Climate Superstars

Educator's Guide 2022

SAMSUNG | CLIMATE SUPERSTARS

ENERGY STAR

NEEF National Environmental Education Foundation

Welcome!

Climate Superstars is an annual contest and collaborative educational partnership between the National Environmental Education Foundation (NEEF), the U.S. Environmental Protection Agency (EPA), and Samsung Electronics America, where educators complete a series of tasks with their students to qualify for a prize drawing.

Overview of Goals, Concepts, and Skills/Practices

The overarching goal of this guide is to present educators with a collection of learning activities that can be used individually or as a series to complete the contest or supplement approved curricula.

This collection of energy themed activities is intended to illustrate the environmental aspects of providing the energy needed to sustain a modern high-tech society. While not specifically articulated, sustainability is an implied concept. Completion of these tasks are likely to increase environmental awareness, scientific understanding, and a willingness to make personal and collective changes.

The learning activities that comprise the contest tasks were developed with the Next Generation Science Standards as a guide. Each task calls out alignment with specific NGSS standards is not called out, including the three components of three-dimensional learning (i.e. core disciplinary ideas, science and engineering practices, and cross cutting concepts). Also embedded but not called out are opportunities for educators to engage learners in development and practice of the 21st century skills set.

Teaching Suggestions

Instructional Level

This collection of learning activities is designed for middle level grades. It can also be adapted for use with upper elementary or secondary grade levels. Some activities include extension resources beyond middle school grade levels as examples.

Time and Scheduling

The ten tasks that comprise this contest can be accomplished in a variety of ways (e.g. as stand-alone activities, as extensions of approved curriculum, as homework). Many factors, such as class size, familiarity with the content, and experience with the digital platform will influence how much time you will need to complete each task. Some tasks include one or more short videos (average length about 10 minutes each).

Curriculum Infusion, Integration, and Extension

Many of the contest tasks provide opportunities for social studies, language development, mathematics, or arts integration. Some tasks could be developed into a series of lessons or be the launching point for project-based learning resulting in a greater understanding of the economic and sociological aspects of energy and climate change. Creative writing, drawing, and problem-solving can be used to expand on the activities presented in each task. These and other suggestions can help to infuse the concepts into other areas of learning or act as a catalyst for taking a deeper dive into ideas and topics being explored.

Contents

Task #1: Learn About Global Climate Change

Overview

Scientists establish baselines from which to measure changes or make comparisons. The classical length of record to determine the climate for any particular place is 30 years, as defined by the World Meteorological Organization. To understand how climate change is occurring requires monitoring changes to long-term weather patterns and specific meteorological variables, such as average temperature, annual precipitation, etc. Monitoring of the various atmospheric gases (covered in more detail in the *Learn How Humans Contribute to Climate Change* activity) is another way scientists track climate change. Changes to the levels of specific gases in the atmosphere are the basis for many of the climate change impacts scientists predict.

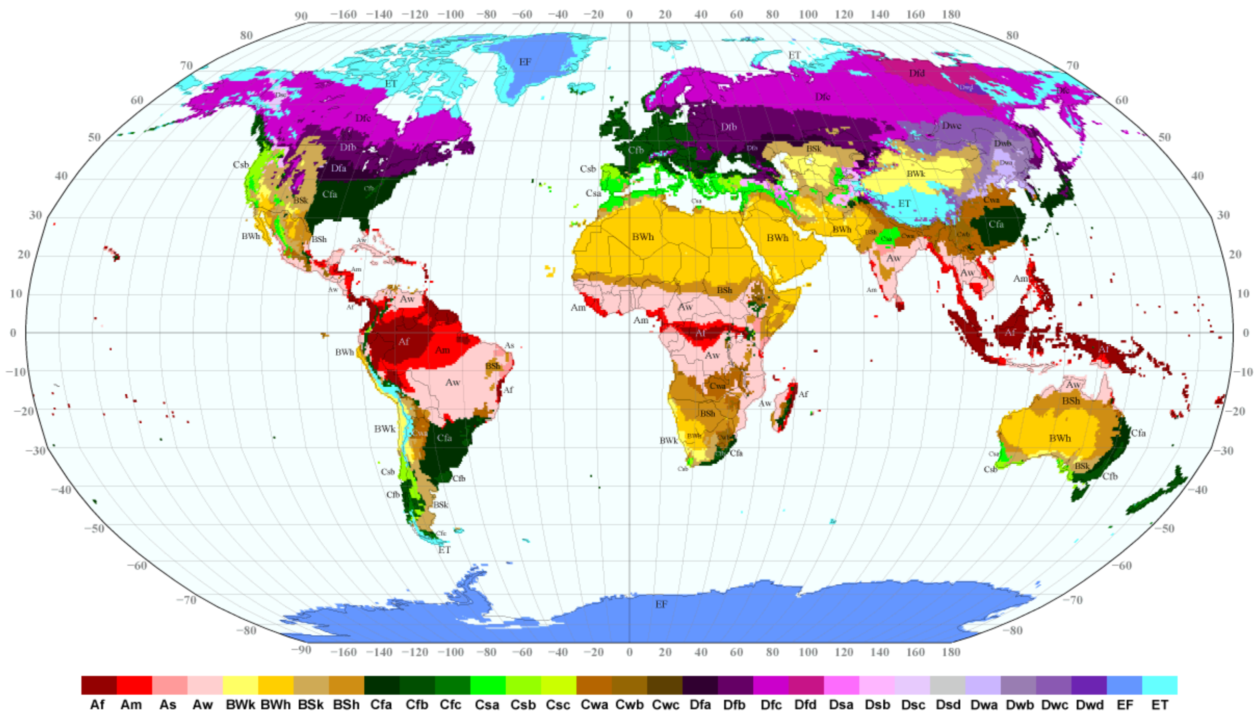
Learning Objectives

- ✓ Students will be able to explain the difference between weather and climate.
- ✓ Students will be able to identify and describe the climate type where they live.
- ✓ Students will be able to define climate change and global warming.

Check out https://www.epa.gov/climatechange-science for a primer on climate change.

Background

The most popular system of classifying climates was proposed by Russian-German scientist Wladimir Köppen. Studying vegetation, temperature, and precipitation data, Köppen and other scientists, like Rudolf Geiger, developed a system for naming climate regions. According to the Köppen-Geiger climate classification system, there are six **climate zones**: **tropical** (A), **dry** (B), **subtropical** (C), **continental** (D), **polar** (E), and **highland** (H).



(Source)

The major climate categories are as follows:

A - Tropical Climates

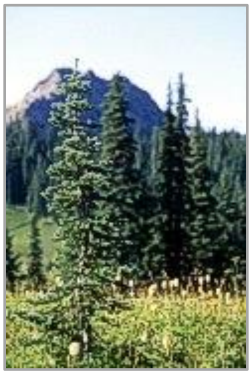
Tropical moist climates extend north and south from the equator to about 15° to 25° latitude. In these climates all months have average temperatures greater than 64°F (18°C) and annual precipitation greater than 59".

B - Dry Climates

The most obvious climatic feature of this climate is that potential evaporation and transpiration exceed precipitation. These climates extend from 20°-35° north and south of the equator and in large continental regions of the mid-latitudes often surrounded by mountains.

C - Moist Subtropical Mid-Latitude Climates

This climate generally has warm and humid summers with mild winters. Its extent is from 30°50° of latitude mainly on the eastern and western borders of most continents. During the winter, the main weather feature is the mid-latitude cyclone. Convective thunderstorms dominate summer months.



D - Moist Continental Mid-Latitude Climates

Moist continental mid-latitude climates have warm to cool summers and cold winters. The location of these climates is poleward of the "C" climates. The average temperature of the warmest month is greater than 50°F (10°C), while the coldest month is less than -22°F (-30°C). Winters are severe with snowstorms, strong winds, and bitter cold from Continental Polar or Arctic air masses.

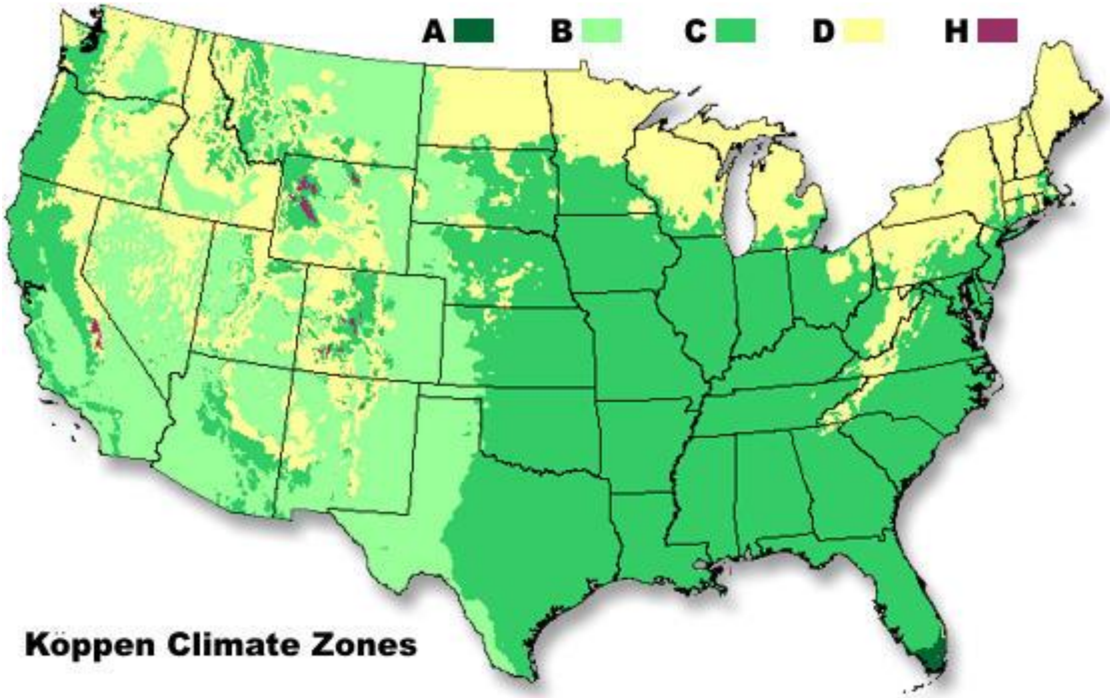
E - Polar Climates

Polar climates have year-round cold temperatures with the warmest month less than 50°F (10°C). Polar climates are found on the northern coastal areas of North America, Europe, Asia, and on the land masses of Greenland and Antarctica.

H - Highlands

Unique climates based on their elevation. Highland climates occur in mountainous terrain where rapid elevation changes cause rapid climatic changes over short distances.

The map (below) shows where these major categories occur in the mainland United States.



(Source)

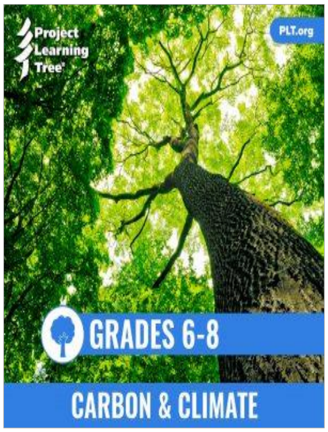
These climate categories are further sub-divided. Learn more about the sub-divisions here.

Vocabulary (Source)

- ✓ **Climate** – a description of the long-term pattern of weather in a geographic area using averages of temperature, humidity, atmospheric pressure, wind, rainfall, and other meteorological elements
- ✓ **Climate Change** – long-term change in the average weather patterns that have come to define earth's local, regional, and global climates (Source)
- ✓ **Climate Variability** – short-term regional changes in temperature and weather patterns (e.g. El Niño, La Niña) resulting from natural physical processes within earth's climate system
- ✓ **Global Warming** – the long-term heating of earth's climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in earth's atmosphere (Source)
- ✓ **Weather** – a description of the short-term condition of the atmosphere in a geographic area using measurements of temperature, humidity, atmospheric pressure, wind, and precipitation

Extension Resources

Middle School: Carbon and Climate



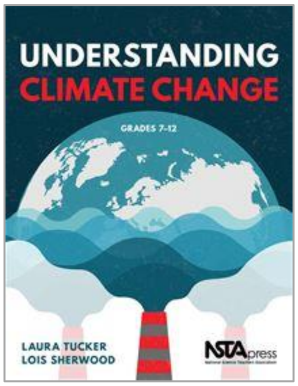
This Project Learning Tree e-unit explores two essential questions, *What is climate? What role does carbon play in climate?* and several others. The unit provides activities and resources to help educators introduce learners to some of the complex issues involved in climate science and its associated challenges.

The unit meets academic standards including: Next Generation Science Standards (NGSS), Common Core State Standards for English Language Arts and Math, and the C3 Framework for Social Studies. Of special note, these Project Learning Tree lessons are not just aligned with NGSS, but have been constructed around NGSS target performance expectations.

GO TO RESOURCE

Additional Reading

Understanding Climate Change



From NSTA Press, *Understanding Climate Change* offers both extensive background and step-by-step directions for using three-dimensional instructional methods to explore this complex subject. Based on what they learn, students can use critical thinking and analysis to draw their own conclusions about what should be done.

The book is easy to use even for teachers with no background in climate science. *Understanding Climate Change, Grades 7–12* is structured as a nine-session module that establishes a conceptual foundation without risking information overload. The material can be covered in three or four weeks or used in part to supplement an existing curriculum.

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Task #2: Observing Signs of Climate Change

Overview

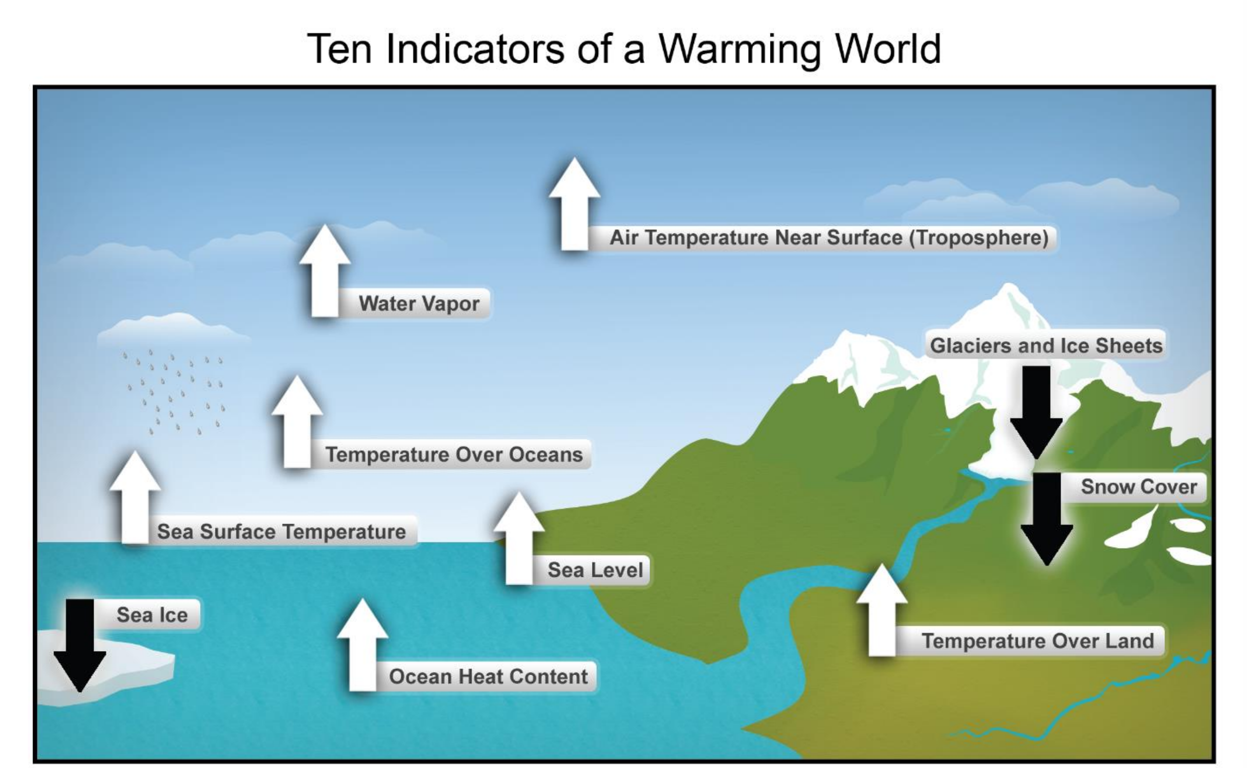
Climate scientists analyze both historical and newly collected data, making comparisons using changes to the historical averages to predict what future trends are most likely. According to the third US National Climate Assessment, "Global climate is changing and this is apparent across the United States in a wide range of observations. The global warming of the past 50 years is primarily due to human activities, predominantly the burning of fossil fuels." (Source)

Learning Objectives

- ✓ Students will be able to explain how years of observational data confirm climate change.
- ✓ Students will be able to identify and describe the types of indicators scientists track.
- ✓ Students will be able to identify direct and inverse relationships using key indicators.

Background

Observations are the foundation for understanding the climate system. The Climate Variability and Change focus area (CVC) at NASA supports research to better understand the overall state of earth's climate and the physical processes that affect it. CVC supports the development of climate data sets and computer models that leverage observations from relevant NASA and non-NASA platforms, including satellites, aircraft, and ships. (Source)



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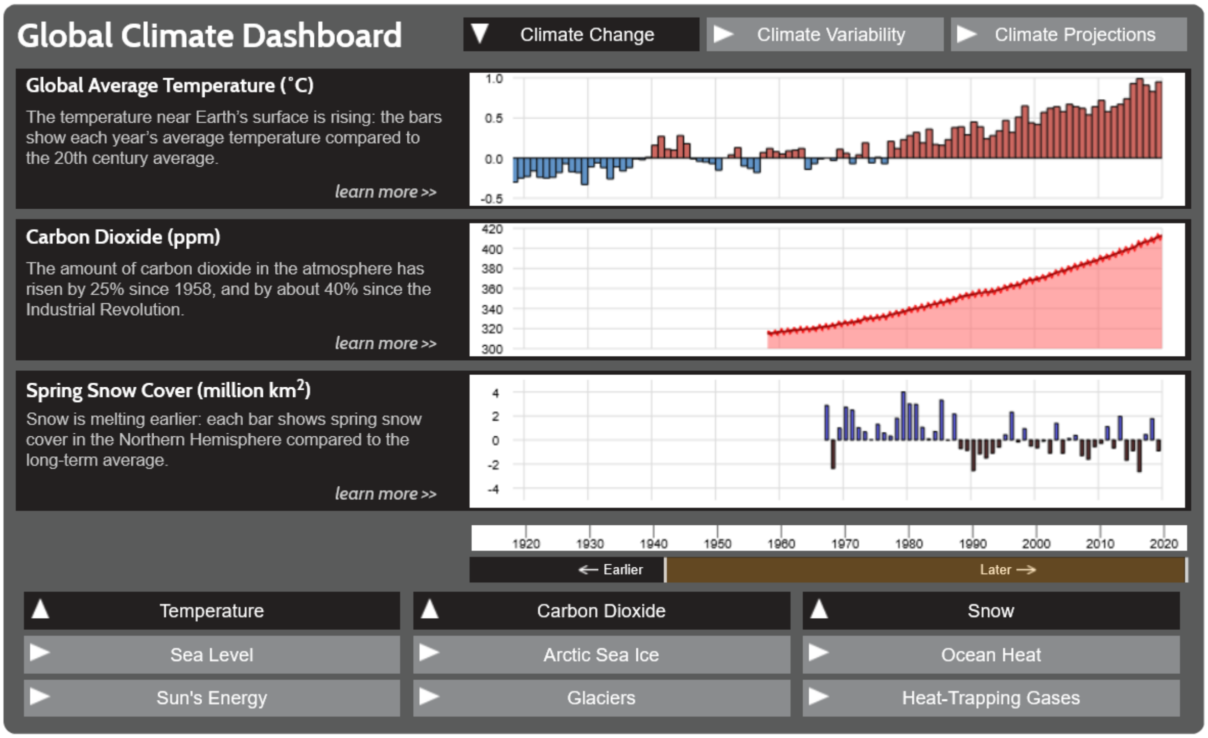


(Source)

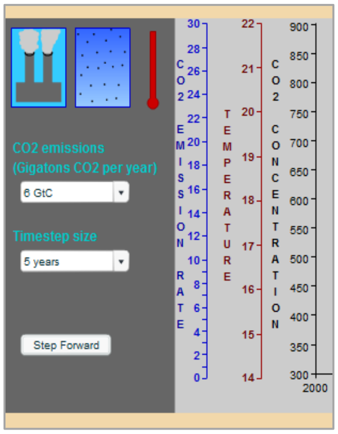
Check out https://www.epa.gov/climate-indicators for additional information and indicators

Vocabulary

- ✓ **Causation** – indicates that one event is the result of the occurrence of the other event (i.e. there is a causal relationship between the two events); this is also referred to as cause and effect
- ✓ **Correlation** – a mutual relationship or connection
- ✓ **Data** – facts and statistics collected for reference or analysis
- ✓ **Direct relationship** – when two variables change in the same direction, effect, position, or order
- ✓ **Indicator** – a measurable variable that characterizes an environment or situation
- ✓ **Inverse relationship** – when two variables change in opposite or reverse direction, effect, position, or order

Extension Resources

Middle School: The Very, Very Simple Climate Model



In part one of this activity, students read an article and examine a graph showing global surface temperature trends over the last century as well as future predictions. They read about climate models as well as levels of accuracy and uncertainty in such models. In part two, students learn about the relationship between carbon dioxide emissions, carbon dioxide buildup in the atmosphere, and average global temperature using an interactive simulation.

The simulation engages students in meaningful scenarios that reflect the interconnected nature of science as it is practiced and experienced in the real world. Students are asked to interpret and represent their ideas. The teacher notes give good questions to ask the students to help guide them in the lesson and thoroughly explains the simulation.

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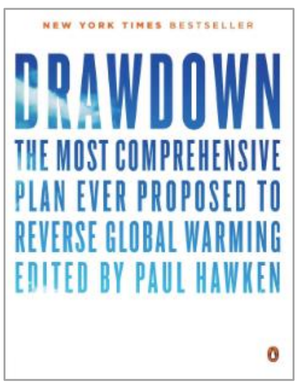
Additional Reading

Drawdown *[fee]*



The 2017 book *Drawdown* describes the 100 most substantive solutions to global warming. For each solution, the authors describe its history, the carbon impact it provides, the relative cost and savings, the path to adoption, and how it works. The goal of the research that informs *Drawdown* is to determine if humans can reverse the buildup of atmospheric carbon within thirty years. All solutions modeled are already in place, well understood, analyzed based on peer-reviewed science, and are expanding around the world. Upcoming guides will help individuals and communities take action on Drawdown solutions. Explore impactful actions you can take to help the world reach drawdown through your everyday lifestyle choices. Discover how you can multiply your impact for a climate-safe future.

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Task #3: Take a Climate Change Tour

Overview

The causes of climate change and global warming are the same all over the world. However, how those changes impact a geographic region differ. In addition to environmental impacts, there are economic, health, and cultural impacts, too. Another challenge climate change presents is the need to work across borders. The atmosphere is a dynamic system that responds to geographic features but not lines drawn on a map. Think global, act local!

Learning Objectives

- ✓ Students will be able to name locally relevant effects of climate change.
- ✓ Students will be able to explain why the impacts of climate change differ by region.
- ✓ Students will be able to identify cause and effect relationships for impacts of climate change

Background Information

Environmental conditions at the time of the first Earth Day celebration in 1970 were worsening dramatically. Rivers were so polluted that they caught fire. Acid rain resulting from the industrial burning of coal was fouling lakes and killing forests. Air-polluting heavy industries and use of leaded gasoline in vehicles blanketed major cities with smog.

Public demand for solutions led to the founding of the Environmental Protection Agency and landmark legislation designed to reign in polluting activities. The Clean Air Act of 1970 was amended in 1990 to allow interstate commissions to develop regional strategies for cleaning up air pollution. At a cost of $65 billion, economic and health benefits from the amendments have exceeded costs by a ratio of 30:1 adding up to a total economic gain through 2020 of $2 trillion. The Clean Water Act of 1972 is another bedrock environmental law, regulating water pollution. Even with these regulatory protections, environmental problems associated with climate change and global warming continue to impact society. [(Source)]

The 1990 Clean Air Act Amendments prevent:

	Year 2010 (cases)	Year 2020 (cases)
Adult Mortality - particles	160,000	230,000
Infant Mortality - particles	230	280
Mortality - ozone	4,300	7,100
Chronic Bronchitis	54,000	75,000
Acute Myocardial Infarction	130,000	200,000
Asthma Exacerbation	1,700,000	2,400,000
Emergency Room Visits	86,000	120,000
School Loss Days	3,200,000	5,400,000
Lost Work Days	13,000,000	17,000,000

This chart shows the health benefits of the Clean Air Act programs that reduce levels of fine particles and Ozone.

Vocabulary

- ✓ **Cause and effect relationship** – the principle that one phenomenon (the cause) makes one or more other phenomena happen (the effect); a combination of action and reaction
- ✓ **Climate change** – long-term change in the average weather patterns that have come to define earth's local, regional, and global climates
- ✓ **Phenomenon** – a fact or situation that is observed to exist or happen, especially one whose cause or explanation is in question

Extension Resources

Middle School: Protecting Our Cities with Levees

In 2005, Hurricane Katrina caused severe damage and suffering to the people who lived in and around New Orleans. The levees that surrounded the city did not hold the immense amount of ocean water that rose from the storm.

In this activity, students will use the engineering design process to design and build their own model levees. Acting as engineers for their city, teams create sturdy barriers using limited materials to prevent water from flooding a city in the event of a hurricane.

Students compare multiple solutions in the final assessment where they present to the class how their prototype met or did not meet the criteria and constraints of the problem.

GO TO RESOURCE

Middle School: Where's the Beach? Investigating Coastline Erosion Protection

Developed by The Nature Conservancy, this lesson engages learners in exploring the phenomenon of soil erosion at the beach, and in designing solutions to mitigate it. In part one, learners research how wave energy affects shorelines, predict the relationship between waves and erosion, and use historic data to study the effects of tides and major storms on the Gulf Coast. They use videos, photos, and an online interactive tool to study the impact of erosion. Learners investigate the exponential relationship between wave height and energy. Learners describe types of barriers to protect shorelines from waves. Then, in part two, learners research a natural oyster reef as a barrier and more extensive, man-made barriers. They create a model shoreline and test the impact of waves on their shoreline with different types of barriers. As the final extension, learners create a cost-benefit analysis of different types of barriers and predict which would be the best to use in certain environments.

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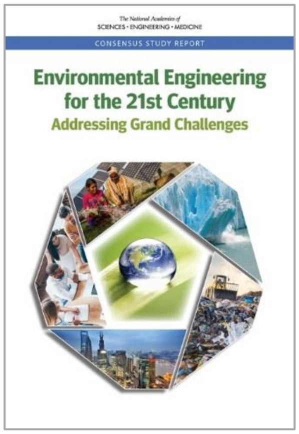
Additional Reading

Environmental Engineering for the 21st Century *[PDF is free]*



Environmental engineers support the well-being of people and the planet in areas where the two intersect. Over the decades the field has improved countless lives through innovative systems for delivering water, treating waste, and preventing and remediating pollution in air, water, and soil. These achievements are a testament to the multidisciplinary, pragmatic, systems-oriented approach that characterizes environmental engineering.

Over the next several decades as the global population grows, society will be faced with pressing challenges such as providing reliable supplies of food and water, reducing climate change and adapting to its impacts, and building healthy, resilient cities. To address the challenges, the report recommends that the environmental engineering field evolve its education, research, and practice to advance practical, impactful solutions for society's multifaceted, vexing problems.

GO TO RESOURCE

Creating Engineering Design Challenges *[fee]*

If you're looking for ways to make science and math more relevant to your middle or high school students, *Creating Engineering Design Challenges* is the book for you. At its core are 13 units grounded in challenge-based learning and the engineering design process. The units are classroom-ready because they were contributed by teachers who developed, used, and revised them during the Cincinnati Engineering Enhanced Math and Science (CEEMS) program, a project funded by the National Science Foundation.

The contributors' goal is to help you benefit from their experience. Working from their advice, you can develop a more student-centered classroom culture and nurture learners who are engaged in real-life engineering challenges.

GO TO RESOURCE

Task#4: Learn How Humans Contribute to Climate Change

Overview

Climate variability is an insufficient explanation for all of the climate changes and impacts now occurring around the world. So, what then are the major causes? Human activities that generate long-lived greenhouse gases are altering the chemical composition of the atmosphere resulting in a buildup of thermal energy that drives global warming.

Learning Objectives

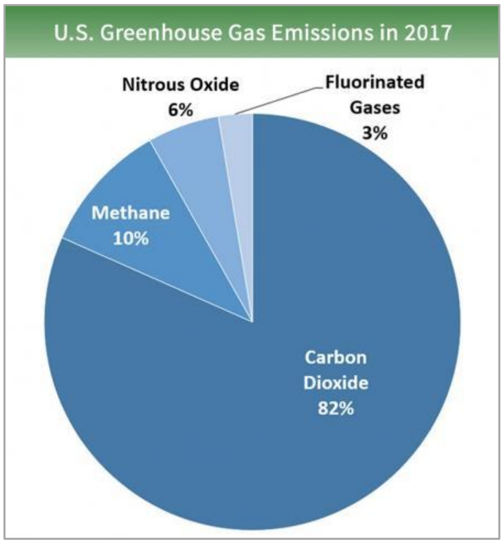
- ✓ Students will be able to explain how human activities contribute to climate change.
- ✓ Students will be able to name several of the greenhouse gases causing global warming.
- ✓ Students will be able to identify cause and effect relationships for impacts of climate change.

Background

Throughout earth's history there have been periods of climate change. A small change in solar radiation resulting from changes in the sun's energy outputs likely played a role in past periods of climate change. The period known as the Little Ice Age (from 1650 CE - 1850 CE) was likely caused in part by low solar intensity. Another likely cause were variations in ocean currents, which move vast amounts of thermal energy around the planet. Other contributors include volcanic eruptions and changes in the earth's tilt on its axis.

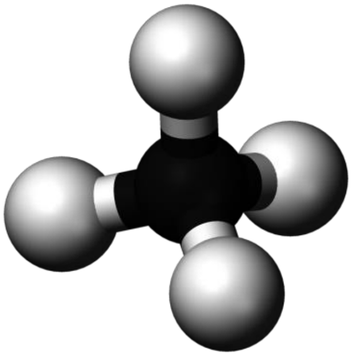
The ability of earth's atmosphere to trap thermal energy, keeping it from radiating into space, is known as the greenhouse effect—which, when functioning as it has historically, is a good thing keeping earth's climate stable, temperate, and habitable for a broad diversity of living things. However, when the concentrations of certain atmospheric gases—the greenhouse gases—increase, too much thermal energy is trapped resulting in global warming.

Many chemical compounds present in earth's atmosphere behave as 'greenhouse gases'. These are gases which allow direct sunlight (relative shortwave energy) to reach the earth's surface unimpeded. As the shortwave energy (that in the visible and ultraviolet portion of the spectra) heats the surface, longer-wave infrared energy (experienced as heat) is reradiated to the atmosphere. Greenhouse gases absorb this energy, thereby allowing less heat to escape back to space, and 'trapping' it in the lower atmosphere.



Many greenhouse gases occur naturally in the atmosphere, while others are synthetic. Atmospheric concentrations of both the natural and man-made gases have been rising over the last few centuries due to the industrial revolution. [(Source)]

The naturally occurring greenhouse gases (GHG) are water vapor, carbon dioxide (CO_2), methane (CH_4), ozone (O_3), and nitrous oxide (N_2O). The man-made or synthetic GHG include the chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of the different greenhouse gases have different global warming potentials. To make comparisons easier scientists estimate emissions in tons of CO_2 equivalent.



Methane (CH_4) molecule (Source)

Water Vapor is the most abundant greenhouse gas. Changes in its concentration are considered to be a result of climate feedbacks related to the warming of the atmosphere rather than a direct result of industrialization.

Carbon Dioxide (CO_2) is naturally produced and absorbed through the terrestrial biosphere and the ocean. However, humankind has altered the natural carbon cycle by burning coal, oil, natural gas, and wood. Carbon dioxide was the first greenhouse gas demonstrated to be increasing in atmospheric concentration.

Methane (CH_4) is an extremely effective absorber of radiation. Its atmospheric concentration is less than CO_2 and its lifetime in the atmosphere is brief (10-12 years). It is released as part of the biological processes in low oxygen environments, such as in swamplands. Human activities such as growing rice, raising cattle, using natural gas, and mining coal add to the atmospheric concentration of methane.

Tropospheric ozone (O_3) is formed in the stratosphere when ultraviolet radiation and oxygen interact. Existing in a broad band, commonly called the 'ozone layer', a small fraction of this ozone naturally descends to the earth's surface. However, during the 20th century, this tropospheric ozone has been supplemented by ozone created by human processes. The exhaust from automobiles, pollution from factories, and burning of vegetation (i.e. deforestation) leads to greater concentrations of carbon and nitrogen molecules in the lower atmosphere which, when acted on by sunlight, produce ozone—an important contributor to photochemical smog. Scientists consider ozone the third most important greenhouse gas after carbon dioxide and methane. An additional complication of ozone is that it also interacts with and is modulated by concentrations of methane.

Nitrous Oxide (N_2O) concentration in the atmosphere began to rise at the beginning of the industrial revolution. It is produced by microbial processes in soil and water, including chemical reactions which occur from use of nitrogen containing fertilizers. Use of these fertilizers has increased over the last century. In addition to agricultural sources for the gas, industrial processes associated with fossil fuel-fired power plants, nylon production, nitric acid production, and vehicle emissions also contribute to its atmospheric load.

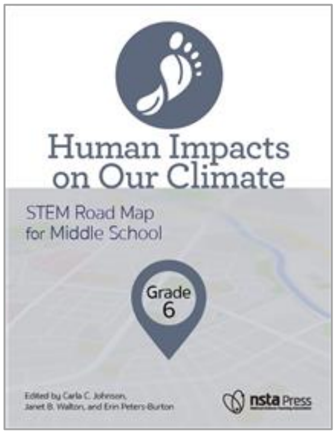
Chlorofluorocarbons (CFCs) do not occur naturally. They were synthesized for use as refrigerants, aerosol propellants, and cleaning solvents. Since their creation in 1928, concentrations of CFCs in the atmosphere have been rising. Due to the discovery that CFCs are able to destroy stratospheric ozone, a global effort to halt their production was undertaken and was extremely successful. So much so that levels of the major CFCs are now remaining level or declining. However, their long atmospheric lifetimes mean that some concentrations of CFCs will remain in the atmosphere for over 100 years. Carbon tetrafluoride (CF_4) and sulfur hexafluoride (SF_6), other long-lived synthesized gases, are also a concern. Another set of synthesized compounds called hydrofluorocarbons (HFCs) are also GHG, though they are less stable in the atmosphere and therefore have a shorter lifetime and less of an impact as a greenhouse gas. (Source)

Vocabulary

- ✓ **Climate variability** – variations in climate patterns, beyond individual weather events, that occur within smaller timeframes, such as a month, a season or a year that are generally attributed to natural causes.
- ✓ **CO_2 equivalent** – a unit of measurement that compares the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas.
- ✓ **Greenhouse effect** – a phenomenon that occurs when gases in the atmosphere trap heat emitted by the planet.
- ✓ **Greenhouse gases** – a set of naturally occurring and man-made gases in earth's atmosphere that trap heat, while allowing sunlight to pass through; many greenhouse gases are extremely long-lived, with some remaining airborne for tens to hundreds of years after being released

Extension Resources

Grade 6: Human Impacts on Our Climate [fee]



An interdisciplinary, three-lesson module that uses project- and problem-based learning to help students investigate aspects of climate change that have been driven by the rise in global temperatures over the past century. Working in teams, students use an engineering design process to identify a local environmental problem, develop a model to help monitor and minimize its impact, and create a presentation about their findings. Students explore differences between weather and climate and explore temperature as an indicator of global warming. They examine the role that greenhouse gases play in global temperature warming. They explain the causes and effects of climate change and how humans have influenced it. They use mathematical modeling and numerical data to explore climate change's impact. They analyze and synthesize credible resources to form scientific arguments regarding climate change. They develop a deeper understanding of how climate change influences the economy, society, and people everywhere.

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High School: Carbon TIME Human Energy Systems Unit

One of six units in the Carbon: Transformations in Matter and Energy curriculum, an NSF-funded research collaboration focused on learning progressions to support environmental literacy. Students should first complete the foundational unit, Systems & Scale, then at least one of the three units at the organism level, and then complete the Ecosystems unit before moving into the culminating Human Energy Systems unit. Each unit focuses on three questions: (1) Where are the carbon pools in the environment? (2) How are carbon atoms cycling among pools? and (3) What is happening to energy? In this unit, students investigate a series of phenomena focused on global carbon cycling and climate change. The highly guided sequence of six lessons helps students interpret large-scale datasets, trace global movements of matter and energy, and explain the consequences of human choices for changes in atmospheric CO_2.

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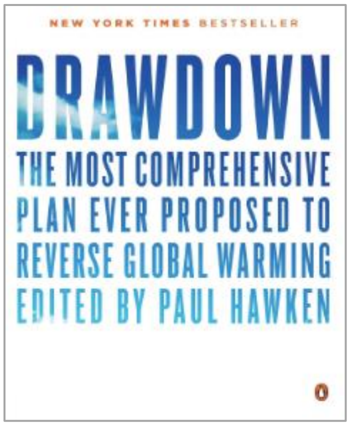
Additional Reading

Drawdown [fee]



The 2017 book *Drawdown* describes the 100 most substantive solutions to global warming. For each solution, the authors describe its history, the carbon impact it provides, the relative cost and savings, the path to adoption, and how it works. The goal of the research that informs *Drawdown* is to determine if humans can reverse the buildup of atmospheric carbon within thirty years. All solutions modeled are already in place, well understood, analyzed based on peer-reviewed science, and are expanding around the world. Upcoming guides will help individuals and communities take action on Drawdown solutions. Explore impactful actions you can take to help the world reach drawdown through your everyday lifestyle choices. Discover how you can multiply your impact for a climate-safe future.

GO TO RESOURCE

Task #5: Learn About Electricity Generation

Overview

Achieving climate literacy, an understanding of our influence on climate and climate's influence on us and society, entails learning about energy. According to the Energy Literacy Framework from the US Department of Energy, energy literacy is an understanding of the nature and role of energy in the universe and in human lives. Energy literacy is also the ability to apply this understanding to answer questions and solve problems.

Learning Objectives

- ✓ Students will be able to list the different non-renewable energy sources.
- ✓ Students will be able to identify and describe the different methods of generating electricity.
- ✓ Students will be able to explain how combustion of fossil fuels results in the creation of greenhouse gases.

Energy is a paradox: it brings light, warmth, security, and mobility. But on the other hand, energy extraction, burning of fossil fuels, and the unequal distribution of energy resources have wrought environmental and social problems for humanity. Energy use is at the root of climate change and many other issues, and people are seeing the beginnings of a global shift in energy sources and energy policy toward more cooperative, sustainable use of energy. (Source)

Background

In the United States, about 60% of total electricity generation in 2020 was produced from fossil fuels (coal, natural gas, and petroleum), materials that come from plants (biomass), and municipal and industrial wastes. Nearly all combustion byproducts have negative effects on the environment and human health. The chemical substances that occur in combustion gases when these fuels are burned include:

- Carbon dioxide (CO_2) is a colorless, odorless, heat-trapping gas produced by burning carbon and organic compounds and by respiration. It is naturally present in air (about 0.03%) and is absorbed by plants in photosynthesis. CO_2 is a greenhouse gas, which contributes to the greenhouse effect.

- Carbon monoxide (CO) is a colorless, odorless, and tasteless, toxic gas. It is the product of the incomplete combustion of carbon-containing compounds, notably in internal-combustion engines. It has significant fuel value, burning in air with a characteristic blue flame, producing carbon dioxide.

- Sulfur dioxide (SO_2) is a pungent, corrosive, toxic gas produced by burning coal or crude oil in power plants and from factories that produce chemicals, paper, or fuel. SO_2 causes acid rain, which is harmful to plants and animals. SO_2 also worsens respiratory illnesses and heart diseases, particularly in children and the elderly.

- Nitrogen oxide (NOx) gases contribute to ground-level ozone (O_3), which irritates and damages the lungs.

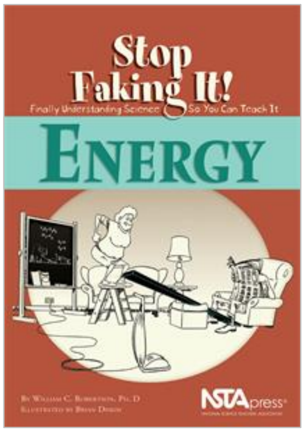
- Particulate matter (PM) results in hazy conditions in cites and scenic areas and coupled with ozone (O_3), contributes to asthma and chronic bronchitis, especially in children and the elderly. Very small, or *fine PM*, is also believed to cause emphysema and lung cancer.
- Heavy metals such as mercury (Hg) are hazardous to human and animal health. (Source)

Vocabulary (Source)

- ✓ **Generator** – a device that converts mechanical (or chemical) energy into electricity using electromagnetic induction**.**
- ✓ **Kinetic energy –** property of a moving object or particle that depends not only on its motion but also on its mass.
- ✓ **Thermal energy –** an example of kinetic energy, as it is due to the motion of particles, with motion being the key. Thermal energy results in an object or a system having a temperature that can be measured. Thermal energy can be transferred from one object or system to another in the form of heat.
- ✓ **Radiant energy –** energy that travels by waves or particles, also known as electromagnetic radiation. Some examples include heat, x-rays, visible light, and radio waves.
- ✓ **Turbine –** a machine for producing continuous power in which a wheel or rotor, typically fitted with vanes, is made to revolve by a fast-moving flow of water, steam, gas, air, or other fluid.

Extension Resources

Energy: Stop Faking It! Finally Understanding Science So You Can Teach It [fee]



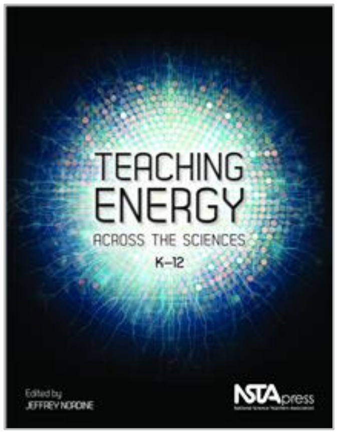
Confounded by kinetic energy? Exasperated by electricity? If you fear the study of energy is beyond you, this entertaining book will do more than introduce you to the topic. It will help you actually understand it. At the book's heart are easy-to-grasp explanations of energy basics—work, kinetic energy, potential energy, and the transformation of energy—and energy as it relates to simple machines, heat energy, temperature, and heat transfer.

Irreverent author Bill Robertson ends each chapter with a summary and an applications section that uses practical examples such as roller coasters and home heating systems to explain energy transformations and convection cells. The final chapter brings together key concepts in an easy-to-grasp explanation of how electricity is generated.

GO TO RESOURCE

Additional Reading

Teaching Energy Across the Sciences K-12 [fee]



This book gives educators strategies and tools they can use to help students understand energy as a concept that cuts across all sciences. The authors posit that students will learn about energy more effectively if teachers present it consistently in all grades and across all scientific disciplines. Their intended outcome is a clear lens for interpreting how energy works in many contexts, both inside and outside the classroom.

"The *NGSS* firmly assert that we can no longer accept teaching energy in a way that does not show students how energy ideas are connected," editor Jeff Nordine writes. Simply and clearly, this book shows educators how to make those vital connections.

GO TO RESOURCE

Task #6: Learn About Renewable Energy

Overview

Although alternative energy and renewable energy both work to cut down on carbon emissions, there is a stark difference between the two. Alternative energy is not infinite in supply like renewable energy, which, as the name suggests, is always available.

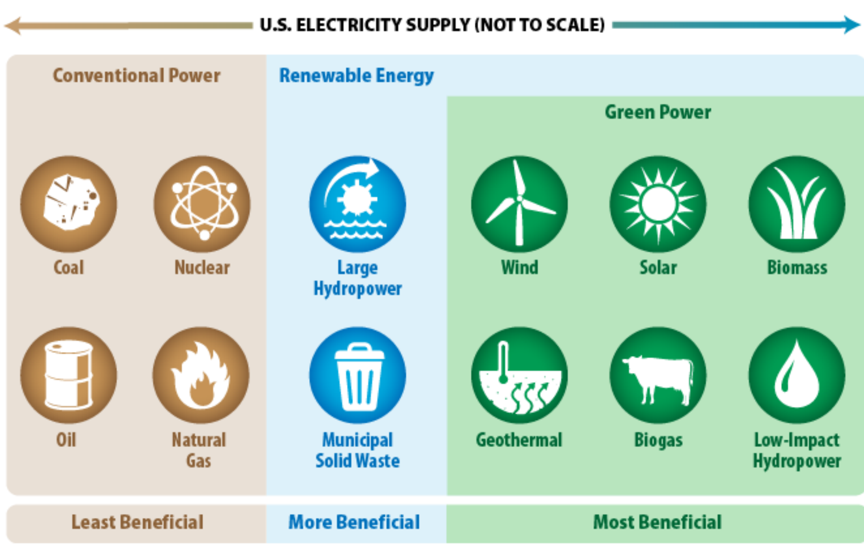
Learning Objectives

- ✓ Students will be able to explain the difference between renewable and non-renewable energy sources.
- ✓ Students will be able to state the main benefit of renewable energy (i.e. reduced greenhouse gas emissions).
- ✓ Students will be able to explain why there are different mixes of renewables used in generating electricity based on location.

Background

What's the difference between alternative and renewable sources of energy? Renewable energy comes from a source that is naturally occurring and replenishes naturally and relatively quickly without the need for human intervention. Examples of renewable energy include biomass resources, geothermal, hydro, solar energy, and wind energy. The most abundant of these resources is solar energy. If you think about it, it makes sense. The sun is always shining at some point everywhere on earth, making it the most abundant to harness.

Alternative energy includes resources like natural gas (often obtained from fracking or the injection of pressure into subterranean rock crevices), natural gas cogeneration, fuel cells or any waste energy that does not naturally replenish but emits lower carbon emissions than fossil fuels. Oil is not considered an alternative energy or renewable resource. Earth's oil reserves will eventually diminish; albeit, it may take centuries.



(Source)

Some renewable energy sources, such as biomass and biofuels, have significant environmental impacts because their production and use results in greenhouse gas (GHG) emissions. Burning **municipal solid waste (MSW)**, or *garbage*, in waste-to-energy plants can result in less waste buried in landfills. On the other hand, burning garbage produces air pollution and releases the chemicals and substances in the waste into the air. Some of these chemicals can be hazardous to people and the environment if they are not properly controlled.

Municipal solid waste contains:

- Biomass, or biogenic (plant or animal products), materials such as paper, cardboard, food waste, grass clippings, leaves, wood, and leather products;
- Non-biomass combustible materials such as plastics and other synthetic materials made from petroleum;
- Noncombustible materials such as glass and metals.

MSW is usually burned at special waste-to-energy plants that use the heat from the fire to make steam for generating electricity or to heat buildings. Many large landfills also generate electricity by using the methane gas that is produced from decomposing biomass in landfills. (Source)

The U.S. Environmental Protection Agency (EPA) applies strict environmental rules to waste-to-energy plants, which require waste-to-energy plants to use air pollution control devices such as scrubbers, fabric filters, and electrostatic precipitators to capture air pollutants.

A waste-to-energy furnace burns at high temperatures (1,800°F to 2,000°F), which break down the chemicals in MSW into simpler, less harmful compounds. Ash from waste-to-energy plants can contain high concentrations of various metals that were present in the original waste. Textile dyes, printing inks, and ceramics, for example, may contain lead and cadmium.

Separating waste before burning can solve part of the problem. Because batteries are the largest source of lead and cadmium in municipal waste, they should not be included in regular trash. Fluorescent light bulbs should also not be put in regular trash because they contain small amounts of mercury.

The EPA tests ash from waste-to-energy plants to make sure that it is not hazardous. The test looks for chemicals and metals that could contaminate ground water. Some MSW landfills use ash that is considered safe as a cover layer for their landfills, and some MSW ash is used to make concrete blocks and bricks. (Source)

The US Environmental Protection Agency (EPA) established the Green Power Partnership (GPP) in 2001 to protect human health and the environment by increasing publicly- and privately-held corporations, federal, state, and local government agencies, nonprofits, and educational institutions voluntary use of green power to advance the development of those renewable electricity sources. The GPP helps to achieve Clean Air Act requirements by reducing the pollution and the corresponding negative health and environmental impacts associated with conventional electricity use. Individuals and private residences are not eligible to join the GPP, but they may find the information and resources available through the GPP useful in finding, evaluating, and procuring green power products. Additional information can be found at EPA's Green Power Partnership webpage.

Here are impact summaries for each of the green power types that are not hydropower based.

Biogas forms as a result of biological processes in sewage treatment plants, waste landfills, and livestock manure management systems. Biogas is composed mainly of methane and CO2. Many facilities that produce biogas capture it and burn the methane for heat or to generate electricity. This electricity is considered renewable and, in many states, contributes to meeting state renewable portfolio standards (RPS). This electricity may replace electricity generation from fossil fuels and can result in a net reduction in CO2 emissions. Burning methane produces CO2, but because methane is a stronger greenhouse gas than CO2, the overall greenhouse effect is lower. (Source)

Biomass is renewable organic material that comes from plants and animals. Biomass was the largest source of total annual U.S. energy consumption until the mid-1800s. Plants that are the source of biomass for energy capture almost the same amount of CO2 through photosynthesis while growing as is released when biomass is burned, which can make biomass a carbon-neutral energy source. Using wood, wood pellets, and charcoal for heating and cooking can replace fossil fuels and may result in lower CO2 emissions overall. Wood can be harvested from forests, from woodlots that have to be thinned, or from urban trees that fall down or have to be cut down.

Wood smoke contains harmful pollutants such as carbon monoxide and particulate matter. Modern wood-burning stoves, pellet stoves, and fireplace inserts can reduce the amount of particulates from burning wood. Wood and charcoal are major cooking and heating fuels in poor countries, but if people harvest the wood faster than trees can grow, it causes deforestation. Planting fast-growing trees for fuel and using fuel-efficient cooking stoves can help slow deforestation and improve the environment. (Source)

Cost per kilowatt-hour: A range of biomass power generation technologies are now mature and represent competitive power generation options wherever low-cost agricultural or forestry waste is available. In addition, new technologies are emerging that show significant potential for further cost reductions.

Secure, long-term supplies of low-cost, sustainably sourced feedstocks are critical to the economics of biomass power plants. Feedstock costs can be zero for some wastes, including those produced onsite at industrial installations such as black liquor at pulp and paper mills or bagasse at sugar mills, and their use can sometimes save on disposal costs. Bioenergy for power using sustainably sourced feedstocks, can provide dispatchable low-cost electricity and – in many circumstances – heat for industrial processes or heat networks. Regional or country weighted average levelized cost of electricity (LCOE) has ranged from $0.057/kWh in India, $0.062/kWh in China to $0.079/kWh in Europe and $0.097/kWh in North America over the last ten years, although if the heat is sold these values would be lower.

Individual projects typically generate electricity that costs between $0.03/kWh and $0.14/kWh. Many of the higher cost projects in Europe and North America using municipal solid waste as a feedstock rely on technologies with higher capital costs, as more expensive technologies are used to ensure local pollutant emissions are reduced to acceptable levels. (Source)

The environmental impacts of **geothermal energy** depend on how geothermal energy is used or how it is converted to useful energy. Direct use applications and geothermal heat pumps have almost no negative effects on the environment. Geothermal power plants have low emission levels because they do not burn fuel to generate electricity, but they may release small amounts of sulfur dioxide and carbon dioxide. Geothermal power plants use scrubbers to remove the hydrogen sulfide naturally found in geothermal reservoirs. Most geothermal power plants inject the geothermal steam and water that they use back into the earth. This recycling helps to renew the geothermal resource and to reduce emissions from the geothermal power plants.

Many geothermal features are national treasures. Geothermal features in national parks, such as geysers and fumaroles in Yellowstone National Park, are protected by law. (Source)

Cost per kilowatt-hour**:** Geothermal is among the cheapest forms of "always on" renewable generation where good resources exist, with costs as low as \$0.04/kWh for the most competitive brown-field projects. Between 2007 and 2019, the weighted-average levelized cost of electricity (LCOE) of geothermal varied from \$0.04/kWh for second-stage development of an existing field to as high as \$0.17/kWh for greenfield developments in remote areas. The global weighted-average LCOE increased from around \$0.05/kWh for projects commissioned in 2010 to around \$0.07/kWh in 2019. (Source)

Solar energy systems/power plants do not produce air pollution or greenhouse gases. Using solar energy can have a positive, indirect effect on the environment when solar energy replaces or reduces the use of other energy sources that have larger effects on the environment. However, some toxic materials and chemicals are used to make the photovoltaic (PV) cells that convert sunlight into electricity. Some solar thermal systems use potentially hazardous fluids to transfer heat. Leaks of these materials could be harmful to the environment. U.S. environmental laws regulate the use and disposal of these types of materials.

As with any type of power plant, large solar power plants can affect the environment near their locations. Clearing land for construction and the placement of the power plant may have long-term effects on the habitats of native plants and animals. Some solar power plants may require water for cleaning solar collectors and concentrators or for cooling turbine generators. Using large volumes of ground water or surface water for cleaning collectors in some arid locations may affect the ecosystems that depend on these water resources. In addition, the beam of concentrated sunlight a solar power tower creates can kill birds and insects that fly into the beam. (Source)

Cost per kilowatt-hour: In 2017, the solar industry achieved a cost target of \$0.06 per kilowatt-hour for utility-scale photovoltaic (PV) solar power, dropping from about \$0.28 to \$0.06 per kilowatt-hour (kWh). Cost targets for residential- and commercial-scale solar have dropped from \$0.52 to \$0.16 and from \$0.40 to \$0.11 per kWh respectively. (Source)

Wind is an emissions-free source of energy. Wind turbines do not release emissions that can pollute the air or water (with rare exceptions), and they do not require water for cooling. Overall, using wind to produce energy has fewer negative effects on the environment than many other energy sources. An individual wind turbine has a relatively small physical footprint. Groups of wind turbines, sometimes called wind farms, are located on open land, on mountain ridges, or offshore in lakes or the ocean.

Modern wind turbines can be very large machines, and they may visually affect the landscape. A small number of wind turbines have also caught fire, and some have leaked lubricating fluids, but these occurrences are rare. Some people do not like the sound that wind turbine blades make as they turn in the wind. Some types of wind turbines and wind projects cause bird and bat deaths. These deaths may contribute to declines in the population of species also affected by other human-related impacts. The wind energy industry and the U.S. government are researching ways to reduce the effect of wind turbines on birds and bats.

Most wind power projects on land require service roads that add to the physical effects on the environment. Producing the metals and other materials used to make wind turbine components has impacts on the environment, and fossil fuels may have been used to produce the materials. (Source)

Cost per kilowatt-hour: The cost of electricity from wind continues to fall, driven by declines in wind turbine prices—prices have fallen by between 44%-78% from their peaks—and plant cost reductions and wind turbine technology improvements, especially larger rotor diameters and higher hub-heights, that mean more energy can be harvested from sites with the same wind speeds.

The global weighted-average cost of electricity of new onshore wind farms in 2019 was $0.053/kWh with country/region values of between $0.051 and $0.099/kWh depending on the region. Costs for the most competitive projects are now as low $0.03/kWh, without financial support.

Offshore wind, with deployment of around 28 GW in 2019 compared to onshore wind with 594 GW, was relatively more expensive than onshore wind but costs have declined from the peak in 2014 to $0.115/kWh in 2019. Cost reductions have been driven by the growing maturity of the industry; the growing competitiveness of the market driven by competitive auctions in both established and new markets; establishment of mature supply chains in regional hubs, economies of scale; and advancements in wind turbine technology driving higher capacity factors and reducing installation costs. These cost reductions have been achieved despite the increasing complexity of projects located farther offshore, in deeper waters with harsher meteorology and oceanography conditions. (Source)

Here are impact summaries for each of the green power types that are hydropower based.

Large Hydropower has several environmental impacts. A dam that creates a reservoir (or a dam that diverts water to a run-of-river hydropower plant) may obstruct fish migration. A dam and reservoir can also change natural water temperatures, water chemistry, river flow characteristics, and silt loads. All of these changes can affect the ecology and the physical characteristics of the river. These changes may have negative effects on native plants and on animals in and around the river. Reservoirs may cover important natural areas, agricultural land, or archeological sites. A reservoir and the operation of the dam may also result in the relocation of people. The physical impacts of a dam and reservoir, the operation of the dam, and the use of the water can change the environment over a much larger area than the area a reservoir covers.

Cost per kilowatt-hour: The weighted average levelized cost of electricity (LCOE) of large-scale hydro projects at high-performing sites can be as low as $0.020/kWh, while average costs of the new capacity added in 2019 was slightly less than $0.050/kWh. For large hydropower projects the weighted average LCOE of new projects added over the past decade in China and Brazil was $0.04/kWh, around $0.08/kWh in North America, and $0.12/kWh in Europe. (Source)

Low-Impact Hydropower plants are run-of-river, meaning they have no reservoir, and their generating output is subject to changes in river flows.

Cost per kilowatt-hour: For small hydropower projects (1-10 MW) the weighted average LCOE for new projects ranged between USD 0.04/kWh in China, 0.06/kWh in India and Brazil and USD 0.13/kWh in Europe. (Source)

Tidal barrages

One type of tidal energy system uses a structure similar to a dam called a *barrage*. The barrage is installed across an inlet of an ocean bay or lagoon that forms a tidal basin. Sluice gates on the barrage control water levels and flow rates to allow the tidal basin to fill on the incoming high tides and to empty through an electricity turbine system on the outgoing ebb tide. A two-way tidal power system generates electricity from both the incoming and outgoing tides.

A potential disadvantage of tidal power is the effect a tidal station can have on plants and animals in estuaries of the tidal basin. Tidal barrages can change the tidal level in the basin and increase turbidity (the amount of matter in suspension in the water). They can also affect navigation and recreation.

Barrage of the tidal power plant on the estuary of the Rance River in Bretagne, France

Source: Stock photography (copyrighted)

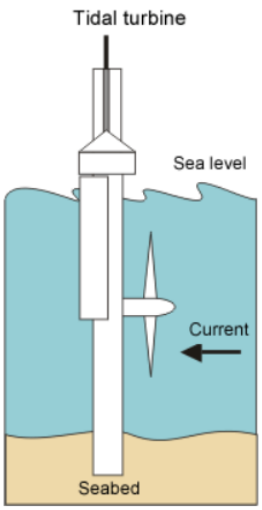
Several tidal power barrages operate around the world. Sihwa Lake Tidal Power Station in South Korea has the largest electricity generation capacity at 254 megawatts (MW). The oldest and second-largest operating tidal power plant is in La Rance, France, with 240 MW of electricity generation capacity. The next largest tidal power plant is in Annapolis Royal in Nova Scotia, Canada, with 20 MW of electricity generation capacity. China, Russia, and South Korea all have smaller tidal power plants.

Tidal turbines

Tidal turbines are similar to wind turbines in that they have blades that turn a rotor to power a generator. They can be placed on the sea floor where there is strong tidal flow. Because water is about 800 times denser than air, tidal turbines have to be much sturdier and heavier than wind turbines. Tidal turbines are more expensive to build than wind turbines but can capture more energy with the same size blades.

There are several demonstration tidal energy projects in various stages of development in the United States:

- Roosevelt Island Tidal Energy (RITE) Project Pilot in the East River of New York
- Western Passage Tidal Energy Project in Maine
- Cobscook Bay Tidal Energy Project in Maine



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

Tidal fences

A tidal fence is a type of tidal power system that has vertical axis turbines mounted in a fence or row placed on the seabed, similar to tidal turbines. Water passing through the turbines generates electricity. As of the end of 2019, no tidal fence projects were operating.

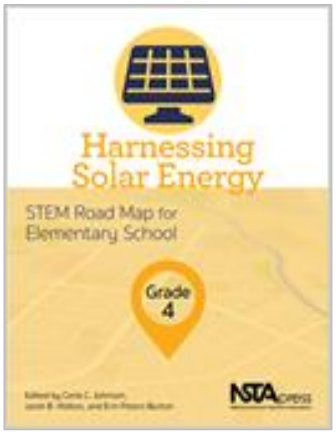
Vocabulary (Source)

- ✓ **Biomass energy** — is produced from non-fossilized plant materials. Wood and wood waste are the largest sources of biomass energy in the United States, followed by biofuels and municipal solid waste.
  - Wood biomass includes wood pellets; wood chips from forestry operations; residues from lumber, pulp/paper, and furniture mills; and fuel wood for space heating and cooking. The largest single source of wood energy is black liquor, a residue of pulp, paper, and paperboard production.
  - Biofuels include ethanol and biodiesel. Most of the fuel ethanol used in the United States is produced from corn. Biodiesel is made from grain oils and animal fats.
  - Municipal solid waste (MSW), or garbage, contains biomass (or biogenic) materials such as paper, cardboard, food scraps, grass clippings, leaves, wood, leather products, and non-biomass combustible materials (mainly plastics and other synthetic materials made from petroleum). MSW is burned in waste-to-energy plants to generate electricity. Many landfills in the United States collect and burn biogas to produce electricity.

- ✓ **Geothermal energy** — is heat from the hot interior of the earth or near the earth's surface. Fissures in the earth's crust allow water, heated by geothermal energy, to rise naturally to the surface at hot springs and geysers. Wells drilled into the earth allow a controlled release of steam or water to the surface to power steam turbines to generate electricity. The near constant temperature of the earth near the earth's surface is used in geothermal heat pumps for heating and cooling buildings.
- ✓ **Hydropower** — is produced from flowing water. Most hydropower produced in the United States is from large facilities built by the federal government, such as the Grand Coulee Dam on the Columbia River in Washington state—the largest single U.S. electric power facility. There are two general types of hydropower:
    - Conventional hydropower uses water in dams or flowing in streams and rivers to spin a turbine and generate electricity.
    - Pumped storage systems use and generate electricity by moving water between two reservoirs at different elevations.
- ✓ **Solar energy** — use of radiation from the sun to produce heat and electricity. There are three basic categories of solar energy systems:
    - Solar thermal systems use solar collectors to absorb solar radiation to heat water or air for space heating and water heating.
    - Solar thermal power plants use concentrating solar collectors to focus the sun's rays to heat a fluid to a high temperature. This fluid generates steam to power a turbine and a generator.
    - Photovoltaic (PV) systems use solar electric cells that convert solar radiation directly into electricity. Individual PV cells are arranged into modules (panels) of varying electricity-producing capacities. PV systems range from single PV cells for powering calculators to large power plants with hundreds of modules to generate large amounts of electricity.
- ✓ **Tidal energy** - The United States does not have any commercially operating tidal energy power plants, although several demonstrations projects are in various stages of development. Two places in the United States with potential for tidal power are the Cook Inlet of Alaska, which has the second-highest tidal range in North America, and several places in Maine. Producing tidal energy economically requires a tidal range of at least 10 feet. (Source)
- ✓ **Wind energy** — wind turbines use blades to collect the wind's kinetic energy. Wind flows over the blades creating lift, which causes the blades to turn. The blades are connected to a drive shaft that turns an electric generator, which produces electricity.

Extension Resources

Grade 4: Harnessing Solar Energy

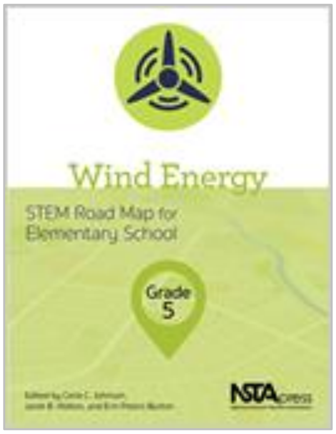


What if you could challenge your fourth graders to use solar energy to provide the world with clean water? *Harnessing Solar Energy* outlines a journey that will steer your students toward authentic problem solving while grounding them in integrated STEM disciplines. The series is designed to meet the growing need to infuse real-world learning into K–12 classrooms.

This book is an interdisciplinary module that uses project- and problem-based learning to investigate energy and energy sources, with a focus on solar energy and water scarcity.

GO TO RESOURCE

Grade 5: Wind Energy



What if you could challenge your fifth graders to develop an economical, eco-friendly wind farm? *Wind Energy* outlines a journey that will steer your students toward authentic problem solving while grounding them in integrated STEM disciplines. The series is designed to meet the growing need to infuse real-world learning into K–12 classrooms.

This book is an interdisciplinary module that uses project- and problem-based learning to investigate the interactions of Earth's systems, including geography, weather, and wind.

GO TO RESOURCE

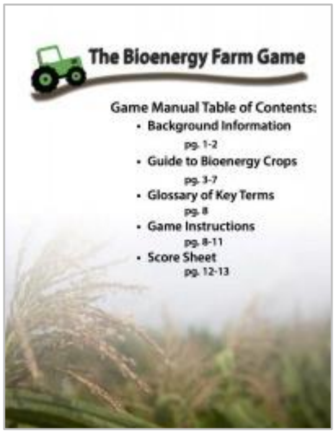
Middle/High School: Working with Wind Energy

The lesson focuses on how wind energy can be generated on both a large and small scale. Students read about anemometer and site testing for wind turbines and learn about engineering design and how engineering can address society's challenges. Students work in teams to design and build their own windmill out of everyday items which they select and purchase with a budget. They test their windmill, evaluate their results, and present reflections to the class.

The teacher can begin the lesson with a video of wind turbines such as the one found at https://www.pbs.org/video/nova-wind-power/ to elicit student questions and prior experiences. The full lesson plan and student worksheets can be downloaded from the TryEngineering.org website. Lessons have been translated into several languages.

GO TO RESOURCE

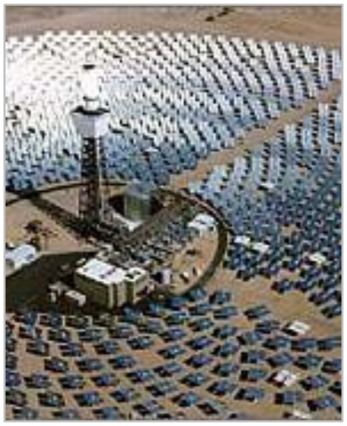
Middle/High School: The Bioenergy Farm Game



In this board game, players take on the role of bioenergy crop farmers trying to earn a living while being good environmental stewards. In the process, players explore the economic and environmental tradeoffs associated with growing different bioenergy crops, more specifically biofuel crops used in ethanol production. The game serves as an engaging way to explore a range of environmental issues and ecological interactions related to climate change mitigation (CO_2 emissions), biodiversity conservation (pesticide use), water quality (erosion/nutrient runoff) and sustainable agriculture. The goal of the game is to plant and manage a farm so as to make money and create positive environmental impacts while respecting chosen values and goals. The resource includes a game board, card deck, and a manual.

GO TO RESOURCE

High School: Concentrated Solar Power

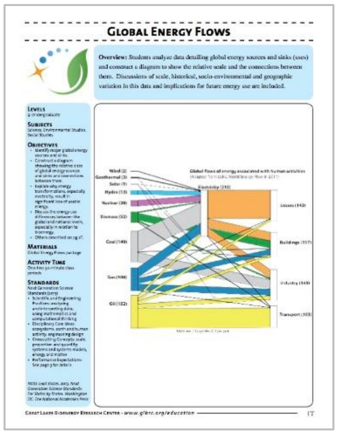


In this activity students learn how the total solar irradiance hitting a photovoltaic (PV) panel can be increased through the use of a concentrating device, such as a reflector or lens. This is the final lesson in the Photovoltaic Efficiency unit and is intended to accompany a fun design project (see the associated Concentrating on the Sun with PVs activity) to wrap up the unit. However, it can be completed independently of the other unit lessons and activities.

This resource provides background information about photovoltaic cells, has class discussion and assessment materials, and then incorporates all of those components into a laboratory activity in which the students determine the optimal angle of a reflector so as to obtain the maximum power output from a photovoltaic cell. The engineering iteration process is a key component of this resource.

GO TO RESOURCE

High School: Global Energy Flows



In this activity students analyze data detailing global energy sources and uses, then construct a diagram to show the relative scale and connections between them. Discussions of scale, historical, socio-environmental, and geographic variation in this data and implications for future energy use are included.

In the assessment students use the information from data obtained, analyzed, and evaluated in parts one through three to make predictions on how and why energy sources and uses will change in the next twenty years. Students must use the science and engineering practice of obtain, evaluate, and communicate information, crosscutting concept of energy and matter, and disciplinary core idea of natural resources to be able to create this visual or written explanation of future energy use.

GO TO RESOURCE

Additional Reading

Creating Engineering Design Challenges [fee]

If you’re looking for ways to make science and math more relevant to your middle or high school students, *Creating Engineering Design Challenges* is the book for you. At its core are 13 units grounded in challenge-based learning and the engineering design process. You can be sure the units are classroom-ready because they were contributed by teachers who developed, used, and revised them during the Cincinnati Engineering Enhanced Math and Science (CEEMS) program, a project funded by the National Science Foundation.

The contributors’ goal is to help you benefit from their hard-won experience. Working from their advice, you can develop a more student-centered classroom culture and nurture learners who are engaged in real-life engineering challenges.

GO TO RESOURCE

Tasks #7 and #8: What are the Best Types of Renewable Energy? Parts 1 & 2

Overview

Not all types of renewable energy have low or no greenhouse gas (GHG) emissions. There are differences between them that may not be apparent when comparing only the generation process. These tasks encourage taking a closer look at the lifecycle impacts of renewable versus green energy.

Learning Objectives

- ✓ Students will be able to explain the difference between renewable and green energy sources.
- ✓ Students will be able to state the main benefits of green energy (i.e. reduced GHG emissions and reduced carbon footprint).
- ✓ Students will be able to explain why lifecycle analysis of renewables helps clarify which energy technologies are the greenest.

Background

The United States is responsible for ~15% of global carbon dioxide emissions, and 93% of carbon dioxide emissions in the United States in 2017 were attributed to fossil fuel combustion related to energy generation (Source).

Decarbonizing the energy system means replacing the fossil fuel energy sources currently being used (such as coal, oil/petroleum, and natural gas) with energy sources that emit far less carbon dioxide (such as wind, solar, and nuclear energy). Decarbonizing the energy system within the next few decades is necessary to prevent catastrophic climate change impacts (Source).

The federal government is required under the National Environmental Policy Act (NEPA) to conduct an environmental assessment or the more comprehensive environmental impact study (EIS) to assess the environmental effects of many proposed actions prior to making decisions. The range of actions covered by NEPA is broad and includes:

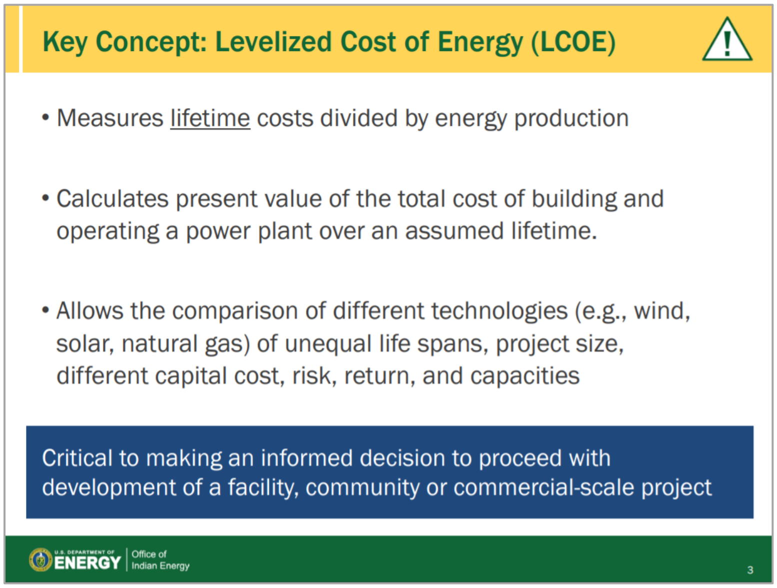
- making decisions on permit applications (e.g. power plant operations),
- adopting federal land management actions, and
- constructing highways and other publicly-owned facilities (e.g. hydro-electric dams).

Since 2010 the Council on Environmental Quality (CEQ) has issued guidance on the consideration of greenhouse gases. In response to a Presidential Executive Order 13990, CEQ rescinded its 2019 Draft NEPA Guidance on Consideration of Greenhouse Gas Emissions and is reviewing, for revision and update, the 2016 Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews. However, neither the CEQ nor NEPA categorize specific sources or types of energy as renewable or green.

So, what's the difference between renewable and green sources of energy? The primary way to differentiate between the two types is to compare their environmental impacts. In other words, how polluting is a particular energy technology? However, such a comparison needs to look beyond just the operational impacts. Utilizing a lifecycle cost assessment allows apples-to-apples comparisons of the different sources.

Power Generation Costs

The cost competitiveness of renewable power has reached historic levels, with 56% of utility-scale capacity of renewables added in 2019 costing less than the cheapest new coal option. Utility-scale solar PV, biomass for power, hydropower, geothermal and onshore wind can all now provide electricity competitively compared to fossil fuels. Concentrating solar power and onshore wind are the much less deployed, but already auction results show they will also be competitive in the coming 2-4 years. Cost reductions for solar and wind power technologies will continue into the future, as further equipment and balance of plant cost reductions and performance improvements can be expected, which will lower the weighted average levelized cost of electricity (LCOE) of renewables.



Consequently, renewable energy technologies now represent the most economical solution for new capacity in a growing number of countries and regions and are typically the most economical solution for new grid connected capacity, where suitable resources are available. (Source)

Vocabulary

- ✓ **Conventional power** - includes the combustion of fossil fuels (coal, natural gas, and oil) and the nuclear fission of uranium. Fossil fuels have environmental costs from mining, drilling, or extraction, and they emit greenhouse gases and air pollution during combustion. Although nuclear power generation emits no greenhouse gases during power generation, it does require mining, extraction, and long-term radioactive waste storage.
- ✓ **Green power** - a subset of renewable energy. It represents those renewable energy resources and technologies that provide the greatest environmental benefit. Green power is defined as electricity produced from solar, wind, geothermal, biogas, eligible biomass, and low-impact small hydroelectric sources.
- ✓ **Lifecycle analysis** – used to assess the overall greenhouse gas (GHG) impacts of a fuel, including each stage of its production and use.
- ✓ **Renewable energy** - resources that rely on fuel sources that restore themselves over short periods of time and do not diminish. Such fuel sources include the sun, wind, moving water, organic plant and waste material (eligible biomass), and the earth's heat (geothermal).

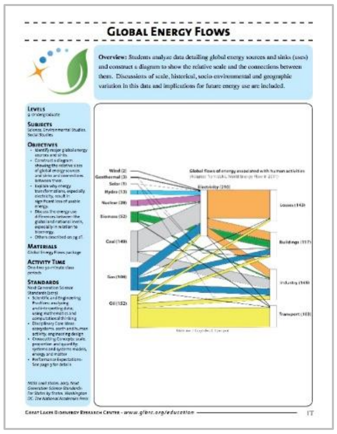
Additional Vocabulary

- ✓ **Council on Environmental Quality (CEQ)** — established by the National Environmental Policy Act (NEPA) to ensure that Federal agencies meet their obligations under NEPA. CEQ oversees NEPA implementation, principally through issuing guidance and interpreting regulations that implement NEPA's procedural requirements. CEQ also reviews and approves federal agency NEPA procedures, approves alternative arrangements for compliance with NEPA for emergencies, and helps to resolve disputes between federal agencies and with other governmental entities and members of the public. (Source)
- ✓ **Decarbonization** — a systematic effort of companies and governments to align with a low-carbon economy by reducing carbon emissions.
- ✓ **National Environmental Policy Act (NEPA)** — was signed into law on January 1, 1970. NEPA requires federal agencies to assess the environmental effects of their proposed actions prior to making decisions. The range of actions covered by NEPA is broad and includes:
    - making decisions on permit applications,
    - adopting federal land management actions, and
    - constructing highways and other publicly-owned facilities.

  Using the NEPA process, agencies evaluate the environmental and related social and economic effects of their proposed actions. Agencies also provide opportunities for public review and comment on those evaluations. (Source)
- ✓ **Net-zero emissions** — a state in which any carbon emissions produced are offset by removing carbon from the atmosphere.

Extension Resources

High School: Global Energy Flows



In this activity students analyze data detailing global energy sources and uses, then construct a diagram to show the relative scale and connections between them. Discussions of scale, historical, socio-environmental, and geographic variation in this data and implications for future energy use are included.

In the assessment students use the information from data obtained, analyzed, and evaluated in parts one through three to make predictions on how and why energy sources and uses will change in the next twenty years. Students must use the science and engineering practice of obtain, evaluate, and communicate information, crosscutting concept of energy and matter, and disciplinary core idea of natural resources to be able to create this visual or written explanation of future energy use.

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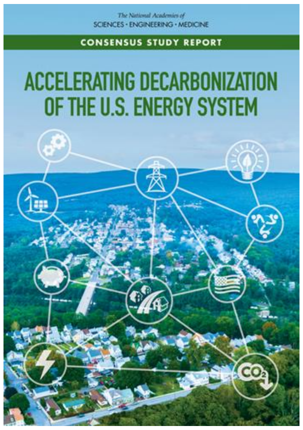
Additional Reading

Accelerating Decarbonization of the US Energy System [Free PDF]



The world is transforming its energy system from one dominated by fossil fuel combustion to one with net-zero emissions of carbon dioxide (CO2), the primary anthropogenic greenhouse gas. This energy transition is critical to mitigating climate change, protecting human health, and revitalizing the U.S. economy.

This report identifies key technological and socio-economic goals that must be achieved to put the United States on the path to reach net-zero carbon emissions by 2050. The report presents a policy blueprint outlining critical near-term actions for the first decade (2021-2030) of this 30-year effort, including ways to support communities that will be most impacted by the transition.

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Task #9: Find Out Why Electric Cars Can Help

Overview

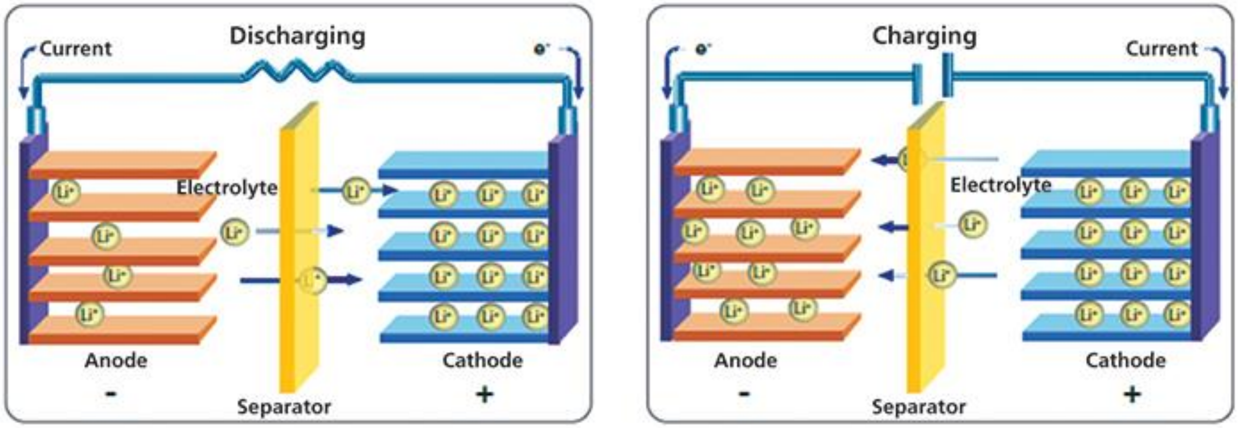
The largest source of greenhouse gas (GHG) emissions from human activities in the United States is from the burning of fossil fuels for electricity, heat, and transportation. To slow climate change, people will need to reduce greenhouse gas emissions in all three categories. In this activity the focus shifts to solutions in the transportation sector, specifically electric powered vehicles (EVs).

Learning Objectives

- ✓ Students will be able to explain the differences between electric vehicle battery components: a cell, a module, and a pack.
- ✓ Students will be able to explain what the three acronyms EV, PHEV, and HEV stand for.
- ✓ Students will be able to name several recent model electric cars.

Background

The electric vehicle was, in fact, developed before the internal combustion engine vehicle, but it did not become the mainstream in the market due to inefficient battery technology. This is changing. Behind the EV revolution is a shift to the lithium-ion battery from lead, nickel-cadmium, and nickel-metal-hydride batteries. Why? Longer life, higher energy density, and better reliability. As battery technology advances, more and more automakers are introducing electrified models.



(Source)

A cell is the smallest unit of a battery. They are comprised of four key components: a cathode, an anode, a separator, and an electrolyte. A battery pack that powers an electric vehicle consists of individual battery cells and modules organized in series and parallel with sensors and controllers, including a battery management system and thermal management system, which are all encased in a housing.

Vocabulary (Source: Samsung)

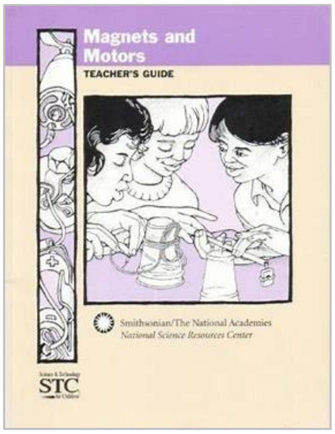
- ✓ **Battery cell** – basic unit of a battery that exerts electric energy by charging and discharging
- ✓ **Battery module** – a battery assembly put into a frame by combining a fixed number of cells
- ✓ Battery pack – final shape of the battery system installed in an electric vehicle (e.g., 8 modules (12 cells per module) go into a battery pack)
- ✓ **Carbon footprint** - the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions.
- ✓ **Greenhouse gas emissions** – gases that trap heat in the atmosphere including carbon dioxide, methane, and nitrous oxide

Additional Vocabulary (Source)

- ✓ **Anode** – the electrode at which an oxidation reaction occurs. This means that the anode electrode is a supplier of electrons. However, the electron flow reverses between charge and discharge activities. As a result, the positive electrode is the anode during charging and the negative electrode is the anode during discharging. To prevent confusion, the anode is normally defined by its activity during the discharge cycle. In this way the term anode is used for the negative electrode in a cell or battery.
- ✓ **Cathode** – the electrode in a battery or other system at which a reduction reaction occurs. The electrode takes up electrons from an external circuit. Accordingly, the negative electrode of the battery or cell is the cathode during charging and the positive electrode is the cathode during discharging. To prevent confusion the cathode is normally specified for the discharge cycle. As a result, the name cathode is commonly used for the positive electrode of the cell or battery.
- ✓ **Electrolyte** – the medium that provides the conduction of ions between the positive and negative electrodes of a cell.
- ✓ **Separator** – the membrane that is required within a cell to prevent the anode and cathode shorting together. With cells being made more compact, the space between the anode and cathode becomes much smaller and as a result the two electrodes could short together causing a catastrophic and possibly explosive reaction. The separator is an ion-permeable, electronically non-conductive material or spacer that is placed between the anode and cathode.

Extension Resources

Grade 6: Magnets and Motors [fee]



Students experience the historical development of the understanding of magnets. Student activities include:

- Making a compass.
- Building electromagnets and conducting experiments to test their strength.
- Constructing and operating two types of rudimentary electric motors to illustrate electromagnetism.
- Disassembling, experimenting with, and rebuilding a commercial electric motor.
- Producing electricity with an electric generator.

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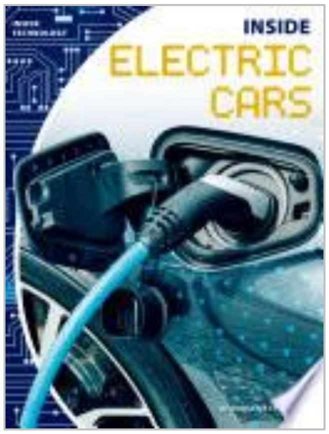
Additional Reading

Inside Electric Cars



Engineers are designing electric cars to replace public transportation, personal vehicles, and semitrucks—all while powered by electricity instead of fossil fuels. *Inside Electric Cars* introduces readers to the uses of electric cars, the hardware and software that make electric cars possible, and the future of electric car technology. Aligned to Common Core Standards and correlated to state standards.

Only available through a library at this time.

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Task #10: Pledge to be a Climate Superstar

Overview

Environmental education, specifically climate focused education, is about more than just disseminating information. The formula for success is often referred to as KAB or knowledge + attitude = behavior change. Individual actions alone will not be enough to avert the impacts of climate change. However, behavior changes do add up. Reducing our individual and collective carbon footprints can help.

Learning Objectives

- ✓ Students will know what the ENERGY STAR® program is and how it works to help protect the climate.
- ✓ Students will be able to explain the connection between saving energy at home and reducing greenhouse gas emissions.
- ✓ Students will be able to describe several actions you can take at home, along with other actions, that can help protect the climate, and why.

Background

The ENERGY STAR® label can be found on products, homes, commercial buildings, and industrial plants. The U.S. Environmental Protection agency sets energy-efficiency specifications that products and buildings meet to earn the ENERGY STAR® certification.

Since 1992, the ENERGY STAR® program and its partners helped American families and businesses save more than 4 trillion kilowatt-hours of electricity and achieve over 3.5 billion metric tons of greenhouse gas reductions, equivalent to the annual emissions of more than 750 million cars. In 2018 alone, ENERGY STAR® and its partners helped Americans avoid $35 billion in energy costs.

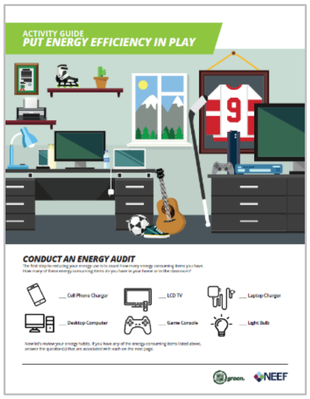
Products that earn the ENERGY STAR® label are independently certified to meet strict standards for energy efficiency set by the EPA. Products are tested in an EPA-recognized laboratory and reviewed by an EPA-recognized certification body before they can carry the label. More than 75 types of products carry the ENERGY STAR® label, including lighting, appliances, electronics and heating and cooling products. The blue label makes it easy for consumers and businesses to purchase products that save them money and protect the climate. (Source)

Vocabulary

- ✓ **Carbon footprint** – the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions. The average carbon footprint for a person in the United States is 16 tons; globally, the average is closer to 4 tons. (Source)
- ✓ **ENERGY STAR®** - the government-backed symbol for energy efficiency, providing simple, credible, and unbiased information that consumers and businesses rely on to make well-informed decisions. (Source: EPA ENERGY STAR®)

Extension Resources

Put Energy Efficiency in Play



This activity guide, developed for the National Hockey League (NHL®) and its partners, is all about making energy-saving plays to reduce individual greenhouse gas emissions, including switching to more efficient lighting and installing solar panels.

Join them by taking action at home or at school to reduce your energy use. Conduct an energy audit to find out how much energy your electronics draw when they're not in use. Then, make your own energy-saving plays to reduce your energy use and greenhouse gas emissions.

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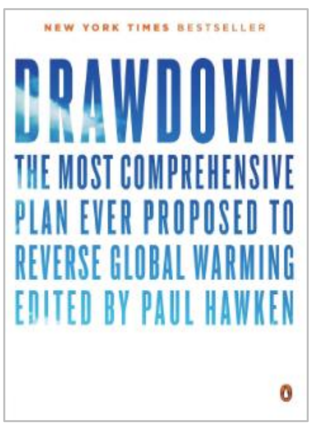
Additional Reading

Drawdown [fee]



Renewable The 2017 book *Drawdown* describes the 100 most substantive solutions to global warming. For each solution, the authors describe its history, the carbon impact it provides, the relative cost and savings, the path to adoption, and how it works. The goal of the research that informs *Drawdown* is to determine if humans can reverse the buildup of atmospheric carbon within thirty years. All solutions modeled are already in place, well understood, analyzed based on peer-reviewed science, and are expanding around the world. Upcoming guides will help individuals and communities take action on *Drawdown* solutions. Explore impactful actions you can take to help the world reach drawdown through your everyday lifestyle choices. Discover how you can multiply your impact for a climate-safe future.

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