) than before. (The first year you start with 8, then 7, then 6…)

5. Once you have received your new allowances (poker chips) and before anyone rolls the dice, a period of buying and selling begins within your small group.
   - You can save all of your allowances for the future, when you will roll the dice.
   - You can sell your allowances to other people in your group who want them, or buy allowances from other people. There is no set price; it’s up to you to negotiate. The price can change every time.
   - You can’t go into debt and you can only sell the allowances (poker chips) you currently have in your possession.

6. After you have traded within your small group, your teacher will announce that you may buy upgrades for your power plants from the bank. These make your power plants more efficient, add new technology, or allow you to invest in clean energy. Buying these upgrades can help you make money later in the game, or help you roll lower numbers to reduce your pollution and avoid getting fined. You can only buy each upgrade once, and you can only buy one upgrade per round. There are a limited number of each one, so choose wisely!
   - Invest in clean energy! In future rounds, you will receive $100,000 profit for every 3, 4, or 5 any player in your group rolls. (Cost to purchase: $200,000)
   - Upgrade your plant’s technology! You can have one reroll in each future round. You made some great updates and have a more efficient plant, which pollutes less. (Cost to purchase: $300,000)
   - Mega upgrade! You can have two rerolls of your dice per round, because you dramatically reduced the pollution your plant emits through new technology. (Cost to purchase: $400,000)
   - Transition to clean energy! You closed one of your fossil fuel-burning plants to open a wind farm. You only have to roll one of the dice instead of both each round. (Cost to purchase: $600,000)
7. After the buying and selling ends, everyone rolls the dice for that year. The teacher will take away one allowance (poker chip) for each unit of pollution emitted through your dice roll. He/she will fine the people who don’t have enough allowances (poker chips) to cover their pollution (dice roll). Again, the fine is $100,000 per additional unit of pollution.

8. Each year, start by receiving your new allowances (poker chips) from the teacher. Then, you may buy and sell allowances with the people in your group, as well as purchase upgrades for your power plants. Finally, you will roll the dice and the teacher will take away the appropriate number of allowances, as well as collecting a fine of $100,000 per unit for any extra pollution you can’t cover with your poker chips. Always record your starting number of money and allowances, your dice roll, and any financial transactions on the Game Chart.

9. At the end of the final round, the player with the most money wins.
# CAP AND TRADE GAME

## Game Chart

<table>
<thead>
<tr>
<th>Year/ Round</th>
<th>Starting Totals</th>
<th>Pollution Units Emitted</th>
<th>Transaction History</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Money</td>
<td></td>
<td>Documentation</td>
</tr>
<tr>
<td></td>
<td>Allowances</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>What you had at the end of last round</td>
<td>New ones given by teacher this round, plus any left over from last round</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$1,000,000</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Record any money you spent on buying allowances or upgrades.
- Record any money you earned from selling allowances or upgrades.
- Note any fines you incurred from polluting over the limit.
# CAP AND TRADE GAME

**Play Money**

<table>
<thead>
<tr>
<th>$100,000</th>
<th>$50,000</th>
<th>$50,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="earth.png" alt="Earth" /> $</td>
<td><img src="earth.png" alt="Earth" /> $</td>
<td><img src="earth.png" alt="Earth" /> $</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$100,000</th>
<th>$50,000</th>
<th>$50,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="earth.png" alt="Earth" /> $</td>
<td><img src="earth.png" alt="Earth" /> $</td>
<td><img src="earth.png" alt="Earth" /> $</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$100,000</th>
<th>$50,000</th>
<th>$50,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="earth.png" alt="Earth" /> $</td>
<td><img src="earth.png" alt="Earth" /> $</td>
<td><img src="earth.png" alt="Earth" /> $</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$100,000</th>
<th>$50,000</th>
<th>$50,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="earth.png" alt="Earth" /> $</td>
<td><img src="earth.png" alt="Earth" /> $</td>
<td><img src="earth.png" alt="Earth" /> $</td>
</tr>
</tbody>
</table>
### CAP AND TRADE GAME

#### upgrade cards

<table>
<thead>
<tr>
<th>Action</th>
<th>Description</th>
<th>Cost to purchase: $200,000</th>
<th>Cost to purchase: $200,000</th>
<th>Cost to purchase: $200,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invest in clean energy!</td>
<td>In future rounds, you will receive $100,000 profit for every 3, 4, or 5 any player in your group rolls.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to purchase: $200,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upgrade your plant’s technology!</td>
<td>You can have 1 reroll in each future round. You made some great updates and have a more efficient plant, which pollutes less.</td>
<td>Cost to purchase: $300,000</td>
<td>Cost to purchase: $300,000</td>
<td>Cost to purchase: $300,000</td>
</tr>
<tr>
<td>Cost to purchase: $300,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mega upgrade!</td>
<td>You can have 2 rerolls of your dice per round, because you dramatically reduced the pollution your plant emits through new technology.</td>
<td>Cost to purchase: $400,000</td>
<td>Cost to purchase: $400,000</td>
<td>Cost to purchase: $400,000</td>
</tr>
<tr>
<td>Transition to clean energy!</td>
<td>You closed one of your fossil fuel-burning plants to open a wind farm. You only have to roll one of the dice instead of both each round.</td>
<td>Cost to purchase: $600,000</td>
<td>Cost to purchase: $600,000</td>
<td>Cost to purchase: $600,000</td>
</tr>
</tbody>
</table>
CODE BLUE: ENDANGERED OCEANS

introduction

As human population has increased and land uses have changed, our oceans have been negatively altered. For centuries, people have regarded the ocean as an inexhaustible source of resources and a convenient dumping ground that could absorb the residues of human activity with little negative impact. Mounting evidence now shows that human activities – overfishing, pollution, and carbon dioxide emissions – are stressing the ocean’s health, leading to the progressive deterioration of marine habitats and species.

Vocabulary: overfishing

materials

- Clear plastic container or bowl of water
- Opaque film canisters or other small lidded containers
- Canister Labels (provided)
- Extraction Cards (provided)
- Extraction Items (provided)
- Plastic drinking cup
- Masking tape
- Canister ingredients (see chart)
- Water
- Salt
- 14 clothespins or binder clips
- Story: “Code Blue” (provided)

procedure

1. Before class:
   a. Fill a large, clear container with water until it is approximately half full.
   b. Print the Canister Labels and tape one to each canister. Fill each canister with the appropriate material from the chart. The canisters represent things that are added to the ocean.
   c. Print the six Extraction Items, laminate them if desired, and tape them to the side of the bowl. The Extraction Items represent something currently found in the ocean.
d. Print the six Extraction Cards and laminate them if desired.
e. Tape the “Sea Level Rise” Canister Label onto the plastic drinking cup and fill with water.

**Note:** There are 17 different characters between the Canister Labels and Extraction Cards. For classes of more than 17 students, create two of some characters so all students can participate.

<table>
<thead>
<tr>
<th>CANISTERS</th>
<th>Character (Canister Label)</th>
<th>Canister Ingredients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algal blooms</td>
<td>Green yarn</td>
<td></td>
</tr>
<tr>
<td>Abandoned nets</td>
<td>Fishing line, dental floss, or hair net</td>
<td></td>
</tr>
<tr>
<td>Antibiotics</td>
<td>Baking soda</td>
<td></td>
</tr>
<tr>
<td>Litter</td>
<td>Cut-up pieces of plastic</td>
<td></td>
</tr>
<tr>
<td>Natural disasters</td>
<td>Broken up toothpicks or craft sticks</td>
<td></td>
</tr>
<tr>
<td>Chemical fertilizers</td>
<td>Vinegar + green food coloring</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>Water + red food coloring</td>
<td></td>
</tr>
<tr>
<td>Off-shore Oil Wells</td>
<td>Cooking oil + red and green food coloring</td>
<td></td>
</tr>
<tr>
<td>Ocean acidification</td>
<td>Vinegar</td>
<td></td>
</tr>
<tr>
<td>Sewage</td>
<td>Water + instant coffee</td>
<td></td>
</tr>
</tbody>
</table>

2. Distribute the canisters and Extraction Cards so each student has one or the other.

3. Explain that you will be reading a story about the history and health of our oceans. Instruct the students to listen for the name of the character printed on their canister or Extraction Card. When they hear the name in the story, they should come to the front of the class and pour the contents of their canister into the bowl. If they have an Extraction Card, they should find the matching Extraction Item from the side of the bowl and remove it. After removing their item, they should hold it up for the class to see and say what they have removed.

4. Tell the students that the clothespins or binder clips represent the world population and that each clip represents 500 million people. You will begin the demonstration with one clip on the side of the bowl and end with 14 (representing 7 billion people). You may decide to have a few students be the “population monitors” and add clips throughout the story so that you do not have to pause.

5. Read the story, adding emphasis and pausing on the bolded words so that students will have a cue to either add their pollutant or make an extraction.

**discussion questions**

1. Who polluted the ocean?

   *Everyone played a part. Students should mention that each person had an impact and everyone shares the oceans.*
2. What effect did increasing population have on the health of the ocean? Can you think of any ways that population increase helped the ocean?

_In this situation, population growth led to increases in pollution sources and decreases in open space and in available wetlands, which filter water. However, the increase in population also led to stronger environmental laws, more efficient uses of resources, and public services like sewage treatment plants._

3. Think about the pollution held in the canisters. What could be done to prevent those types of materials from entering the water?

_Answers may include: use less chemical fertilizers, be selective with what types of products we purchase and eat, recycle, participate in beach clean-up projects, use alternative transportation, etc._

4. Think about the organisms that were removed or destroyed due to human activities. They aren’t confined to just one area of the world, but swim freely. Who owns these animals? Who should manage how many of these creatures people are allowed to remove? How can these management systems be enforced internationally?

_Answers will vary. Guide students to understand that there are international management groups that sign treaties to protect international interests (ICCAT, IPCC, IWC) but that these treaties are difficult to enforce._

5. Were all of the inputs human caused? Which ones were? Which ones weren’t?

_Many were human caused, but natural disasters like tsunamis and mudslides can’t be prevented. However, human activities can affect how devastating these natural disasters are by destroying natural buffers to storms, like mangrove forests, coral reefs, or cutting down trees that are meant to stop erosion and nutrient depletion. We also increase the intensity and frequency of these storms through global warming._

6. Think about the impacts of sea level rise in coastal communities. Where will these impacts be the worst?

_Areas with high population density living in very low-lying areas. The poorer, tropical regions will be the most impacted._

7. Is it easier to prevent pollution by managing ocean resources beforehand, or to clean it up and restore it later?

_To prevent it in the first place._

8. What could each of us do to help improve the health of the oceans?

_Answers may include: using alternative transportation besides just cars, conserving water, eating organic foods or foods produced with natural fertilizers, only eating sustainably harvested seafood, etc._

assessment

_Students complete an exit ticket identifying three ways humans impact oceans and two ways these impacts can be mitigated._
follow-up activities

1. Have students research a piece of the story that seemed the most interesting or relevant to them. For example, they could research overfishing, ocean acidification, whaling, the Plastic Gyres, or sea level rise and climate change. Then, have students write a short essay with more specific details and examples of how their research topic impacts the oceans. Students can also research impacts that were not included in this story.

2. Discuss international policymaking. What are the difficulties of getting countries to solve problems together? What is the best method of solving these problems? Have students research an international policy or regulatory body of their choice (Montreal Protocol, Kyoto Protocol, Paris Agreement, International Panel on Climate Change, International Whaling Commission, or the Convention in the Trade of Endangered Species). Ask them to write a short paper on the history of the policy, which countries were major players in the debate, and why it was important or controversial. Alternatively, they could work in groups and give a short presentation to the rest of the class on their treaty or commission.

3. Have students explore some of the following sources to learn more about ocean health:

Information on various international organizations that are working on these issues:

   - International Whaling Commission – [https://iwc.int/home](https://iwc.int/home)
Story: Code Blue

Throughout humans’ existence on Earth, we have made our home on the coasts of the ocean, depending on its resources for food and transportation. The ocean makes up over 70 percent of the Earth’s surface, is teeming with wildlife, and is responsible for much of our climate patterns. Imagine that this container of water represents the ocean 500 years ago (pour salt into the container). Back then, our world population was 500 million, or about 1/14 of what it is now (place one clothespin on the side of the bowl). The oceans were filled with diverse ecosystems of corals, invertebrates, fish and mammals, all relying on each other in interconnected food webs.

However, the ocean has changed a lot since 1500 and this is a story of those changes.

One hundred years passed by and starting in the 1600s, people began to recognize the ocean’s wealth as harvestable. **Whaling** began in Northern Europe where men would use large harpoons to kill whales and convert their blubber into a source of oil. Over the course of 200 years, whaling became a prominent industry and decimated whale populations throughout the north. Currently, there is an international moratorium on commercial whaling; however, some countries such as Norway, Iceland, and Japan continue the practice.

In the early 1800s, world population had reached 1 billion (place another clothespin on the bowl) and scientists and farmers were looking for ways to increase crop yields to feed the population. Scientists began creating **chemical fertilizers** with high levels of nitrogen, phosphorous, and potassium. Nitrogen is highly soluble and when used in large amounts, can run off into large bodies of water. Increases in nutrients in the ocean cause **algal blooms** that consume all of the oxygen in an area and create a dead zone where no other organism can live. Dead zones occur in many areas, including the East Coast of the U.S. and the Gulf of Mexico, which has the second largest dead zone in the world. Worldwide, there are now some 146 coastal dead zones. However, the small amounts of chemical fertilizers used in the early 1800s weren’t enough to cause these troubles, and people never thought that the human population would grow enough to overuse fertilizers to the extent that they would become a problem.

The Industrial Revolution in the mid-19th century ushered in a new era of technologies and jump-started a fossil-fuel based economy. **Coal** was the new main energy supply, but it caused a large amount of air pollution. Burning coal was also a source of mercury poisoning in our ocean system. Trace amounts of mercury found in coal were released as coal was burned, and it moved into our atmosphere and our oceans. Fish ingest the mercury and humans are susceptible to illness if they eat fish with high mercury content.

- **What has changed about the oceans from 1500 to 1850?**
- **How have humans been helped/hurt by these changes?** Possible answers: **Helped**—more access to food due to fertilizer use and whaling; better transportation systems. **Hurt**—less biodiversity because of the algal blooms and whaling; water has high levels of mercury.

In the early 1900s, the first **off-shore oil wells** were dug off the coast of California to try to keep up with growing demand for oil. The first major oil spill was in California in 1910 and dumped 378 million gallons of oil into the Pacific, devastating the ecosystem. By 1930, when world population reached 2 billion (place two more clothespins on the bowl), oil companies began constructing platforms in the Gulf of Mexico. Today there are over 1,470 offshore oil rigs around the world. One of the largest spills occurred as a result of an oil rig explosion on April 20, 2010. It took nearly three months to stop the flow of oil into the Gulf of Mexico, which had devastating effects on the environment but also for the Gulf Coast community and economy.

In the 1950s, much of the maritime technology that was developed during World War II was converted into new **fishing technologies** to help feed the 3 billion people on the planet (place two more clothespins on the bowl). However, these technologies caused severe overfishing, as fishermen could now catch thousands of pounds of fish in one outing. These new technologies, including trawling, a technique the scrapes the seafloor...
with large nets, would catch anything and everything. Additionally **BYCATCH**, or the accidental catch of marine life, was becoming a problem as turtles, dolphins, and other fish were often caught and killed in fishing gear that was meant for other animals. **ABANDONED NETS**, fishing lines, and traps can also continue to kill animals for weeks after they have been deployed if fishermen forget to retrieve them. As of 2014, two-thirds of the world’s fisheries are fully exploited and a third are overexploited, depleted, or recovering from depletion. The cod fishery in the Northeastern United States and Canada had record high catches in the 1960s but later collapsed due to overfishing.

Even with the fishing boom, we weren’t producing enough fish to provide for our growing population. In the 1970s when world population reached 4 billion, **AQUACULTURE**, or raising fish in pens as you would cows or chickens, became a growing industry, especially in Asian countries such as Indonesia and Thailand. In many rural areas, coastal ecosystems were decimated as fish farmers cleared mangrove forests to create room for more aquaculture. These mangroves were home to hundreds of species of birds and fish but were converted into large feeding pens of shrimp and salmon. Due to the density in which the fish are grown, they must put large quantities of **ANTIBIOTICS** in the water to keep the animals healthy. Unfortunately, these antibiotics seep into the oceans and pollute our water, endangering our public health as well as our food sources.

By 1987, world population was at 5 billion people who were together producing millions of pounds of trash. This **LITTER** from land sources, commercial ships, and cruise vessels entered the ocean system as pollution. By 1997, with population nearing 6 billion, scientists discovered two “Plastic Gyres” in the Pacific and Atlantic Oceans. These massive swirling mounds of plastic, created by water currents, seep chemicals into the water and kill **MARINE BIRDS** who consume the plastic.

Litter isn’t the only pollution we have to worry about. In many countries, sewage treatment facilities are not available, and **SEWAGE** from cities and households runs directly into our rivers and oceans. This isn’t only in developing countries. Even Venice, Italy is just beginning to implement a sewage treatment plan.

Recognizing the global nature of the problems our oceans were facing, international bodies have been created to monitor pollution, climate, and fishing industries. However, it was and still is difficult to get countries to agree on an action plan, and, without an enforcing body, many countries still do not comply with the agreements. As the world population reached 7 billion people in 2011 all of the detrimental effects of our abuse of the ocean were accumulating. Increased concentrations of carbon dioxide, or CO₂, in the air from burning oil and coal led to Arctic ice melting and **SEA LEVEL RISE**. Low lying countries such as Bangladesh, Papua New Guinea, and islands in the Pacific Northwest have already had to evacuate some communities due to permanent sea level rise.

Similarly, increases in CO₂ alter the ocean’s chemistry and lower the pH of the water, causing **OCEAN ACIDIFICATION**. Many organisms can only handle a narrow range of pH in their environment and this acidification has caused the death of **CORAL REEFS** and the rich biodiversity that relies on coral. Both coral reefs and the mangrove forests normally act as natural buffer zones against storms for coastal communities. With increases in global temperatures, storms, like hurricanes, are increasing in intensity, and without these natural protective structures, **NATURAL DISASTERS** wipe out entire towns and wash them into the water. Mangrove forests are also a “carbon sink,” sequestering – or soaking up – carbon dioxide from our atmosphere. Without them, the cycle of global warming and ocean acidification continues.

Our oceans are essential for nutrition, transportation, recreation, and so much more. But with so many new people and new technologies on the Earth, they have become extremely threatened. It is important that all people work together to start to fix the dangers to the oceans before it is too late.
Print and tape each label to a canister.

<table>
<thead>
<tr>
<th>Label</th>
<th>Label</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF-SHORE OIL WELLS</td>
<td>ABANDONED NETS</td>
<td>ANTIBIOTICS</td>
</tr>
<tr>
<td>CHEMICAL FERTILIZERS</td>
<td>ALGAL BLOOMS</td>
<td>COAL</td>
</tr>
<tr>
<td>LITTER</td>
<td>SEWAGE</td>
<td>OCEAN ACIDIFICATION</td>
</tr>
<tr>
<td>NATURAL DISASTERS</td>
<td>SEA LEVEL RISE</td>
<td></td>
</tr>
</tbody>
</table>
**Extraction Cards:** Print and give one to six students in the class instead of a canister.

- **WHALING**
- **MARINE BIRDS**
- **BYCATCH**
- **FISHING TECHNOLOGIES**
- **AQUACULTURE**
- **CORAL REEFS**

**Extraction Items:** Print and tape to the side of the clear bowl of water.
EARTH: THE APPLE OF OUR EYE

introduction

Only about 3 percent of the Earth's surface is capable of growing food. Over the past century, farming technology has made it possible to produce more food from the world's limited cropland in order to feed the growing world population. However, much of this arable (farmable) land has been taken out of production for urban/suburban development and livestock grazing, or has been mismanaged, leading to irreparable soil erosion. By 2050, food production must increase by 70 percent to feed the expected 9 billion people who will be sharing the planet. Protecting our arable land resources is becoming more important than ever.

Vocabulary: arable, crop rotation, deforestation, erosion, fallow, hectare, over-farming, overgrazing, topsoil

materials

Part 1:
• Apple
• Knife

Part 2:
• None

Part 1: The Size of Arable Land

procedure

Slice the apple according to the instructions, narrating as you go.
<table>
<thead>
<tr>
<th>Apple</th>
<th>Earth</th>
<th>Narrative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Apple</td>
<td>Planet Earth</td>
<td>Hold the apple out so the class can see it.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“This apple represents our planet.”</td>
</tr>
<tr>
<td>3/4 Water</td>
<td></td>
<td>Cut the apple into quarters. Hold out 3/4 in one hand.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ask the class, “What do these 3/4 represent?” (Water.)</td>
</tr>
<tr>
<td>1/4 Land</td>
<td></td>
<td>Set the three “water” sections aside and hold out the remaining quarter.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ask the class, “What fraction of the apple remains?” (1/4) “So, this 1/4 represents the total land surface.”</td>
</tr>
<tr>
<td>1/8 Inhospitable &amp; non-arable land</td>
<td></td>
<td>Slice the land (the remaining 1/4) in half, lengthwise.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hold out one of the pieces and ask the class, “What fraction of the apple is this?” (1/8) “This 1/8 represents the Earth’s land that is inhospitable to people and to crops: the polar regions, deserts, swamps, and high or rocky mountains.”</td>
</tr>
<tr>
<td>1/8 Habitable land</td>
<td></td>
<td>Set that 1/8 aside and hold out the other.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“This 1/8 represents the other half of the Earth’s land. These are the areas where people can live but can’t, or don’t, necessarily grow food.”</td>
</tr>
<tr>
<td>3/32 Habitable, but not used for farming</td>
<td></td>
<td>Slice this 3/32 crosswise into four equal pieces.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hold out three of the pieces and say, “These 3/32 represent land on which people can live but cannot grow food. Some of it was never arable because it’s too rocky, wet, cold, steep or has soil too poor to produce food. Some of it used to grow crops but has since been developed – turned into cities, suburbs, highways, etc. Governments have earmarked other areas, such as parks, nature preserves, and other public lands to remain undeveloped forever.”</td>
</tr>
<tr>
<td>1/32 Arable land</td>
<td></td>
<td>Set the 3/32 aside and hold out the 1/32.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“Only 1/32 of the Earth’s surface has the potential to grow the food needed to feed all of the people on Earth.”</td>
</tr>
<tr>
<td>1/32 Top soil</td>
<td></td>
<td>Carefully peel the 1/32 slice of Earth.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hold up the peel and say, “This tiny bit of peel represents the topsoil, the dark, nutrient-rich soil that holds moisture and feeds us by feeding our crops.”</td>
</tr>
</tbody>
</table>
Some Facts About Farmland

**Erosion** by wind and water is the most serious cause of soil loss and degradation. Although it is a natural process, erosion is accelerated greatly by things like construction, deforestation, unsustainable farming practices, and animal grazing.

- Around the world, soil is being swept away 10–40 times faster than it is being replenished, destroying roughly 23 million acres of cropland every year. As a result of soil erosion over the past 40 years, 30 percent of the world’s arable land has become unproductive.²
- In order to feed the 9 billion people expected in 2050, food production must increase by 70 percent.³
- Land degradation is intensifying in many parts of the world, with more than 24 percent of cultivated areas undergoing degradation, affecting one-fourth of the world’s population.⁴

**discussion questions**

1. What are things humans do to arable land that make it more vulnerable to erosion?

   *Answers may include:*
   
   - **Deforestation** – When trees are cut down, the soil loses the shelter of branches and leaves that protect it from the force of rain and wind that otherwise blow and wash it away. The root systems that hold the soil in place from underneath are also destroyed.
   
   - **Over-farming** – Each kind of crop takes certain elements from the soil. Over-farming occurs when the same crop is grown in the same place for too many years in a row, and the soil can’t renew itself. Eventually, all of that particular element is gone, and that soil is unable to grow anything. One way to avoid this is **crop rotation**. Farmers divide their land into sections, and every year, they change the kind of crop grown in each section. One section might be left unplanted, or **fallow**, for a growing season, giving the soil microbes time to break down dead plant matter and/or animal matter into soil nutrients.
   
   - **Overgrazing** – When cattle eat grass, they pull it out of the ground by the roots, taking some soil with it. Each bite leaves a patch of ground uncovered, exposed to the wind and the rain. These animals’ sharp hooves also tear up the surface a little with each step.

2. How do you think population growth contributes to the loss of arable land?

   *Answers will vary. When population grows, more people need places to live and work so land is often developed. As more people become affluent and start to consume more animal-based diets, more land is required to meet this demand. Also, a growing population can mean more potential for pollution.*

3. Display the map on page 4 (from [www.WorldPopulationHistory.org](http://www.WorldPopulationHistory.org)).

   Tell students that the graphic represents world population in 2017 and that each dot represents 1 million people. Why are some parts of the Earth not populated by dots? Do all countries or regions have an equal amount of arable land?

   *Answers will vary depending on students’ geo-literacy and you may need to prompt them by asking about the climate/geography of these regions. The areas without dots are known for their harsh climates (e.g. tundra, desert, mountain, dense jungle/forest). Areas with harsh inhabitable climates have a smaller share of arable land. In other words, arable land is not distributed equitably around the world.*
4. How many people do you think the Earth can feed with its existing croplands?

Answers will vary. Although much of the hunger problem stems from uneven food distribution, rising affluence also plays a role in the number of humans that the world’s food supply can sustain. Per capita consumption of grain in a low-income nation such as India, whose people’s diets consist of primarily a single starchy staple like rice, is 200 kg/year. However, per capita consumption in a more developed nation like the U.S. or Canada is 800 kg of grains each year. Most of this grain is indirectly consumed from eating animal products such as beef, pork, poultry, eggs, milk, and other dairy products. In other words, the grain is used for animal feed instead of being directly consumed by people.

5. The current world grain harvest is 2 billion tons. How many people could we support if everyone consumed at:
   a. the U.S. level of consumption (800 kg of grain per person for food and animal feed)?
   b. the Italian level of consumption (400 kg of grain per person for food and animal feed)?
   c. the Indian level of consumption (200 kg of grain per person for food and animal feed)?

   Note: 1 ton = 907 kg

The world’s grain harvest could support about 2 billion Americans, 5 billion Italians or 9 billion Indians.

U.S.: 800 kg/907 kg = 0.88 tons/person; 2 billion tons/0.88 tons = 2.3 billion people
Italian: 400 kg/907 kg = 0.44 tons/person; 2 billion tons/0.44 tons = 4.5 billion people
Indian: 200 kg/907 kg = 0.22 tons/person; 2 billion tons/0.22 tons = 9.1 billion people
**Part 2: Our Arable History**

**procedure**

1. Display the Population vs. Arable Land/Person graph. Point out the two different variables, population (orange line) and arable hectares per person (blue bars) and the two different y-axis scales. Explain that this type of graph is often used to illustrate a relationship between two variables. The x-axis shows years.

2. Have students look at the title and define hectares/person: A hectare is 2.47 acres, or 10,000 square meters. To help students visualize this, tell them a baseball field from home plate to the start of the outfield is roughly a hectare.

![Population vs. Arable Land/Person graph, 1965-2010](image)

**Sources:** The World Bank, Open Data; United State Census Bureau, International Data Base

**discussion questions**

1. What is the overall trend of human population from 1965 to 2010?

   *Human population increased between 1965 and 2010. It grew from just over 3 billion to close to 7 billion.*

2. What is the overall trend of arable hectares per person during the same time period?

   *The amount of hectares per person decreased over time. In 1965, there were 0.35 hectares per person, and in 2010 there are just over 0.2 hectares per person. Converted to acres, that’s 0.86 acres/person in 1965 and 0.49 acres/person in 2010 (about half the size of a football field).*

3. What is the relationship between the amount of arable land per person and population size? Why do you think this is true?

   *Arable land isn’t increasing, as it is a finite resource. However, human population is growing steadily. As human
As population increases, the amount of arable hectares available per person decreases; each person’s “share” gets smaller and smaller. This is an inverse or indirect relationship – as one variable increases (population), the other decreases (arable land per person). Also, to support the demands of more people, arable land often gets used for other purposes like housing, roads, industrial purposes and so on, decreasing the total amount over time.

4. Do you think this relationship holds true if we look at the population and arable land of a country rather than the entire world? If yes, does that mean each country is impacted by an increasing population in the same way?

Yes, the relationship holds true and remains indirect. However, each country is not impacted by a growing population in the same way. A country with a small amount of arable land and a large population would have the fewest arable acres per person, and a country with a small population and a lot of arable land would have the most arable land per person.

5. How might a country that can’t support its population on its available arable land support its people?

They could import food or receive aid from other countries.

6. Human population is expected to increase to over 9 billion by 2050. How can we preserve farmland in order to feed everyone?

Answers may include:

- By not building on arable land – Land covered up by building, highways, and other forms of development can’t be used for growing crops.
- By eating lower on the food chain – While over a billion people suffer from malnutrition or starvation, meat production requires a disproportionate amount of grain input. Producing a pound of beef in a feedlot requires seven pounds of grain, a pound of pork requires four, and a pound of poultry requires two pounds of grain. The land that is used to produce grain for consumption by animals is inaccessible for growing grain for human consumption.
- By reducing pollution – Pollution impairs the ability of the land and the seas to provide food that’s both sufficient in quality and free of contaminants.
- By stabilizing human population growth – Food supply is an excellent example of the relationship between any resource and the size and consumption patterns of the population that depends on it. Simply put, the more people there are to feed, the less food there is to go around.

assessment

Students draw a diagram(s) or infographic that pictorially represents: the amount of arable land on the planet, the relationship between arable land and population size, and one way to preserve farmland.

follow-up activity
Have students imagine that they are citizens of a town that is rapidly growing, and the city council is considering expanding the urban area onto some nearby farmland. Have each student write an op-ed for a fictitious newspaper in this town explaining the consequences of doing so.

Part 1 adapted from an activity that first appeared in KUITATK, a Native American Science Education Association Issue Publication.


introduction

Our stuff has a secret life – a life that exists long before it reaches you as a consumer and extends long after you’re done with it. Most people aren’t aware of the life cycle stages our stuff goes through, not to mention how those stages impact the planet and other people’s lives and economic well-being.

Consider the garment industry and a single cotton-polyester t-shirt. Arable land, fossil fuels, and water are consumed to provide its raw materials. The shirt’s production impacts the lives, jobs, and homes of the people who manufacture it. It is responsible for carbon dioxide emissions as it is shipped, sometimes thousands of miles, to the store where it will be sold to consumers. Once it’s in use, the shirt is washed in detergents, often in heated water, and then sheds synthetic microfibers that wreak havoc on local waterways. After the consumer tires of the shirt, it may be exported and sold on a shipping pallet to a developing country, where reselling it provides jobs for some but disrupts the market for local craftsmanship. Or, it is simply tossed in the trash – an estimated 10.5 million tons of American clothing ends up in landfills every year.

A life cycle analysis, or LCA, is a technique that assesses the impact of a product and can help identify changes that will decrease a product’s eco-impact over the course of its life. As our population grows, it is more important than ever to consider how the clothes we wear are intricately connected to other people’s lives and to our environment.

Vocabulary: composted, developing country, greenhouse gas, life cycle analysis (LCA)

materials

• Paper bag
• T-shirts with legible tags
• 5 personal computers/tablets
• Student Worksheet

preparation, before class:

1. Arrange the room in five collaborative work stations that can each accommodate 4-6 students. (If you prefer smaller
groups of students, make two of each station so there are 10 total, each accommodating 2-3 students.) Each station should have a computer or tablet with sound and internet access.

2. Ask students to bring in a clean t-shirt from home. It can be any material, design, or size if it has a legible tag and does not display inappropriate images or messages. The t-shirt will not be damaged during the lesson. Bring in 5-10 additional t-shirts, preferably from different countries of origin and made of different fabrics, for students who are unable to provide their own; each student will need one shirt. If you prefer to bring in t-shirts for all students rather than asking them to bring their own, make sure there is a good variety of different fabrics and countries of manufacture.

procedure

1. Bring a paper bag to class, and ask students to hypothesize what they think it means to conduct a life cycle analysis (LCA) of a product. Then brainstorm the paper bag’s LCA as a class. You can display the circle image below if they have trouble determining the five stages. As you go through each stage as a class, ask students to think about what factors influence the environmental impact of that stage.

Here’s an overview of potential impacts during each stage:

**Materials** – The materials used to create a product must come from somewhere. Some are extracted from mines, others are grown specifically to be used by humans, while others might be taken from the ocean or a forest. Removing these materials impacts the Earth’s natural resource base and gathering them requires labor and energy.

**Manufacturing** – Each piece of a product has to be created separately before being combined with the other parts. The manufacturing of each piece requires energy and water and can produce toxic waste. The processing of metals and plastics is especially resource intensive because they must be melted and refined before use.

**Distribution** – Many things must be transported for a product to exist – the raw materials to the production factory, the product to stores, and finally, the product to consumer homes. All of this transportation emits greenhouse gas and contributes to the eco-impact of the product.

**Usage** – Some things require energy to work (appliances, electronics, cars, etc.), and this gets factored into their life cycle analysis. Others may require energy to maintain and reuse them, such as clothing. Length of use also plays a role – items that can be used longer have less of a footprint, since they don’t need to be replaced by new versions as often. This often means that buying high-quality or reusable items (such as rechargeable batteries) contributes to a lower impact over time than lower-quality, often less-expensive items.
Disposal – Both the product itself and its packaging must be eliminated. Materials that can be recycled or composted, like cardboard, have less of an impact than those that cannot, like Styrofoam. Some items are also easier to reuse or donate than others.

Paper Bag LCA:

2. Divide students into groups of 4-6 and distribute a Student Worksheet to each student. Explain that they will build on their experience of conducting a quick life cycle analysis for the paper bag by doing an in-depth LCA of another everyday consumer product: a t-shirt.

3. Students should follow the directions on the Worksheet to complete LCA of their t-shirt. For each life cycle stage:

   a. Students conduct guided research, accessing specific articles and/or videos.
   
   b. Students then use their own data (from the t-shirt they brought in, or from their own experiences and habits) to describe the social and environmental impact of the t-shirt in that stage.
   
   c. They will then describe at least one idea for improvement that could lessen that impact.

Students should work together in their groups to access all of the resources for each life cycle stage and collaborate when discussing answers. However, every student should complete his or her own Worksheet and use the t-shirt brought from home or provided by the teacher. So, some answers will be different within a particular group.

4. Each stage should take approximately 20-30 minutes to complete. Provide students with a time check and let them know when they should switch to the next step.

5. Once all stations are complete, explain the final question on the Student Worksheet, which asks students to write an action plan based on their ideas for improvement. Give students time to write this plan in their groups collaboratively.

Discussion questions

1. Which stage of your t-shirt’s life cycle do you believe had the greatest environmental impact overall?

   Answers will vary. Some students may say that the materials stage has the greatest impact because of the amount of arable land and water required to grow natural fibers, or the plastic and energy required to create synthetic ones. Other students may note the growing scientific concern over microplastic fibers during washing and argue that usage is the stage with the largest ecological impact.
2. Which stage of your t-shirt’s life cycle had the greatest social impact overall?
   
   Answers will vary. Students will likely focus on the manufacturing stage, as most shirts are made in developing countries with low minimum wages and often difficult working conditions. However, some students may note that this provides job opportunities for those who need them – these students may focus more on the disposal stage and the impact of the massive shipments of donated clothes from the U.S. to parts of sub-Saharan Africa, which can disrupt the local economy by flooding the market.

3. Could we assign a monetary cost to these environmental and social impacts? Explain.
   
   Right now, most items with lower environmental and social costs tend to have higher monetary costs because they require higher quality materials or more expensive labor. So it would be difficult to flip that paradigm, although regulations (laws, fines) may help discourage products that have an especially high impact on the Earth. When consumers are more aware of the impacts of a product, though, some may be willing to pay more money for a product that has a smaller footprint.

4. Would you be more likely to buy a product that had a smaller environmental impact over another one? Why or why not?
   
   Answers will vary.

5. When and how does a consumer have the most power to change the t-shirt’s impact? What are some of these possible changes?
   
   Answers will vary. Students might argue that usage is the best place to reduce impact, since that is the stage where the consumer is in possession of the item and can decide when and how to launder it, as well as how long to wear it before disposal. Others may note that when you buy a t-shirt, you have the power to affect both materials and manufacturing, since you can select the fabric and the country of origin, as well as purchase from companies with sustainable and socially responsible practices.

6. Based on your research, what would be the “perfect” t-shirt? How would it be made, shipped, used, and disposed of?
   
   Answers will vary. You may wish to have each group briefly share its action plan for improvement. Students should combine the ideas shared to come up with an “ideal” t-shirt. It is likely that some groups did the same stage for their action plan and may disagree with each other. You can discuss with students why that is the case and provide them with opportunities to defend their action plan with notes from their research. If no group chose a particular stage to improve upon, briefly come up with some potential suggestions as a class and jot them down on the board.

7. Why do you think companies don’t make the “perfect” t-shirt? What factors are stopping us from creating clothing with the smallest possible impact?
   
   Cost is a major prohibitive factor. Companies must be profitable, and so they tend to go for the cheapest options. If the company pays more for higher quality materials or for better wages for its workers, then it will pass these additional costs on to the consumer. Many people cannot afford to buy more expensive clothing. There is also an awareness factor – consumers are not always educated about the ways their purchases impact the Earth and other human beings’ lives around the world, so they do not see the point of changing their buying habits. Finally, all may not agree on what constitutes the “perfect” t-shirt. For example, some people may say that we should save our valuable crop land for growing food by avoiding cotton clothing, while others would argue that synthetic fibers have a major impact on the world’s bodies of water and we should avoid them instead.
assessment

Assess students’ action plans for clarity and creativity, as well as incorporation of the research findings.

follow-up activities

1. Have students send their LCA of the t-shirt to their favorite clothing store. They can explain their concerns and interests as consumers, and describe what steps the store should take to improve the footprint (social and environmental) of the clothes for sale.

2. Students create an LCA for products that the school or district uses, such as desks, carpets, or textbooks. They can identify ways to decrease the school’s impact and share it with the principal or school board.

3. Students research other everyday items, besides t-shirts, to see if anything is being done to lower their impact. For example, Nike uses a program called Nike Grind (https://www.nikegrind.com) to create sports fields out of pieces of old shoes that were otherwise bound for the landfill.
For each stage of your t-shirt's life cycle, first visit the listed websites and examine the information provided. Then fill in the chart columns for pros and cons beside each fact. Next, answer any additional questions in that life cycle stage. In the "Impacts" portion, provide a detailed analysis of the environmental and social effects of your particular t-shirt, using your answers to the questions that came before it. Finally, identify at least one way to decrease the impact in this life cycle stage as an "Idea for Improvement."

**life cycle stage 1: materials**


Video/article: [https://apps.npr.org/tshirt/#/cotton](https://apps.npr.org/tshirt/#/cotton)

<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rayon is a natural fiber harvested from bamboo forests and refined using chemicals in factories.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Synthetic fibers like polyester and nylon make up over half of the global market for fabric.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton, which is the most widely used fabric in the world, uses about 2 percent of the Earth's arable land and almost 3 percent of the global water supply.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 90 percent of all cotton crops grown in the United States are genetically modified to be pest-resistant or higher yield.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Look at the tag on your t-shirt to determine what fabric(s) it is made of and record them here, with percentages:

Imprints of My Shirt: ____________________________

______________________________

______________________________

______________________________

______________________________
life cycle stage 2: manufacturing

Video/article: https://apps.npr.org/tshirt/#/people
Podcast/article: http://www.npr.org/sections/money/2013/12/03/247360855/two-sisters-a-small-room-and-the-world-behind-a-t-shirt

<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compared to other countries that make and export large amounts of clothing, Bangladesh has the lowest minimum wage.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Many women in Bangladesh are leaving subsistence farming villages and moving to cities to work in garment factories.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Due to lack of regulation by the government, pollution from factories (such as chemical dyes) often enters the living areas of people in Bangladesh.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In what country was your t-shirt made? ________________________________
Describe any dyes or colorings used in your t-shirt.

______________________________________________________________

What is the minimum wage in that country* for garment workers?

______________________________________________________________

*If it isn't available in this chart of the top 20 apparel-exporting countries, look it up on the internet.

Impacts of My Shirt:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Idea(s) for Improvement:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
life cycle stage 3: distribution

Article: https://www.theguardian.com/environment/2014/nov/02/environmental-impact-of-shipping-goods
Article: https://www.theguardian.com/sustainable-business/2014/aug/01/sustainable-shipping-is-making-waves

<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 90 percent of the world’s exports are shipped by sea.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New regulations will require the world’s freight ships to invest in better fuel or install scrubbers to remove pollution.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Impacts of My Shirt: ____________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Idea(s) for Improvement: ____________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
**life cycle stage 4: usage**


<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newer models of washing machines and dryers tend to be more efficient and use less energy to do laundry.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How often do you (or someone in your family) wash your clothes? ___________ machine loads/week

Do you use hot/warm water, cold water, or a mix? _______________________________________________________

How do you dry a typical t-shirt after washing it? _______________________________________________________

What type of detergent do you use when washing clothes? ____________________________________________________

What type of fabric is your shirt made of? ________________________________________________________________

Impacts of My Shirt: ________________________________________________________________

___________________________________________________________

___________________________________________________________

___________________________________________________________

___________________________________________________________

___________________________________________________________

Idea(s) for Improvement: ________________________________________________________________

___________________________________________________________

___________________________________________________________

___________________________________________________________

___________________________________________________________
life cycle stage 5: disposal

Article: http://www.huffingtonpost.com/entry/these-african-countries-dont-want-your-used-clothing-anymore_us_57cf19bce4b06a74c9f10dd6

<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Fast fashion” is growing rapidly, much more quickly than traditional fashion retailers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The United States exports over 1 billion pounds of used clothing every year, shipping it across the ocean to developing countries.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The East African Community inter-governmental group considered a ban on imported clothing.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How long do you usually own an article of clothing before getting rid of it? __________________________

What do you usually do with your clothing when you don’t want to wear it anymore? __________________________

Impacts of My Shirt: ______________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Idea(s) for Improvement: ____________________________________________________

________________________________________________________________________
action plan

Choose your best Idea for Improvement and identify an action plan to reduce the impact of your t-shirt during that stage of its life cycle. Explain who will be responsible for taking action (individual consumers, governments, companies that sell shirts, non-profit organizations, or any combination). Describe how you expect these actions to reduce the impact of a t-shirt. Be as specific as possible, using details from your research. In addition to identifying the positive effects of your plan, note any possible negative consequences it may have.
Suggested Answers to Student Worksheet

stage 1: materials

<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rayon is a natural fiber harvested from bamboo forests and refined using chemicals in factories.</td>
<td>It’s not made from fossil fuels, unlike synthetic fibers. Bamboo is very fast-growing so it takes relatively little space to grow.</td>
<td>Some chemicals are dangerous to the workers who breathe them in. Often, old-growth forests are cut down to make room for bamboo fields to make rayon. Arable land is sometimes dedicated to rayon instead of food.</td>
</tr>
<tr>
<td>Synthetic fibers like polyester and nylon make up over half of the global market for fabric.</td>
<td>No arable land is dedicated to growing these materials, and they do not require watering as crops do. Consumers may find synthetic fibers to be lighter-weight and better for athletic activities.</td>
<td>Making these fabrics requires plastic which is fossil-fuel based. Melting the plastic into fibers involves energy and water. Also, these synthetic fabrics shed tiny microplastic fibers that can get into waterways and cause harm to ecosystems.</td>
</tr>
<tr>
<td>Cotton, which is the most widely used fabric in the world, uses about 2 percent of the Earth’s arable land and almost 3 percent of the global water supply.</td>
<td>Cotton is a natural fiber that isn’t made from fossil fuels. Unlike synthetics, it doesn’t break down into microplastics in the wash. It’s biodegradable too.</td>
<td>This arable land could be used to grow food for those who are malnourished. Growing cotton diverts water from other sources, such as food crops or drinking water.</td>
</tr>
<tr>
<td>About 90 percent of all cotton crops grown in the United States are genetically modified to be pest-resistant or higher yield.</td>
<td>This produces more cotton per plant and prevents pests from eating the cotton. It could lower the use of pesticides if plant is genetically pest-resistant. It saves money for farmers and thus saves money for consumers in the long run.</td>
<td>Pest-resistant cotton could harm other non-pest insects. Many consumers don’t trust GMOs. Some companies own the rights to certain seeds and charge more money for them.</td>
</tr>
</tbody>
</table>
### stage 2: manufacturing

<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compared to other countries that make and export large amounts of clothing, Bangladesh has the lowest minimum wage.</td>
<td><strong>Bangladesh is a major exporter of garments, which can help its economy. The huge number of factories there can reduce poverty by providing jobs.</strong></td>
<td>It can be difficult for workers to get out of debt or make enough money to save for a future outside of the factory job. It is also energy intensive to ship large quantities of garments for U.S. consumers to and from Bangladesh, increasing the emissions that cause climate change.</td>
</tr>
<tr>
<td>Many women in Bangladesh are leaving subsistence farming villages and moving to cities to work in garment factories.</td>
<td><strong>Women are able to earn more money in the new job than they were before. They are also empowered to work outside the home and support their families, and have more choice about when they get married and have kids.</strong></td>
<td>Cities become crowded and living conditions deteriorate. Working prevents some girls from finishing school, limiting their options later in life. In addition, women have to leave their homes and families (including their kids) to move to cities. Factories can also be dangerous places to work.</td>
</tr>
<tr>
<td>Due to lack of regulation by the government, pollution from factories (such as chemical dyes) often enters the living areas of people in Bangladesh.</td>
<td><strong>This column should be left blank.</strong></td>
<td>This harms the health of people nearby, as well as of factory workers. It also negatively impacts the economy by ruining crops and destroying ecosystems.</td>
</tr>
</tbody>
</table>

### stage 3: distribution

<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 90 percent of the world’s exports are shipped by sea.</td>
<td><strong>It’s more efficient and less polluting than air travel. Thus, it contributes less to climate change than if it were being flown on planes.</strong></td>
<td>This requires significant amounts of fuel. The people who work on the ships often lack safe and healthy working conditions.</td>
</tr>
<tr>
<td>New regulations will require the world’s freight ships to invest in better fuel or install scrubbers to remove pollution.</td>
<td><strong>These decrease the negative health impacts of shipping on workers. It reduces air pollution that causes illness.</strong></td>
<td>The scrubbers are not addressing major greenhouse gases that cause climate change. These higher costs to the company mean higher consumer costs. If shipping by sea becomes more expensive, it could lead to more air freight, which is a bigger polluter.</td>
</tr>
</tbody>
</table>
### stage 4: usage

<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newer models of washing machines and dryers tend to be more efficient and use less energy to do laundry.</td>
<td>People can contribute less to climate change if they upgrade their appliances. This requires no additional work on your part once you have the newer machines. This saves money on your water and electric bills.</td>
<td>Making and buying these new washers and dryers requires energy and labor. These appliances have their own LCA with social and environmental impacts. It also might encourage people to use the laundry machines more often if they think it’s better for the Earth, rather than doing less laundry and/or air-drying their clothes.</td>
</tr>
</tbody>
</table>

### stage 5: distribution

<table>
<thead>
<tr>
<th>Fact</th>
<th>What are some pros of this?</th>
<th>What are some cons of this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Fast fashion” is growing rapidly, much more quickly than traditional fashion retailers.</td>
<td>The clothing is cheaper for consumers. This allows people of all income levels to express themselves according to the latest fashion trends.</td>
<td>Frequent turnover of styles creates lots of excess waste. The clothing doesn’t last very long, so consumers have to buy new clothes more often, which may not be as cheap in the end and means a higher footprint from the previous life cycle stages.</td>
</tr>
<tr>
<td>The United States exports over 1 billion pounds of used clothing every year, shipping it across the ocean to developing countries.</td>
<td>It is better to keep using the clothes than for them to take up landfill space. Sending these clothes overseas allows secondhand stores to get rid of clothes no one will buy. This provides clothing in places where there aren’t as many reliable retailers.</td>
<td>The used clothes are shipped which requires energy, contributing to carbon emissions. Because Americans think they are doing good for the world by donating clothes, they may choose to do that, instead of doing more eco-friendly options, such as keeping their clothes for longer, upcycling them, or swapping with friends/family.</td>
</tr>
<tr>
<td>The East African Community intergovernmental group considered a ban on imported clothing.</td>
<td>People who make clothes locally would be able to compete better if imports were banned. This would mean less shipping of clothes from other countries which requires energy and causes carbon emissions. This ban may encourage pride in local fabrics and artisans.</td>
<td>Many people in these East African nations would lose their jobs reselling clothes. It would be difficult for local retailers or artisans to meet the demand for clothes. The U.S. and other developed countries would have a huge excess of used clothes that they would likely sell to countries outside the EAC instead.</td>
</tr>
</tbody>
</table>