ENVIRONMENTAL LITERACY TEACHER GUIDE SERIES

# Changing Climate

## A Guide for Teaching Climate Change in Grades 3 to 8

NATIONAL GEOGRAPHIC

# 6 Solutions for a Changing Climate

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**"We cannot make the mistake of thinking that just because scientists tend to focus on the 10 percent they don't know, the 90 percent they do know isn't already a call to action."**
*Friedman (2008)*

Climate change is the preeminent socio-ecological issue of our time. Every person will need to understand climate change in order to participate in decision-making that will affect our future and our way of life. Climate models predict that continued warming will have an impact on energy, water, transportation, agriculture, health, and ecosystems in the following decades (IPCC 2007). The solutions we choose to address these problems will impact our economy, our city planning, and our everyday way of life and consumer practices.

Understanding the science behind climate change will be critical to the citizens who will be making choices for their own lives or empower their political leaders to make choices on behalf of their communities. Encouraging a new generation of students to study climate change, especially solutions, is important so that their understanding of the topic continues to grow.

As we have seen in the preceding chapters, there is consensus in the scientific community that climate change is real and that humans play a key role in accelerating the process. Likewise, we are capable of slowing it down. Then, why have we done so little about it?

A 2010 study by the Yale Project on Climate Change Communication titled "Global Warming's Six Americas" shows that 39 percent of American adults are either "alarmed or concerned" about climate change while 29 percent remain doubtful or dismissive (Leiserowitz

| GRADE | STANDARD | EEI UNIT |
|---|---|---|
| Grade 3 | 3.1.2<br>3.3.3<br>3.4.1-2<br>3.5.1-3 | The Geography of Where We Live<br><br><br>California's Economy—Natural Choices |
| Grade 4 | 4.1.3-5<br>4.4.6<br>4.5.3 | Reflections of Where We Live |
| Grade 5 | 5.7.3 | |
| Grade 6 | 6.6.a<br>6.6.b | Energy: It's Not All the Same to You!<br>Energy and Material Resources: Renewable or Not? |
| Grade 7 | | |
| Grade 8 | 8.3.6<br>8.12.5 | <br>Industrialization, Urbanization, & Conservation |

et al. 2010). Why is the alarmed and concerned 39 percent of the population not acting on their concerns? How can we bridge the gap between concern and action? Is education the answer?

A similar report titled Climate Change in the American Mind found that, even during the economic downturn, 90 percent of Americans think the United States should act to reduce climate change, even when there is a financial cost involved (Leiserowitz et al. 2010). Furthermore, more than 73 percent believe that climate change will harm Americans within the next 50 years, and 47 percent believe the harm is already being done or will be, within the next 10 years. Still, only a few alarmed Americans (8 percent) have actually contacted their elected officials about the issue within the last year.

Why are values not aligning with action? According to a report from the American Psychological Association (APA 2010), there are many emotional barriers that stand in the way of actions that would help solve the problem. Climate change is about large-scale systems over long periods, with uncertain outcomes. Research shows that while scientists generally are more concerned with long-term global

## CHAPTER OVERVIEW

**Taking action against climate change may seem daunting to some citizens, especially our students. Given a better understanding of climate change, students may develop a sense of empowerment and belief that even the smallest of actions can aggregate to have large-scale change.**

**This chapter discusses four types of solutions necessary to take action against climate change. Mitigation is one solution that focuses on reducing the causes of climate change. For example, regulating carbon dioxide emissions from vehicles is one mitigation strategy. Mitigation strategies are made possible through a second type of solution—innovation. With new innovative technologies, we can change the way we consume fossils fuels and the way we alter our landscape. New innovations can be factored into mitigation plans. Action on the part of people is a third solution that influences both mitigation and innovation. When people—as voters and consumers—place pressure on business and political leaders, those leaders and business owners will be more likely to listen to the needs of people in order to stay in office or stay in business. A last solution to climate change is to prepare for the changes already underway. Our communities are already faced with changes, and we will need adaptation strategies in order to cope with them.**

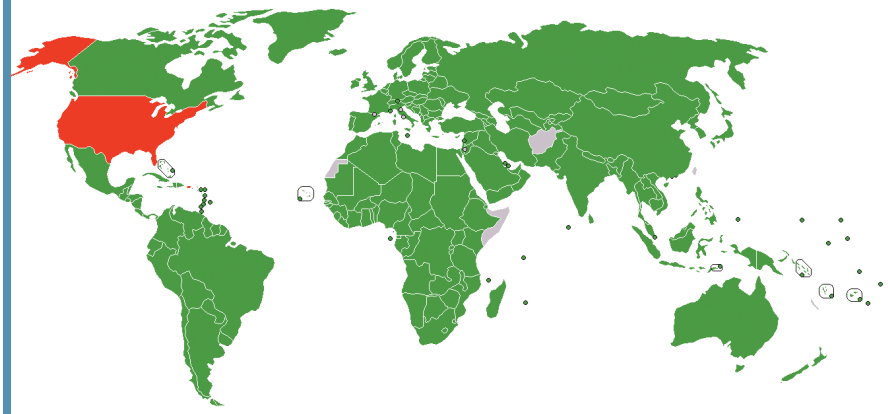
problems, the general public tends to be more concerned with immediate, local issues. Sterman and Booth Sweeney (2002) found that large time scales and the large scope of the climate crisis "dwarfs normal human concern" (p. 2). Time is a relative factor, and youth, in particular, may view a "long" time as a month or year, as opposed to a decade or longer.

Public perception is also a key component. People may have other worthy goals and aspirations or be worried about threats and problems that seem more pressing in time and space, such as pandemics, war, or an economic crisis, which draw from their time, effort, and resources. They may feel overwhelmed by the problem of climate change or believe that solutions outside of human control will address it. As a result, people may fall into a place of passivity, inaction, and disempowerment. So while people may believe they should act, they may also believe their actions have no real influence. In many cases, the very same individual may be engaged in actions that show immediate positive impact on local environmental issues because results are more immediate and tangible.

A special burden is placed on educators with respect to climate change education, especially educators of science and social studies. Teachers must help students make the connection between climate change at the global level with impacts at the local level and help students see that there are real actions they can take in their community to help—actions that when aggregated on the large-scale will have profound impacts.

In this chapter we talk about the many solutions that are being discussed, developed, and implemented by many governments, organizations, enterprises, and individuals around the globe. They are concentrated in four key areas:

**KYOTO PROTOCOL PARTICIPANTS JUNE 2009**



**Countries that ratified the Kyoto Protocol as of June 2009 are shown in green. Grey indicates countries that are undecided, and red indicates countries that have signed, but with no intention to ratify.**

- Mitigation: What laws and regulations are being considered to slow down the pace of climate change?
- Innovation: What exciting initiatives or discoveries are underway for new technologies or new sources of energy?
- Adaptation: As the effects of climate change reach our doors, how will people adapt to a new reality on a changing planet?
- Action: What can your school, your students, and your community do to make a difference?

## Mitigation

For climate, mitigation refers to actions that decrease greenhouse gas emissions or increase their capture. Examples of climate mitigation include establishing new standards to make vehicles and appliances more efficient, switching from fossil fuels to renewable energy sources for generating electricity, and setting a limit on the total amount of emissions industries can put into the air. Planting new trees and protecting existing forests from being cut down are also examples of mitigation.

**The Earth Summit and Kyoto Protocol.** More than 15 years ago, the UN Framework Convention on Climate Change (UNFCCC), an international treaty ratified by 193 countries, entered into effect. The treaty was the outcome of the UN Earth Summit, held in Rio de Janeiro in June of 1992 with the goal of

### Definition of Mitigation

The IPCC defines ***mitigation*** as "technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG [greenhouse gas] emissions and enhance sinks."
*IPCC AR4, 2007, p. 818*

considering climate change mitigation and adaptation strategies and policies. More recently, several nations agreed on an addition to the treaty, which we know today as the Kyoto Protocol. The Kyoto Protocol, which is more widely known today than the UNFCCC, included updated and significantly more powerful measures for mitigation of climate change.

While the Rio de Janeiro Convention encouraged industrialized countries to reduce their greenhouse gas (GHG) emissions, the Kyoto Protocol actually committed countries to targets to achieve reduction goals. The UNFCCC target for 37 industrialized countries and the European Union was set to an average reduction of 5.2 percent from 1990 levels by the year 2012. The protocol was adopted in Kyoto, Japan, in December 1997. To date, 184 countries have ratified the the Kyoto Protocol, but the United States is not one of them.

Nonetheless, within the United States, an impressive move on the part of individual states and cities has shown increased support for the Kyoto Protocol measures and goals. The U.S. Conference of Mayors' Climate Protection Agreement has the support of 1,044 mayors, each pledging to reduce his or her city's carbon emissions below the 1990 levels (U.S. Conference of Mayors 2009). Regional initiatives in the United States include the Regional Greenhouse Gas Initiative (RGGI), comprised by states in the Northeast and Mid-Atlantic regions of the country (RGGI 2010). A similar effort is taking place on the West Coast, through the Western Climate Initiative (WCI). California, one of the key partner states of the WCI, has taken the lead in mitigation efforts (WCI 2010). In 2006, California's former governor Arnold Schwarzenegger signed the Global Warming Solutions Act (California Energy Commission 2008). In the following pages we present a case study showcasing California's strict emissions policies and practices.

**Copenhagen Climate Change Conference, 2009.** The 15th meeting of representatives of the UNFCCC took place in Denmark in 2009. The Copenhagen Accord, the international agreement that was developed during that meeting, included the long-term goal of limiting the maximum global average temperature increase to no more than 2°C (3.6°F) above pre-industrial levels. There was, however, no agreement on how to accomplish this goal in practical terms. Participants did make progress on establishing the infrastructure needed for effective cooperation and in narrowing options that could be followed, but the meeting was also marked by controversy, especially over the divide between developed and developing countries.

Another issue that received much attention in Copenhagen was the emission trading approach known as **cap-and-trade.** The cap-and-trade approach works in two levels: The cap limits the amount of greenhouse gases a polluter can emit. Companies will need to acquire emission permits, which allow them to release a certain quantity of GHGs into the atmosphere. The trade part allows for companies effective in reducing their emissions to sell their permits to companies that need additions to their own permits. This system controls the overall emissions from companies, while allowing effective GHG reducers to profit from the trade—an incentive for GHG polluters to reduce emissions and invest in clean energy sources.

One of the main issues with the cap-and-trade system is determining the "starting" level of emission permits given to companies. There is some concern about the possibility that some governments might "grandfather" or give away initial permits to polluters based on their current level of emissions. Not only could this potentially "reward" polluters, but also it could also increase the inequity between the rich countries and big companies and the smaller players. Some of the alternatives being proposed include governments auctioning the initial permits and recycling the revenue back into the economy to invest in green (or more environmentally friendly) technology to offset energy price increases and to facilitate a smooth transition to a low-carbon economy (Leonard 2010).

## Tips for Teaching

The United States has signed but not ratified the Kyoto Protocol. The signature alone does not bind a country to the protocol mandates unless it ratifies the protocol. Students might find this difficult to understand. This is a great opportunity for a class discussion and reflection. Ask your students: Why do you think our country leaders at the time decided not to ratify the protocol? What are the consequences of this? What would have happened if we had actually ratified the protocol?

Case Study

# What's So Cool About California?

California is at the helm of climate-change mitigation initiatives. The government of the state of California decided the debate on climate change was over by passing the Global Warming Solutions Act of 2006, an environmental law, signed by former Governor Arnold Schwarzenegger on September 27 of that year. The bill established a timetable and the measures necessary to bring California closer to the goals of the Kyoto Protocol. This bill was the first approved legislation by any U.S. state to cap emissions across all economic sectors. California, where one out of eight Americans live, now requires major industrial producers to reduce emissions 25 percent by 2020. In other words, California has to cut its annual release of carbon dioxide by 174 million metric tons. The reductions are so significant that it would take a forest twice the size of New Jersey to process all those emissions (California Energy Commission 2008).

In order to achieve these goals, California has set a series of key strategies in six areas. The strategies are taken from the California's Climate Plan Fact Sheet (California Energy Commission, 2008). Visit http://www.climatechange.ca.gov/ to see complete versions of each strategy and learn more about California's climate plan.


**Santa Rosa CityBus uses diesel-electric hybrid buses.**

**Solar panels transform light energy into forms of energy we can use.**

**Cap-and-Trade Program.** By setting a limit on the quantity of greenhouse gases emitted, a well-designed cap-and-trade program will complement other measures in California. The program provides a firm cap on 85 percent of the state's greenhouse-gas emissions.

**Transportation.** California will reduce 30 percent of its vehicle greenhouse-gas emissions by 2016. By 2020, California will decrease by 10 percent carbon-intensive vehicle fuels through its low-carbon fuel standard. Other transportation measures include using more efficient delivery trucks, heavy-duty trucks, and goods movement.

**Electricity and Energy.** California continues to improve appliance and building standards. By 2020, a total of 33 percent of the energy used in the state will come from renewable sources. Other efforts include the following programs: Million Solar Roofs; Solar Hot Water Heating; Green Buildings; and water efficiency.

**High Global Warming Potential Gases.** In order to minimize gases that potentially influence global warming, the state is making an effort to capture high global-warming-potential gases already in use. California is also reducing future impact by encouraging the use of leak-resistant equipment, putting restrictions upon use of products that release these gases, and imposing additional fees.

A former industrial site is replanted with trees.

**Forestry.** California is making an effort to preserve forest sequestration by minimizing the cutting down of forested areas so the protected trees will continue to take up, or sequester, carbon dioxide from the atmosphere. Additionally, California is reducing atmospheric carbon dioxide by encouraging forestry projects in which new trees are planted.

**Agriculture.** The agriculture industry in California contributes to production of carbon-dioxide emissions, as well as the release of other GHGs. In order to reduce the impact of agriculture on climate change, California is promoting the use of more efficient agricultural equipment and by minimizing fuel and water use through transportation and energy measures.

**Changing Energy Portfolio.** In early 2011, the state of California voted to increase its Renewable Portfolio Standard (RPS) to 33 percent by 2020. This legislation means that renewable energies must comprise 33 percent of utility companies' retail sales by that time.

## Explore More

Cool California is a great resource created as part of the efforts under the Global Warming Solutions Act. This website, created through a partnership between government, universities, and nongovernmental organizations, offers a toolkit for schools, as well as success stories that can inspire your students to act in their school and community (California Air Resources Board 2010). Examples include:

- The city of San Diego reduced its GHG emissions by 3,814,000 tons between 1999 and 2003. Between 2003 and 2010, the city had a target to reduce an additional 5,488,000 tons to accomplish its goal (California Air Resources Board). Explore more at http://www.coolcalifornia.org/case-study/city-of-san-diego.
- Solar capacity in the city of Santa Monica has doubled since the launch of its solar program (Solar Santa Monica). To date, there are 139 grid-connected solar projects in the city, representing 926 kilowatts of solar capacity. Explore more at www.coolcalifornia.org/case-study/sustainable-santa-monica.
- In 2001, Marin County became the first local government to calculate its ecological footprint. Marin County has set a target to reduce GHG emissions 15—20 percent below 1990 levels by the year 2020 for internal government and 15 percent countywide. Explore more at www.coolcalifornia.org/case-study/reducing-residents-ecological-footprint.
- Reforest California is a million-tree challenge to help raise funds to replant trees in Southern California State Parks that have been impacted by wildfires (The Coca Cola Company 2009). Explore more at www.reforestcalifornia.com.

Pictures of Practice

# Our Different Carbon Footprints

Students often have trouble identifying indirect actions that result in a large carbon footprint. They identify cars as major producers of $CO_2$, but only think of it in terms of human transportation, as opposed to the transportation of goods. Students also have a hard time conceptualizing the manufacturing of goods such as clothing, in which the raw materials are transported to one country where the fabric is created, another country where the garments are assembled, and still another country where they are sold. When looking at these hidden contributors to climate change, it may be best to give examples that students are familiar with. Groceries such as apples, tomatoes, and milk are good examples of items students come into contact with at local stores. By using real-life examples, students can understand that their carbon footprint branches out not only to what they do, but also to what they chose to buy, and how and where it is produced. It is also important to have your students look at the big picture, and this often means having them compare the carbon footprint of a typical person in the United States to someone in a developing country. Showing examples of different ways that the same task is done can help students understand how some countries contribute more to climate change than others.

**Students: Grade 6**

**Location: South Gate, California (a coastal community)**

**Goal of Video: The purpose of watching this video is to see students discuss what a carbon footprint is.**

## Classroom Context

Ms. Walker taught a two-week unit on climate change and concluded the unit with lessons on carbon footprints. During her lessons, students began to compare an American carbon footprint with the footprint of people in other countries. This video represents students' ideas after several lessons about climate change.

## Video Analysis

This video begins with Ms. Walker asking her class what *carbon footprint* means. A carbon footprint is determined by one's daily practices and the amount of $CO_2$ emitted into the air because of those practices. Carbon footprints in industrialized countries tend to be much greater than those in developing countries because of the use of fossil fuels and consumer practices. To start the discussion, Ms. Walker uses a common grocery item, milk, to demonstrate that many items students consume are indirectly linked to carbon dioxide through production and transportation. This point was driven home in the class when students began to discuss how their grandparents (many located in Mexico and Central and South American countries) had a smaller carbon footprint because they did things such as walk to the market, eat locally-grown produce, and wash their clothes by hand. In the end, Alan's post interview shows he has a good handle on the definition of carbon footprint.

## Reflect

### What key concepts would you teach on the carbon footprint? Why?

Ms. Walker was able to help her students understand that consumers contribute to carbon footprints. She was also able to drive the idea home that different countries often have different carbon footprints because so many of her students had firsthand experience with families (their own and others) from another country. What concepts do you think are most important to teach about the carbon footprint? How would you address the issue of unequal carbon footprints between industrialized and developing countries?

Pictures of Practice

# Climate Action

Once students know what climate change is and what causes it, the next step is helping them to understand practical ways they can help reduce their own contributions to it. This can be difficult, because often students are told about car emissions and industrial emissions, both of which seem out of their control. They also may believe that reducing emissions to below previous levels would mean going back to "simpler times." Ideas such as using more candles or washing clothes by hand may sound good in theory but are not practical solutions for everyday life. It is important that students understand that other actions, such as reducing consumption of disposable items, increasing recycling, and unplugging electronics when they are not being used can go a long way in contributing to an overall decrease in carbon emissions and climate change.

**Students: Grade 6**

**Location: South Gate, California (a coastal community)**

**Goal of Video: The purpose of watching this video is to see students discuss "the old-fashioned way" as a solution to climate change.**

## Classroom Context

Previously, Ms. Walker had talked with students about their carbon footprints and identified that students in America have a larger carbon footprint than their peers in developing countries. The discussion of carbon footprints led to a discussion of actions to reduce carbon emissions.

## Video Analysis

In this video, you will see students brainstorm what they can do to help reduce their carbon footprints and slow down climate change. Interestingly, students propose that people go back to "the old-fashioned way of doing things." For example, students propose washing clothes by hand and milking cows by hand. While these solutions correctly identify industry and electrical appliances as contributors to climate, in reality these solutions are not practical ways to solve our climate problems. Ms. Walker asks her students if they are willing to do things the old-fashioned way or willing to pay more for others to do these tasks. Ms. Walker surveys the class on who would be willing to do that, and many students agree. She then goes on to ask what milking cows by hand would do to the cost of milk, and students concede that it would go up. Students then agree that they would not want to spend more money for milk, and Ms. Walker ends with the question: "How are we going to solve our carbon dioxide problem?"

## Reflect

### How would you respond to ideas about the old-fashioned way?

Notice that students' previous discussion about carbon footprints in developing countries influenced their ideas about how to solve climate change. They suggested going back to old-fashioned methods such as hand-washing clothes and milking cows by hand because these tasks are done by family members in developing countries. How would you respond to these students' ideas? What climate actions would you focus on in your instruction?

## Alternative Energy

When learning about mitigation initiatives, community leaders, the general public, and especially educators, might ask, "what can we do?" The answer? "Turn to renewable resources!" While nonrenewable resources, such as coal and petroleum, will eventually be used up, renewable resources can be regenerated. Virtually as long as there is Earth as we know it, there will be wind, water, and sun. Some might suggest that one solution is to use renewable, or clean, energies; but most would agree that we need to learn to use energy wisely. However, just exactly what are these clean options? This section will review the benefits and possible negative impacts of renewable alternatives to the burning of fossil fuels for energy.

**Hydroelectricity.** **Hydroelectricity** is also known as hydropower. This energy is generated by water movement. It is ultimately derived from sunlight, which drives the water cycle, and gravity, which causes water to flow downward. A hydropower plant uses the energy of motion in flowing water to rotate a turbine, which activates a generator to produce electricity. In creating the dams that produce hydroelectric power, habitats can be destroyed, and animals can be driven to the brink of extinction as flows are changed dramatically. (The Environmental Education Exchange 2004).

**Wind Energy.** The harvesting of wind energy occurs as the motion of the wind is used to spin wind turbines, which transforms mechanical energy into electric energy. This process produces no solid waste, hazardous waste, water pollution, air pollution, or greenhouse gases. However, the spinning blades of the turbines can kill or injure migrating birds passing by, and there are visual and noise considerations.

**Biomass and Bioenergy.** Bioenergy is energy made available from **biomass.** Biomass is material from biological sources and includes plant matter such as trees, grasses, and agricultural crops, as well as solid waste, animal waste, and food-processing wastes. Biogas, the gas from the decomposition of organic matter, is a form of biomass. Methane is a common form of biogas collected from landfills. Other than biogas from landfills, the process of creating biomass and bioenergy tends to be water intensive, and there are concerns about food crops being diverted to biogas production, leaving many people hungry (The Environmental Education Exchange 2004).

**Geothermal.** **Geothermal power** is derived from Earth's internal geological processes, such as volcanic activity. Geothermal power can be a cost effective and **sustainable** source of electricity but in the past has been limited to areas near tectonic plate boundaries. Additionally, there is some concern that the drilling for geothermal power can impact an area in strange and possibly dangerous ways as it changes local geological and tectonic forces.

**Passive and Active Solar Energy.** Solar energy is the energy that comes from the sun. Use of solar energy might be passive or active. A passive use of this energy is orienting a building to take advantage of sunlight. For example, sunrooms in a home use passive solar energy to warm them. Active solar energy involves the use of electrical and/or mechanical equipment. Two types of active solar energy are **photovoltaics** and solar thermal collectors.

Photovoltaic energy (PV) is created when sunlight is converted directly into electrical energy. PV technology can be used to provide energy on almost any scale, from calculators to a single private home to large-scale commercial power plants. Active solar energy, such as photovoltaic, tends to be very expensive, and it still is not as efficient in capturing the sun's energy as would be ideal (The Environmental Education Exchange

2004). Solar thermal is another active-solar option, in which sunlight is collected and concentrated to become heat, which may be used to warm a liquid or to warm a space.

**Ocean Energy.** Ocean energy is a clean, renewable source of energy with no by-products and a relatively consistent source. Think about how reliable energy would be if it was generated at every high and low tide or using the power of our ocean currents? However, environmentalists are concerned about the impact on marine animals and the environment. New construction, whether offshore or coastal, could change animals' habitats and migration patterns, similar to the impact of dams on salmon. Furthermore, the energy must be transferred to the preexisting electrical grid. The farther the energy is transferred, the more energy is lost by the time it reaches its destination.

**Nuclear.** Energy resulting from fission, or the splitting of uranium atoms, is known as nuclear energy. Even though uranium is a nonrenewable source of energy—there is a finite amount of it in our planet—nuclear energy is considered by many to be a clean source of energy, because virtually no greenhouse gases are being released. Nonetheless, many argue against the use of this type of energy because of safety concerns related to radioactive waste that is harmful to humans.

## Teaching Tip

What do students know about where their energy comes from? Do they know the ultimate source of energy for the electricity they receive in their homes? How far can they trace back their energy?

- Students may struggle with understanding energy transformations.
- Students often confuse electricity with energy. They do not necessarily understand that electricity is a secondary form of energy, obtained through a primary source.
- Power plants (especially what goes on in a power plant and how the "power" gets to homes) can be a mystery to students.
- Students tend to perceive electricity as a clean source of energy, because they cannot see the pollution being released at the power plant.

Take **biofuels** as an example. How might energy transformations get confusing and complicated for students when discussing biofuels? Why are biofuels being considered? (In the simplest form, plants are net zero for carbon emissions.) However, it takes energy to make energy, and biofuel production actually uses more energy in the process than we get out of the fuels.

**Geoengineering: Where Mitigation Meets Innovation.** Also known as climate engineering, this concept groups a set of practices that involve large-scale engineering of our environment to mitigate the effects of changes in atmospheric chemistry (National Academy of Sciences 1992). One controversial example of this is iron fertilization of the oceans—adding large amounts of iron to the ocean waters to feed the algae that absorbs carbon dioxide. This is similar in intention to reforestation, as we are increasing the capacity of our oceans to sequester greenhouse gases. The controversial nature of this practice is related to the unknown possible impact a sudden increase in algae population might have in the ocean's ecosystem.

Case Study

# Solar Energy

Adapted from *Powering Our Future: Renewable Energy Education* (The Environmental Education Exchange 2004)

The sun is the ultimate source of energy on Earth. The sun drives water cycling and wind and weather patterns and is the source of energy for all life on Earth. This means that solar energy is the ultimate source of many other energy sources on Earth, including fossil fuels, biomass, and wind. Of course, the term *solar energy* is commonly used to refer to the forms of energy that we obtain more directly from the sun. Sunlight, also called solar radiation, is the most inexhaustible, renewable source of energy known to humankind. The amount of energy that the sun radiates onto Earth every hour is greater than the amount of energy used worldwide in a full year.

In general, the ways we use the sun's energy can be described as passive or active. Passive solar energy involves using the sun's energy with no or minimal mechanical or electrical devices. Passive solar energy can involve using the sun's energy as a light or a heat source. Lighting buildings with natural light is called daylighting. Passive applications of solar thermal energy, or the heat energy of the sun, include heating water and buildings. Using passive solar techniques for heating is very efficient. Heat energy is considered low-quality energy. Electricity, for instance, is a high-quality energy because it is very concentrated. When electricity is converted to another form, heat, a low-quality energy, is given off. Using electric heat, for instance, is inefficient. You are using a high-quality energy source for a low-quality need. A lot of energy is "wasted." Passive thermal systems prevent this type of waste. This is because the energy is used in the same form (heat) rather than converted from one form to another.

Active solar energy is any type of solar application that uses electrical and/or mechanical equipment. Solar thermal power plants are an example of active solar thermal application. At such plants, sometimes called "power towers," the sun's rays are concentrated as a heat source to boil water or another fluid, producing steam. The steam is used to rotate a turbine, activating a generator that produces electricity. This is very different from photovoltaic energy.

**British Motor Car Distributors in San Francisco, California, installed solar panels on their carports to supply the dealership with enough power to meet its daily energy needs.**

Photovoltaic, or PV, energy is a form of active solar power that is created when light energy from the sun is converted on an atomic level directly into electrical energy. Photovoltaic technology actually produces electricity with no moving parts and without burning fuel. PV technology is based on an interesting fact of physics and chemistry that light energy can stimulate an electrical current in certain materials or semiconductors.

The basic building block of all photovoltaic systems is the photovoltaic cell. The PV cell is where the energy conversion process takes place. Although other materials can be used, today almost all photovoltaic cells are made of a very thin wafer of crystalline silicon. Silicon is the second most-abundant element in Earth's crust (the first being oxygen). The photovoltaic effect occurs when sunlight strikes silicon (or certain other semiconductors) and the light energy is absorbed, energizing electrons so that they become free from their atoms and move through the material. A PV cell is designed to enhance this natural process. By connecting the cell to a circuit along which the electrons can flow, we can harness the electricity and put it to use.

**More than 3,300 solar panels have been erected on a vacant five acres at NASA's Kennedy Space Center in Florida to create the Solar Energy Center.**

Sunlight is comprised of a range of wavelengths. It is light energy, per se, that causes the photovoltaic effect. The heat energy in sunlight is central to solar thermal applications, like passive solar buildings and water heaters, but plays no role whatsoever in photovoltaics.

The performance of a PV cell is measured in terms of its efficiency at converting light energy into electricity. Some types of PV cells available today reach efficiencies of about 15 percent. *Efficiency* refers to the amount of energy that is actually obtained from a process, as much energy is lost as heat when it is converted into electricity or other forms. As per the laws of physics, no conversion of energy can be 100 percent efficient. For comparison, use of fossil fuels to create electricity is about 30 percent efficient; that is, 70 percent of the energy is lost during conversion and transport.

Photovoltaic power has proven extremely reliable. A photovoltaic array has no mechanical (or moving) parts, and PV equipment can operate reliably for long periods with virtually no maintenance. No fuel or input is required other than sunlight. Because sunlight is free, there are no fuel costs (and no unpredictable variations in fuel costs over time). The cost of a PV system is almost entirely paid up front for equipment and installation, and operating costs are quite minimal. Developing PV plants, however, can be very expensive.

Producing PV cells does result in some pollution. However, in contrast to electricity generated by conventional energy sources, photovoltaic electricity does not involve the release of greenhouse gases and other air pollutants, production of toxic or radioactive waste, large PV projects can cover thousands of acres, which disrupts the natural ecosystem. The downside of using photovoltaic power is the high cost of the technology and the habitat loss when solar plants are built in pristine habitats. Of course, solar units cannot generate power at night and are less efficient during cloudy weather. Also the storage of energy from PV plants can be a challenge. Although solar panels are expensive, the price of PVs is decreasing and will continue to do so as the technology improves and more homes and businesses purchase it.

Student Thinking

# Renewable Resources

Often, students are introduced to renewable energy resources as a "no harm" energy alternative to traditional fossil fuels such as oil, coal, and natural gas. While students are interested in learning about renewable energy, they often have misconceptions that may hinder their understanding of these resources. They may also be confused about how to determine whether an energy source is renewable or not.

| | Common Student Ideas | Scientific Concept |
|---|---|---|
| **Impact on Environment** | Renewable energy resources have no negative impacts on the environment. | Harnessing renewable resources can endanger wildlife and disrupt ecosystems. |
| **Biofuels** | It is only the heat produced by burning biomass that can be used for energy (such as burning firewood). | While biomass can be burned to create heat for cooking and heating, biogas can also be used as organic matter decomposes, creating natural gases such as methane. Biogas from landfills is a viable option, but scientists are worried that biofuels from crops is too labor-intensive and may divert food and water from food-crop production. |
| **Efficiency** | Renewable energy resources are 100 percent efficient. | No energy resources are 100 percent efficient. In fact, some renewable energy resources, such as solar power from PV cells (see **Case Study: Solar Energy,** page 98), are less efficient than fossil fuels. |
| **Nuclear Energy** | Nuclear energy is renewable because it is considered a "clean" form of energy. | Nuclear energy emits virtually no greenhouse gases, so it is often lumped together with renewable resources. However, there is a finite amount of uranium on the planet, and therefore, it is not renewable. |

## Ask Your Students

1. What kind of impact do renewable energy resources have on the environment?
2. How is biomass such as wood, agricultural crops, and so on, used to create energy? Are there any drawbacks to using biofuels?
3. How efficient are renewable energy resources?
4. Is nuclear energy renewable?

## Adaptation

According to the latest assessment by the Intergovernmental Panel on Climate Change, very specific information is currently available across a wide range of sectors concerning the nature of future impacts of climate change. The following is an overview of some of the most important concerns.

**Effects of Climate Change.**

Scientific evidence shows that climate change will likely have significant costs, and the problem will continue to grow over time (IPCC 2007). Scientists have observed and recorded many changes on our planet that are caused by global climate change. All of these changes impact plants and animals in the natural world, but because humans are also part of the natural systems, we are vulnerable to the negative effects of climate change as well. Many of the effects predicted by scientists in the recent past as a result of global climate change are now occurring: loss of sea ice, accelerated sea-level rise, and longer, more intense heat waves.

There is high confidence among the scientific community that global temperatures will continue to rise for decades to come, largely due to greenhouse gases produced by human activities. The Intergovernmental Panel on Climate Change (IPCC) predicts a temperature rise of 2.5 to 11.5 degrees Fahrenheit (1.4 to 6.4 degrees Celsius) over the next century.

According to the IPCC, climate change effects will vary in individual regions over time, and the ability of different groups of society and environmental systems to mitigate and adapt to change will depend upon many socio-economic, political, and natural factors.

**Island nations may be affected most by climate change. These nations may need to reserve money to adapt as their coastlines change.**

**Adapting to Climate Change Effects.** There are many actions we can take to adapt to climate change, ranging from technological strategies (e.g., sea defenses) to behavioral changes (e.g., altered food and recreational choices) to the way we manage our food systems (e.g., altered farm practices) and policies we pass at the local to national levels (e.g., planning regulations).

The following are adaptation strategies provided by the Environmental Protection Agency (EPA 2010). More information about these strategies can be found directly on the EPA website: www.epa.gov/climatechange/effects/adaptation.html.

**Human Health**

- Prevent an increase of diseases in a world of climate change by providing sufficient public-health resources.
- Provide alerts to the public regarding dangerous weather or heat advisories and information about actions to take in excessive weather and heat conditions.
- Develop systems for storing grain and plans for emergency feeding stations.

**As sea level rises, we will need to plan for repairs and replacement of existing coastal structures.**

### Coastal Areas and Sea Level Rise

- Develop maps and plans for areas requiring shore protection to determine areas with the greatest need of help. Determine the most sustainable action for shore protection to reduce negative environmental consequences.
- Map wetland areas in danger of negative consequences from sea-level rise, and develop plans for managing these areas.
- Protect water supplies that may be contaminated by saltwater.

### Agriculture and Forestry

- Adapt to changing growing conditions by 1) altering planting dates, 2) altering crop selection for new climate conditions, and 3) breeding new species tolerant to changes in conditions.

### Water Resources

- Promote conservation and change water demand by human communities
- Improve water-use efficiency.
- Develop plans for alternative water sources (such as treated wastewater or desalinated seawater).

### Energy

- Promote energy conservation by human communities.
- Increase energy efficiency.
- Develop energy plans that include diverse alternatives and backup supplies in the event of failures of power plants.

### Ecosystems and Wildlife

- Develop plans to manage and protect wildlife populations by 1) promoting wildlife corridors that allow wildlife to migrate with climate, and 2) developing plans for conservation.
- Develop strategies to promote resilience in ecosystems.

**The American pika may be a victim of climate change in the future. They live is high alpine areas of the western United States and are sensitive to temperature changes.**

**Careful planning for water resources will be important for a future with changing precipitation patterns. We need to ensure water for our homes and agriculture without taking too much from our natural systems.**

## Teaching Tip

It is important to make the issue of climate change personal. Seeing the direct relevance and urgency of the issue will help your students truly understand the need for each of us to modify our lifestyles. This will be especially important as the effects of climate change become more evident. The following scenarios are interesting problems to make climate change more personal for your students:

- What if sea level rises 2 feet (61 cm)? How will California be affected? How will I be affected?
- What if precipitation decreases by 5 inches (12.7 cm) each year? How will California be affected? How will I be affected?
- What if ocean organisms began to move to different areas as the temperature and chemistry of the ocean changes? How will the California economy be affected? How will I be affected?
- What if crops that are dependent on specific climates, such as vegetables in California, have trouble surviving, are not as good quality, or both? How will the California economy be affected? How will I be affected?

## Action

Given that many adult Americans express a sense of feeling powerless against climate change, imagine how young students may feel. But there is much you and they can do as consumers, as citizens of this country, and ultimately as inhabitants of planet Earth.

## What Can You and Your Family Do?

**Use Your Consumer Power.** Make choices as consumers to support sustainable companies and sustainable products. Reward those companies with consumer support.

**Follow the Three R's.** The order of the three R's (Reduce, Reuse, and Recycle) is not arbitrary. Some people tend to think of recycling first, and of reducing and reusing as less important, but this is incorrect. If we start by reducing the amount of new things we purchase or buying only things we need, we can make less trash. Reducing is actually the most efficient way to conserve resources, followed by reusing. We can reuse things we have and avoid buying single-use items (such as plastics utensils and paper plates). Recycling is also important, but is not as efficient as reducing and reusing. All three, however, are important practices for protecting our natural resources.

**Reduce Your Carbon Footprint.** A carbon footprint describes the amount of greenhouse gases put into the air from activities you do. The goal is to reduce your carbon footprint by making changes to your habits. Turn off light bulbs and appliances when not in use, and be conscientious about the miles you drive each day. Also buying local, sustainably-grown food reduces transportation emissions and fertilizer use. Reducing water use cuts down on energy use, especially when one limits the amount of hot water used in the home. Lastly, consider eating less meat during the week, as growing livestock takes a lot more energy and water than growing plants.

**Reducing use of disposal plastics, like water bottles, is even better than recycling.**

## What Can Your Classroom and School Do?

**Develop Three R's School Program.** There are many activities you can use to engage your students in the three R's. Start a classroom or school-wide program each year that challenges individual students or classrooms to compete with each other to reduce their classroom use of materials and classroom waste and to recycle as much as possible. Sometimes people add a fourth *R* to follow: Rot. Ask the school administrators and cafeteria staff if composting could happen at the school, which could then be used to enrich the school grounds.

**Great Energy Challenge.** Develop a program at school to reduce energy use. Have each classroom develop an energy plan and then monitor the school's energy use across the year. The energy plans might include reminding students to turn off lights when not in use, replacing school light bulbs with energy efficient alternatives, and adjusting classroom temperatures a few degrees.

**Develop a List of Local Sustainable Vendors**. Have your students develop a list of vendors—shops, restaurants, grocery stores, and markets—that carry locally-grown or locally-made products or companies that have programs to lower their use of fossil fuels. Once your class has created a list, consider asking these vendors to visit your classroom to talk about what they are doing to reduce their carbon footprints.

## What Can Your Community Do?

**Support Public Transportation.** Advocate for efficient public transportation and safe bike trails. If these systems are in place, support them by using them whenever they provide a reasonable alternative to driving a single vehicle.

**Get Connected.** Get connected to local parks, businesses, and community groups so that you can be part of the programs happening in your local community. Become aware of these options, and learn about what partnerships might be appropriate for your students.

**Support Parks and Green Spaces.** Support your local parks and green spaces by visiting them often and learning more about how they can use your help. Community greening programs are a great way to participate in community-wide programs or events and to become more educated about local issues. Community greening involves planting native plants, which are an important carbon sink, and one way to improve water drainage as well.

**Let Your Voice Be Heard.** Investigate ways to get involved in the community or community issues being discussed. As a class, weigh in on the issues. Write a class letter to your local newspaper, create a blog, or make a video about what's important to your classroom.

**Buying local food reduces the carbon footprint of your groceries.**

In the Classroom

# My Carbon Footprint


Carbon footprint activities are one way to help students see how their behaviors and choices influence carbon emissions. There are numerous carbon-footprint calculators available through the Web, but many of these calculators are complicated. Facing the Future developed a middle school climate curriculum that includes a carbon-footprint activity. In the activity, students learn what the carbon footprint is, calculate their footprint, and then compare it to average footprints around the world. Students then develop plans to act in order to decrease their footprint. For the full activity and a free climate-change unit, see Facing the Future: http://www.facingthefuture.org/.

## Materials

- My Carbon Footprint worksheet
- Access to Internet and a carbon-footprint calculators: http://calc.zerofootprint.net/youth/ (For a more advanced calculator use U.S. EPA's Household Emissions Calculator: http://www.epa.gov/climatechange/emissions/ind_calculator.html)
- 1 incandescent and 1 compact fluorescent light bulb. These are to be shown to students so they are able to recognize which kind is being used in their homes.

## Directions

1. Prior to the lesson, explore carbon-footprint calculators and develop a carbon-footprint worksheet, or use the Facing the Future materials directly (http://www.facingthefuture.org/). The worksheet should ask students to record information about their energy use, transportation, and food choices.
2. Review greenhouse gases (GHGs) and their role on Earth. Explain to students that a carbon-footprint calculator helps people track how much carbon they put into the air. Have students share information from the carbon-footprint worksheets.
3. Direct students to the carbon-footprint calculator and have students input their worksheet data to obtain a carbon-footprint estimate.
4. Then ask students to compare carbon footprints to each other and others around the world. For more information, visit http://www. zerofootprintkids.com.
5. Once students learn about their footprint, they can review and change some of their answers in the calculator and observe the changes in the results.

## Ask Your Students

1. Why are the GHG emissions of a person or a business called a "carbon footprint"?
2. In which ways can you reduce your carbon footprint?
3. What did you learn from the carbon-footprint calculator? What actions would be easiest for you to implement to start reducing your carbon footprint?

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## Teaching Resources:

California Education and the Environment Initiative resources: http://www.calepa.ca.gov/Education/EEI/default.htm.

Climate Crisis: http://www.climatecrisis.net/take_action/reduce_your_impact_at_home.php.

EPA's Climate Ready Estuaries Program: http://www.epa.gov/cre/.

The Story of Stuff: http://www.yesmagazine.org/for-teachers/curriculum/the-story-of-stuff-another-way.

Green America: http://www.greenamericatoday.org/.

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