Welcome!

Climate Superstars is an annual contest and collaborative educational partnership between the National Environmental Education Foundation (NEEF), the 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. Although alignment with specific NGSS standards is not called out, components of three-dimensional learning (i.e. core disciplinary ideas, science and engineering practices, and cross cutting concepts) are evident throughout. 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, etc.). 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.
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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.

Background Information

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).

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.

(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.

Koppen Climate Zones

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, etc.) 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.
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.
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)

Background Info

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)

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.

Ten Indicators of a Warming World

Scientists use key indicators (i.e. quantifiable variables) to track changes over time. NOAA has developed a dashboard to help visualize the data sets. Use the dashboard to explore how these indicators are related.

(Source)
Click the parameters to move them into one of the three viewing slots. The dashboard provides a visual way to learn more about how the changes scientists are observing relate to each other.

Vocabulary

- **Correlation** – a mutual relationship or connection
- **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.

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.
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 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!

Background Info

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]

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.

<table>
<thead>
<tr>
<th>The 1990 Clean Air Act Amendments prevent:</th>
<th>Year 2010 (cases)</th>
<th>Year 2020 (cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult Mortality - particles</td>
<td>160,000</td>
<td>230,000</td>
</tr>
<tr>
<td>Infant Mortality - particles</td>
<td>230</td>
<td>280</td>
</tr>
<tr>
<td>Mortality - ozone</td>
<td>4,300</td>
<td>7,100</td>
</tr>
<tr>
<td>Chronic Bronchitis</td>
<td>54,000</td>
<td>75,000</td>
</tr>
<tr>
<td>Acute Myocardial Infarction</td>
<td>130,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Asthma Exacerbation</td>
<td>1,700,000</td>
<td>2,400,000</td>
</tr>
<tr>
<td>Emergency Room Visits</td>
<td>86,000</td>
<td>120,000</td>
</tr>
<tr>
<td>School Loss Days</td>
<td>3,200,000</td>
<td>5,400,000</td>
</tr>
<tr>
<td>Lost Work Days</td>
<td>13,000,000</td>
<td>17,000,000</td>
</tr>
</tbody>
</table>

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

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.

*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.
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.

*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.
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.

Background Info

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 (CO₂), methane (CH₄), ozone (O₃), and nitrous oxide (N₂O). The man-made or synthetic GHG include the chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). Emissions of the different greenhouse gases have different global warming potentials. To make comparisons easier scientists estimate emissions in tons of CO₂ equivalent.
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 (CO₂)** 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 (CH₄)** is an extremely effective absorber of radiation. Its atmospheric concentration is less than CO₂ 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 (O₃)** 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 (N₂O)** 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 (CF₄) and sulfur hexafluoride (SF₆), 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.
- **Greenhouse effect** – a phenomenon that occurs when gases in the atmosphere trap heat emitted by the planet.

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.
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 CO₂.

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.
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.

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 Info

In the United States, about 65% of total electricity generation in 2018 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 (CO₂) 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. CO₂ 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 (SO₂) 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. SO₂ causes acid rain, which is harmful to plants and animals. SO₂ also worsens respiratory illnesses and heart diseases, particularly in children and the elderly.

- Nitrogen oxide (NOx) gases contribute to ground-level ozone (O₃), which irritates and damages the lungs.
- Particulate matter (PM) results in hazy conditions in cites and scenic areas and coupled with ozone (O₃), 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.
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.
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.

Background Info

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.

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.

Some renewable energy sources (e.g. biomass and biofuels) have significant environmental and social impacts because their production and/or use involves combustion that results in emissions. A subset of renewables are called green energy or green power because of their better environmental footprint.
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.

**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.
  ✓ 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.
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.

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/](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.
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 (CO₂ 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.

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.
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.

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.
Help Protect the Climate, Take the ENERGY STAR® Pledge

Overview

ENERGY STAR® is the government-backed symbol for energy efficiency, providing simple, credible, and unbiased information that consumers and businesses rely on to make well-informed decisions. Thousands of industrial, commercial, utility, state, and local organizations—including about 40% of the Fortune 500®—partner with the U.S. Environmental Protection Agency (EPA) to deliver cost-saving energy efficiency solutions that improve air quality and protect the climate.

Background Info

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

- Energy efficient – uses less energy to get the same job done.
- Metric ton (or tonne) – a unit of mass equal to 1,000 kilograms (approximate equivalent is 2,205 lbs.)
- Short ton – a mass measurement unit equal to 2,000 pounds-mass (907.18474 kg). Its usage is confined to the United States.

Extension Resources
Designing a Sustainable Neighborhood

Learn to design homes that are both energy efficient and affordable.

Additional Reading

Renewable Energy and Wildlife Conservation [fee]

Renewable energy is often termed simply "green energy," but its effects on wildlife and other forms of biodiversity can be quite complex. While capturing renewable resources like wind, solar, and energy from biomass can require more land than fossil fuel production, potentially displacing wildlife habitat, renewable energy infrastructure can also create habitat and promote species health when thoughtfully implemented.

The authors of *Renewable Energy and Wildlife Conservation* argue that in order to achieve a balanced plan for addressing these two crucially important sustainability issues, actions at the nexus of these fields must be directed by current scientific information related to the ecological effects of renewable energy production.
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).

Background Info
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.

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.

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)

✓ **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.
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.
Streaming Smart

Overview

Most people are blissfully unaware that whenever they access the internet, they are actually using a considerable amount of electricity. In fact, the greenhouse gas emissions released to power the internet are greater than the emissions from the entire world airline industry. And, according to a new report, this energy consumption is growing alarmingly fast, chiefly owing to one particular behavior, which is eclipsing all other internet traffic: people streaming video and movies. [Source]

Background Info

When it comes to listening to music or watching TV things sure have changed. The Horowitz Research report, State of Pay TV, OTT and SVOD 2017, reveals that 70% of those viewing video content did so through a streaming service, and that 40% of TV viewing was done this way, twice the number from five years earlier. Millennials, the report said, streamed 60% of the content they viewed. Internet use and online services underpin everyday life, and the resultant energy demand is almost entirely hidden, yet significant and growing: it is anticipated to reach 21% of global electricity demand by 2030 and to eclipse half the greenhouse gas emissions of transportation by 2040. Driving this growth, the viewing of real-time video streaming is estimated at around 50% of all peak data traffic. [Source]

Learning Objectives

✓ Students will be able to identify which types of streaming devices are most energy efficient.
✓ Students will be able to explain where the unseen energy needed for streaming is consumed.
✓ Students will be able to give an example of when streaming is less energy efficient long-term.
Learn About Energy Vampires

Overview

In a culture of instant everything it should come as no surprise that many consumer products are standing by ready to do their thing with the press of a button. This standby power mode has become ubiquitous, but at a hidden cost. What is that hidden cost? Wasted electricity. Electricity that, depending on its source, produces greenhouse gas emissions that contribute to global warming and climate change.

Background Info

What can be done to fix this energy vampire problem? Ensuring that devices are designed to use as little electricity as possible when not in use is a challenge for the business sector. Optimizing energy use will help reduce emissions and slow the need to build new energy infrastructure capacity.

There are actions that consumers can take, too. Just like turning off the lights when not in a room, turn off devices fully when not using them. Use a power strip or unplug devices that cannot be fully turned off. And when the time comes, replace inefficient devices with ENERGY STAR® certified products.

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.
Additional Viewing

The Story of Electronics

*The Story of Electronics*, released in November 2011, employs the Story of Stuff style to explore the high-tech revolution’s collateral damage—25 million tons of e-waste and counting, poisoned workers, and a public left holding the bill. Host Annie Leonard takes viewers from the mines and factories where gadgets begin to the backyard recycling shops in China where many end up. The film concludes with a call for a green ‘race to the top’ where designers compete to make long-lasting, toxic-free products that are fully and easily recyclable.