
Sean Hanley and G. Anthony Svatek

## UNIT 1

# Energy & the environment

# INTRODUCTION TO THE UNIT FOR TEACHERS

## Observing energy on Jones Beach

What is energy? The *Energy & Us* curriculum explores this question first at the smallest scale, on the level of atomic phenomena, chemical interactions, and physical laws. Energy shapes every corner of the universe but is particularly easy to find on Jones Beach, where waves crash and sunlight filters through clouds.

In this Unit, students will synthesize a baseline of knowledge about the physics of energy through a close engagement with the landscape of the beach itself. Exploring the beach on foot yields plenty of examples of different forms of energy, instances of energy transfer in action, and places where the physical laws that govern energy, including the laws of thermodynamics, can be observed at work.

Then, returning to the Jones Beach Energy & Nature Center building, students begin to connect manifestations of energy in the environment to the role of energy as a tool of human use and how it can be produced, distributed, and consumed using technology. Hands-on experimentation with the building blocks of electricity demonstrates how certain conditions must be met for electrons to flow in a current through a closed circuit built out of a generator, conductor, and insulator. First-hand observation of the electrical system in the building sets the stage for subsequent discussions of efficiency and system design. Both experiences help underscore the physicality of energy.

Finally, the atomic is connected to the societal level through the environmental impacts of energy consumption. Extracting, processing, distributing, and consuming energy sources necessarily alters, and often damages, the complex natural dynamics that connect all aspects of the environment. Foremost among these impacts is the greenhouse effect, a molecular event with global consequences. In this Unit, students begin to think through the social consequences of energy consumption and grapple with the hard choices inherent in any attempt to balance human society, environmental stewardship, and the physics and chemistry of energy.

## Objectives

Synthesize what students already know about the physical science of energy.

Reflect on the different ways that energy exists in and moves through natural systems, including students' own bodies.

Recognize the human-built systems and tools that transform and transfer energy for human purposes.

Consider how history, society, and culture shape relationships to energy and the development of energy systems.

Understand students as agents with the potential to impact local and global environments through participation in energy networks.

## Learning standards

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

### Science Learning Standards

**PS1-8 PS1-2 PS1-4 PS1-12 PS2-3 PS2-5 PS2-6 PS3-1 PS3-2 PS3-3 PS3-4**
**PS3-5 PS3-6 PS4-1 PS4-3 PS4-4 PS4-5 LS1-2 LS1-3 LS1-5 LS2-1 LS2-2 LS2-3**
**LS2-4 LS2-5 LS2-6 LS2-7 LS2-8 LS4-5 ESS2-1 ESS2-2 ESS2-5 ESS2-6 ESS2-7**

### Social Studies Framework

**Practices | A1 A2 A5 A6 B5 D1 D3 F2 F4**

**Themes | ID GEO TECH**

### More information:

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

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

## Key terms

Work
Energy transfer
First Law of Thermodynamics
Second Law of Thermodynamics
Conservation of Energy
Kinetic energy
Potential energy
Mechanical energy

Radiation
Photon
Atom
Neutron
Nucleus
Proton
Electron
Molecule
Matter
Boiling point, melting point
Conduction, conductor
Convection

Chemical energy
Combustion
Endothermic
Exothermic
Photosynthesis
Chemical digestion
Cellular respiration

Metabolism
Hibernation

Energy sources
Energy consumer
Energy producer
Distribution
Energy budget
Background energy consumption
Energy efficiency

Electrical energy
Electricity
Electromagnetism
Electron excitement
Generator
Electromagnetic induction
Current
Voltage
Electrical potential

Circuit
Short circuit
Load
Resistance
Insulation, insulator
Superconductor
Efficiency

Battery
Anode
Cathode
Electrolyte

Renewable energy sources
Fossil fuels
Human impacts
Hydraulic fracturing, fracking
Crude oil
Pollution

Greenhouse effect
Enhanced greenhouse effect
Anthropogenic climate change
Greenhouse gases
Radiative forcing
Infrared
Global Warming Potential
Black Carbon
Carbon Dioxide ($CO_2$)
Fluorinated gases
Methane ($CH_4$)
Nitrous Oxide ($N_2O$)

## CORE CONCEPT 1

# Energy occurs naturally in the environment

Energy in the environment takes different forms, including heat, light, and movement. Energy can be transformed and transferred, but never created or destroyed.

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## Welcome to Jones Beach

With this Core Concept, students begin to build awareness of the relationship between energy and change in natural and human-made environments. Observing energy in action around the Jones Beach Energy & Nature Center and on the West End of Jones Beach, students synthesize the principles of energy transfer and transformation at the atomic scale in order to better understand and describe the physical phenomena they directly witness. At both the micro and macro scale, energy is a capacity for work in constant flux throughout the material world. This knowledge is foundational for later Core Concepts, as students consider how the physical mechanics of energy shape the design of energy infrastructure and renewable energy technologies, as well as energy-efficient and carbon-neutral design.

Jones Beach provides abundant examples of energy and energy transfer in nature, such as the radiant energy of sunlight and the kinetic energy of wind and waves. The discussion activity is presented with guidance for an inquiry-based walking tour of the Jones Beach Energy & Nature Center and its surrounding landscape, so groups working with the curriculum on site can observe energy in action and connect their direct experience to principles from the science classroom.

In the take-home activity, students use these observations to begin to recognize the natural sources of energy that are available around them at all times. Students document and diagram instances of energy transfer they observe in their home environment and begin to think about what would be necessary to convert these sources of energy into other forms. By the end of this Core Concept, students should be able to describe narratively how different masses possess different amounts of energy in relation to each other, how energy moves between masses, and how masses change when they possess different kinds of energy. They should also begin to think critically about the duality of energy as an object of inquiry within science and as a concept in society and culture.


Jones Beach Energy & Nature Center, south side
Michael Moran, courtesy of nArchitects

# What is energy?

**How do I define energy?**

**How does my body use energy?**

**How do I encounter energy in my daily life?**

Energy is an abstract concept or idea in everyday life, describing intentionality or agency.

Energy is something that exists in living bodies. The term can refer to the nutrients that bodies consume and digest, or a felt sense of physical capacity deriving from that consumption.

Energy is also something in the social world that people use and struggle over. Students might think of fuel or electricity, as well as "climate change," "energy policy," or "renewable energy."

At the Jones Beach Energy & Nature Center, energy underlies relationships of interdependence between humans and their environment. The Center is dedicated to exploring the natural and human-made energy systems that shape the world in which we live, from the food web to the Energy Grid, as well as the continuous flow of exchange between those systems.

All of these definitions of energy have a role to play on Jones Beach and in this Curriculum.

## PRIMER

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

# DISCUSSION

## AT THE CENTER

Location:
South Porch

Prepare to walk from the Center to the beach. The walk takes about 15 minutes.

Groups working with the curriculum off site can use the Ecosystems Video to ground the discussion.

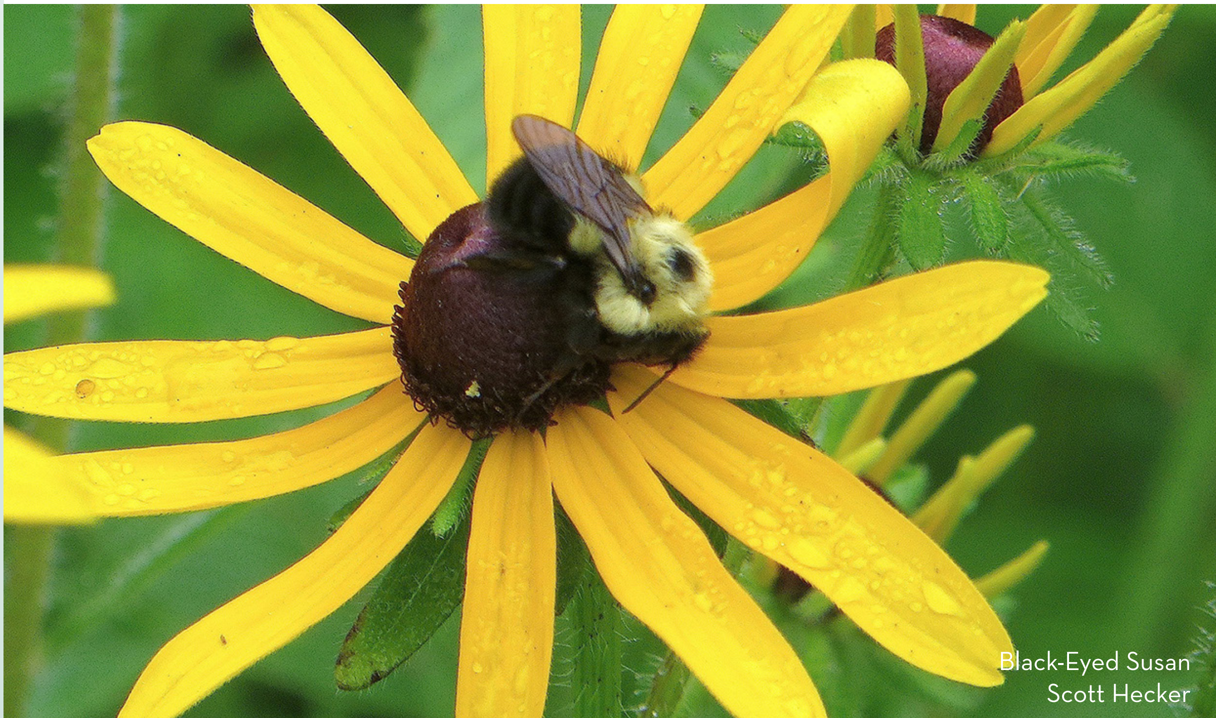
### Where do we find energy on Jones Beach?

Note light and warmth from the sun, the motion of the water and wind, the sound of breaking waves, and the food local animals eat as examples where energy is clearly present here.

Jones Beach Island is a barrier island, located in the Atlantic Ocean off the southern coast of Long Island, New York. Jones Beach is part of New York's state park system, and the West End of Jones Beach provides protected habitat for a number of Endangered and Threatened species. Jones Beach is a rich landscape that includes several distinct ecosystems, from the beach front to the dunes to the salt marsh to the Center's own Pollinator Garden. In each of these systems, energy moves within and between organisms as they eat, digest, grow, reproduce, die, and decompose in a continuous cycle of life.

Scientists in different disciplines define and study energy in different ways because they examine the world at different scales. Biologists, for instance, study how living beings work; in biology, energy moves between cells within organisms, allowing them to perform the cellular functions necessary for life. Ecologists, meanwhile, study the relationships between living beings in an environment, as energy cycles through an ecosystem and allows organisms to grow and reproduce.

Energy can also be studied at a much smaller scale, as changes take place within the physical material – the matter – that makes up ecosystems, organisms, and their cells. This scale is the domain of physics and chemistry. For these disciplines, energy is a quantity of potential, the ability to do "work," which is to say the capacity to create change within matter, by changing its state or its position in the universe. In fact, all of the phenomena that indicate the movement of energy through bodies and ecosystems – a bird flying, a flower blossoming, a turtle laying eggs – reflect the work occurring at microscopic and atomic scales.



Black-Eyed Susan
Scott Hecker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## Energy in the universe

Matter is anything that has mass and takes up space in the universe. Atoms are the basic building blocks of all matter. Each atom contains a nucleus, made of neutrons and protons, and an orbit of constantly moving, negatively charged electrons, which surround and are bound to the nucleus by their electromagnetic attraction to positively charged protons. Molecules are formed by a chemical bond between atoms that share electrons.

To understand how energy creates change within the matter that makes up the universe, scientists separate systems from their surroundings. A system is the part of the universe being studied, and the surroundings includes everything else.

### What is "matter" on Jones Beach?

On the beach, matter includes ocean water, seaweed, salty air, sand, and the flesh of Piping Plovers and the insects they eat. For the purposes of scientific observation, a system could be the whole planet, the Atlantic Ocean, an oyster reef, an individual fish, or a single cell. No matter the scale of our inquiry, the principles governing how energy moves through the universe remain the same.

Energy enables all the plants, animals, microbes, soil, water, and air of Jones Beach to effect change within each other constantly. To understand how energy shapes an environment like Jones Beach, we must understand the connection between the larger energetic phenomena that can be observed with human eyes and events that occur at the microscopic and sub-microscopic level. Luckily, the beach is an ideal place to observe energy in motion at all of these scales and to see how the fundamental principles of energy express themselves in the physical world.

## AT THE CENTER

Location:
West End beach,
facing the tideline

Ricky Shore

**REVIEW**

## Types of energy in physics

Kinetic energy is the energy of movement: mass in motion has kinetic energy. But forms of energy that do not appear as movement to the naked eye are nonetheless kinetic energy — heat and light, for instance, are produced by the motion of particles.

Potential energy is stored energy, possessed by an object by virtue of its position relative to other objects. Matter is subject to forces, like gravity or electromagnetism, that push it toward or away from different objects. In the moments before the matter obeys the forces acting upon it, the matter contains potential energy; when matter finally obeys the force, this energy is released.

Chemical energy, the energy released by breaking chemical bonds, is also potential energy. This kind of stored energy is derived from the position of particles, atoms, and molecules relative to one another. Potential energy transforms into kinetic energy when matter changes its state or when energy is added to a system.

## Energy conservation and transfer

Energy cannot be created or destroyed. Any time energy is transformed or transferred, the total amount of energy in the universe remains the same. This principle, often referred to as the "Conservation of Energy," is the basis of the First Law of Thermodynamics. According to this law, adding any amount of heat to a system causes the internal energy of that system, and its ability to do work on its surroundings, to increase an equal amount.

Energy in the universe flows in one direction: from high energy concentrations to low energy concentrations, seeking an equilibrium. In the context of thermodynamics (specifically the Second Law of Thermodynamics) this means that heat naturally flows from warm objects and systems to colder objects and systems. The same principle applies when light, sound, and vibration, rather than heat, are the physical evidence of energy moving through matter.

Because energy naturally dissipates, maintaining a system in a state of high energy requires a continuous input. This explains why machines require an energy source in order to keep running, and why organisms die without food.

## What types of energy can be found on Jones Beach?

Waves rise and fall, tides flow in and out. Water in motion clearly possesses kinetic energy. Piping Plovers run across the sand, people walk to and from the beach or swim in the water, and the wind blows through the grass. These are all examples of matter possessing kinetic energy.

Waves are also an example of potential energy. Like all matter, water is subject to gravity: when water is massed at the peak of a wave, it contains potential energy in proportion to the force of gravity acting on that mass. The ocean's tides are also subject to the gravitational force of the moon, so waves contain potential energy in proportion to that force. Anyone who has floated in the ocean's waves will be familiar with the feeling of suspension at the top of a wave before it comes down toward the shore. As the wave breaks, that potential energy transforms into kinetic energy. Other examples of gravitational potential energy transforming into kinetic energy on the beach include seagulls drifting on currents and then diving, a shell picked up and dropped back to the ground, or detritus sinking to the ocean floor.

All organisms rely on chemical energy in order to live, grow, heal, and reproduce. The Pollinator Garden may be a better place to observe and discuss this kind of energy, but examples can be found on the beach as well: look for shorebirds picking insects out of the sand, sea gulls diving for scraps, or the dune grasses and seaweeds continually photosynthesizing.

## Where is energy transfer occurring on Jones Beach?

Breaking waves can be a fearsome sight, a wall of water crashing powerfully down onto the beach. But most of that energy seems to disappear as the water begins to pull slowly back to sea. In fact, the energy in breaking waves transfers into the surrounding water, ground, and air.

This process of energy transfer can be leveraged to protect the coast from damage during storms. Marsh grasses that grow between the beach and the open ocean can help to attenuate the strength of storm waves, absorbing much of the energy that the water possesses, before it reaches the shore. Engineers have purposely cultivated marshes in several places along Long Island's southern coastline in order to stop storm waves from battering coastal homes and communities.

Direct sun during the summer months can make the beach scorching hot underfoot, as the energy in sunlight transfers into the mass of the sand and stones. But over the course of a day, the ground becomes cooler to the touch — it doesn't stay scorching for long. Where does the heat go? It may dissipate through the Earth's crust and into the air or be transferred to the palm of your hand.

## Energy, temperature, and states of matter

Even when a mass appears completely still, its component molecules, atoms, and sub-atomic particles are constantly in motion and in possession of kinetic energy. This motion produces a slight vibration that our nervous system interprets as warmth. Indeed, "temperature" simply describes the average kinetic energy of the atoms in a given substance or system. The physical state of matter – solid, liquid, or gas – is also a reflection of how much kinetic energy this moving mass contains, relative to the strength of the chemical bonds that hold its component atoms and molecules together.

When matter is in a solid state, its bonds have more energy. The component atoms vibrate very slightly or twist around in place while the molecules hold together in a stable, well-organized structure. In a liquid state, the energy of the molecules' vibration is stronger than their attraction to one another, and so they remain in constant motion. But at the same time, the force of attraction between the molecules is strong enough to keep the substance cohesive and stop them moving too far away from one another. In gases, meanwhile, the kinetic energy of the molecules is much stronger than their attraction, and the substance expands continuously.

Energy transfer can change the state of matter by increasing the energy of a given system. If enough energy is added, all matter will eventually reach a "melting point" or a "boiling point" wherein the kinetic energy overcomes the potential energy of the chemical bonds, and solids become liquids or liquids become gases. Conversely, as energy leaves a system, the state of matter can change in the opposite direction: gases condense into liquids and liquids congeal into solids. In either case, the amount of energy transfer required to change the physical state of matter depends on its chemical makeup.

Alexander Klepnev

## How does energy affect different kinds of matter on the beach?

Consider a grain of sand. Its molecular structure is a crystal, composed of millions of molecules, typically of the compound silicate (SiO2), held together with very strong bonds. Meanwhile, the bonds between the molecules of water (H2O) in a drop of ocean water are much weaker. Much less energy would need to be added to the drop of water than to the grain of sand to trigger a phase shift: a puddle of water on the beach will quickly evaporate, while a similarly sized patch of sand won't melt in the sun. But it is possible to melt sand if enough heat is applied – for centuries, glass was made by melting sand at very high temperatures in a furnace.

The size of the system that is being heated influences whether a phase shift occurs, as the energy dissipates throughout the matter in the system – a larger system requires a greater input of energy to raise the average kinetic energy of each molecule enough to reach a boiling point. Speed also plays a role. Consider when lightning strikes a beach, giving rise to the melted sand formations called fulgurite or "fossil lightning." The lightning possesses tremendous energy, but only makes contact with a relatively small surface area. The strike heats the small area of sand to a high enough temperature and quickly enough that the chemical bonds are broken and the phase shift occurs before the energy can dissipate throughout the rest of the system. Then, as the energy transfers out of the melted sand into the surrounding ground and air, the liquid congeals once more into the new, larger crystal structure.

## Energy transfer through conduction

Conduction occurs when energy passes through substances that are in direct contact with one another. Consider two bodies of matter: one is a source of energy, and the other is the conductor into which the energy will move. The atoms in the source possess kinetic energy that causes them to collide with atoms in the conductor. When this collision occurs, the electrons in the conductor's atoms absorb the impact and become excited, vibrating faster and moving further away from their nuclei. If a material is a good conductor, its excited electrons can then flow freely through the mass, conveying energy from atom to atom. Materials that inhibit the flow of energy are described as good insulators.

## Energy transfer through radiation

Radiation occurs when, rather than imparting energy through collisions with another material, matter emits electromagnetic waves that travel through space and are absorbed by a receiving mass. Radiant energy includes the photons that convey the sun's energy to Earth, as well as other kinds of visible light, infrared radiation, radio waves, microwaves, and others. When these waves intersect with matter, the electrons in the matter become excited and radiate electromagnetic waves of their own, while also transferring the energy through the matter via conduction.

All matter emits and absorbs radiant energy constantly, but our ability to perceive this activity in the form of heat, light, or color varies. The ability of matter to absorb or emit radiant energy at different frequencies depends on the material's chemical structure. Energy that is absorbed by matter makes electrons excited, raising the temperature. Energy that is not transformed into the kinetic energy of excited electrons is reflected, emitted from the mass in the form of radiant waves. Matter at higher temperatures radiates shorter waves, which are more visible.

### Where do conduction, insulation, and radiation occur on Jones Beach?

Have you ever gone swimming in the late summer or early fall, and found the water to be warmer than the air? Solar energy is transferred to the air, land, and water over the course of the summer season, but the energy that accumulates in the air and land dissipates more easily, while the heat absorbed by the water lingers longer. This is because water is a relatively poor conductor; energy moves through it with difficulty, so it is slow to heat up and slow to cool down. (Students might be familiar with the idea that water is a strong conductor of electricity, to sometimes dangerous effect. In fact, pure water can't conduct electricity, but it acts as a solvent for other kinds of matter that do, such as salts.)

Air is a good insulator and a poor conductor. Ever wondered how fur and down help keep animals warm? It's not the quantity of hairs or feathers that matters, rather the width of the layer of air trapped inside these materials that stops energy from being conducted out of the body into the surrounding air. This is why birds fluff up during


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the winter: the number of feathers is the same, but they insulate more effectively when a greater volume of air is trapped inside them.

In the example of sunlight hitting the beach, radiant energy from the sun transforms into the kinetic energy of excited electrons in the sand, which vibrate, producing what we experience as warmth. The excited electrons also produce new photons, that radiate away from the sand. This is encountered as the brightness or glare of sand reflecting light.

Have you ever seen sunlight shine through a leaf, making its green color glow all the more vibrantly? The chemical chlorophyll inside plant cells allows leaf matter to absorb energy from photons, which the cells then transform into chemical energy for the purposes of growth and reproduction through photosynthesis. (More on that later.) But to the extent that the leaf does not absorb all the energy imparted by the photons, it simultaneously reflects or emits radiant energy at a frequency that our brains perceive as the color green. When more light hits the leaf and the leaf matter absorbs more radiant energy, it emits more radiant energy as well, making the color appear more intense.

## AT THE CENTER

Location:
West End beach,
facing the dunes


Seaside Goldenrod
Homer Edward Price


James Pezzella

## REVIEW

## Heat transfer through convection

At the atomic level, energy can only be transferred by radiation or conduction. But at a larger scale, convection describes the movement of heat through the cycling of fluid matter – liquids or gases – in space.

As fluid matter absorbs energy through conduction or radiation from below, it expands, becoming less dense. Less dense matter is subject to weaker gravitational force and rises above denser, cooler matter, leaving a pocket of low pressure in its wake. The cooler matter moves into this space, closer to the energy source, in order to reestablish a pressure equilibrium. In this way, the fluid matter circulates and heat spreads throughout the substance. The cycle stops when heat is distributed evenly and no more energy is being added to the system.

## AT THE CENTER

Location:
West End Beach,
facing the horizon

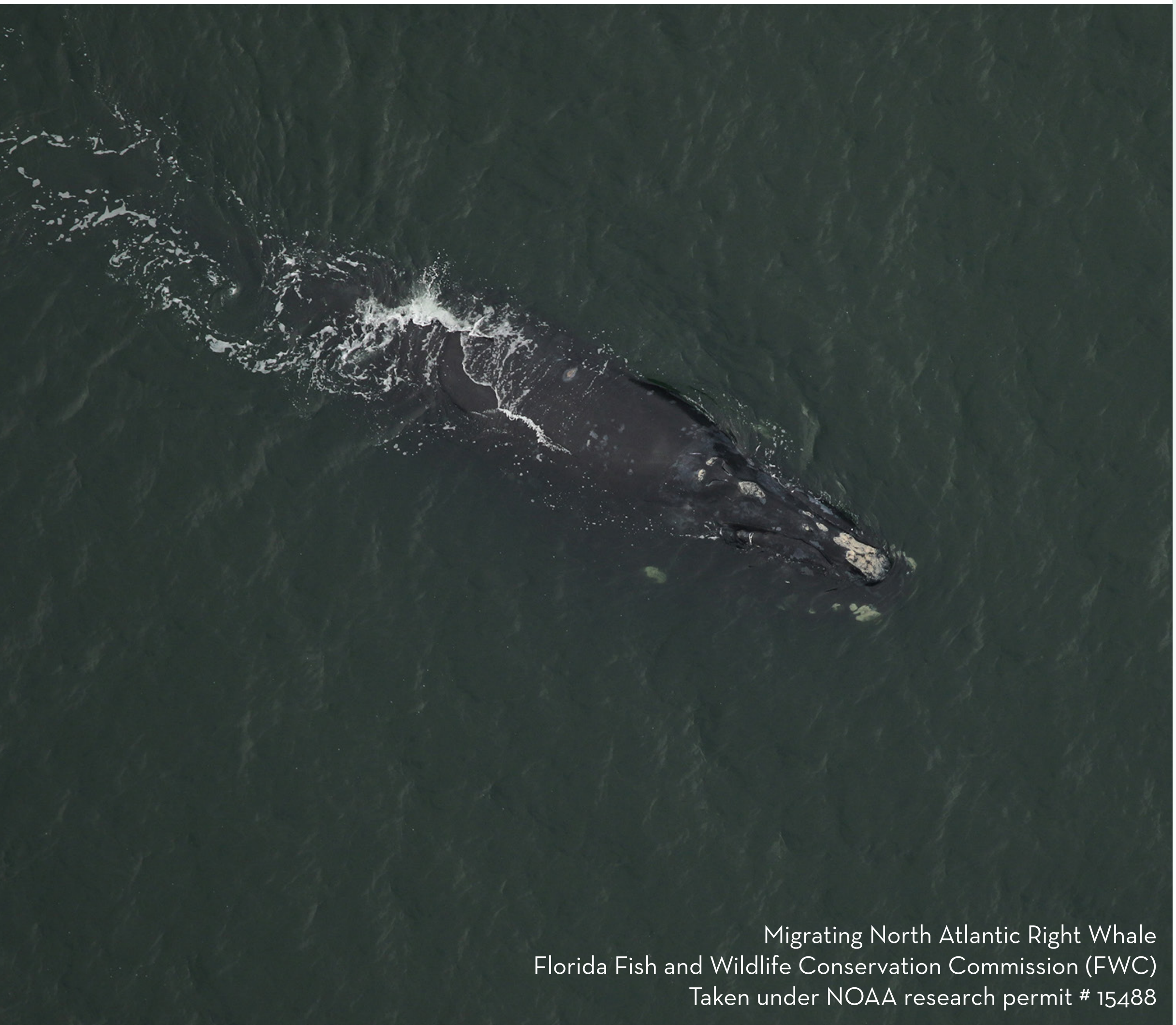
### Where does convection occur on Jones Beach?

Look to the horizon. What clouds are visible? Which direction does the wind seem to be blowing?

Convection is the main driving force behind the climate cycles that maintain all global ecosystems. Energy from the sun radiates to the Earth, where it warms the ground and water on the surface. Energy then transfers from the ground and water to the air through conduction, which triggers convection in the atmosphere. But the warming is not evenly distributed across the planet: as the sun heats the Earth's surface and warm air rises in one place, cooler air from another place moves laterally through the atmosphere towards the pocket of lower pressure. This produces the movement of air that we experience as wind. The Coriolis Effect, which is caused by different parts of the Earth's surface moving at different speeds during the planet's rotation, forces the air to move in a curved, rather than straight, line. In the Northern Hemisphere, air currents are deflected to the right, and in the Southern Hemisphere, they are deflected to the left.

Meanwhile, the transfer of energy to the water triggers the physical state of the matter to change: as the surface water warms, it evaporates, becoming less dense and rising into the atmosphere as water vapor. The vapor cools again as it rises into the colder parts of the atmosphere, where it condenses and forms clouds. Though clouds are denser than air, the circulation of wind due to convection keeps them aloft and pushes them from place to place.

Wind is a main driver of surface-level ocean currents. The same dynamic driving the circulation of air in the atmosphere — rising, warmer, less dense matter replaced by colder, denser matter — also drives deep water circulation, which moves larger masses of water through the ocean, bringing nutrients and oxygen to the places that need them. Sea creatures like whales, sharks, sea turtles, and many kinds of crustaceans use deep-ocean currents to migrate long distances, while birds and insects use air currents for the same purpose.

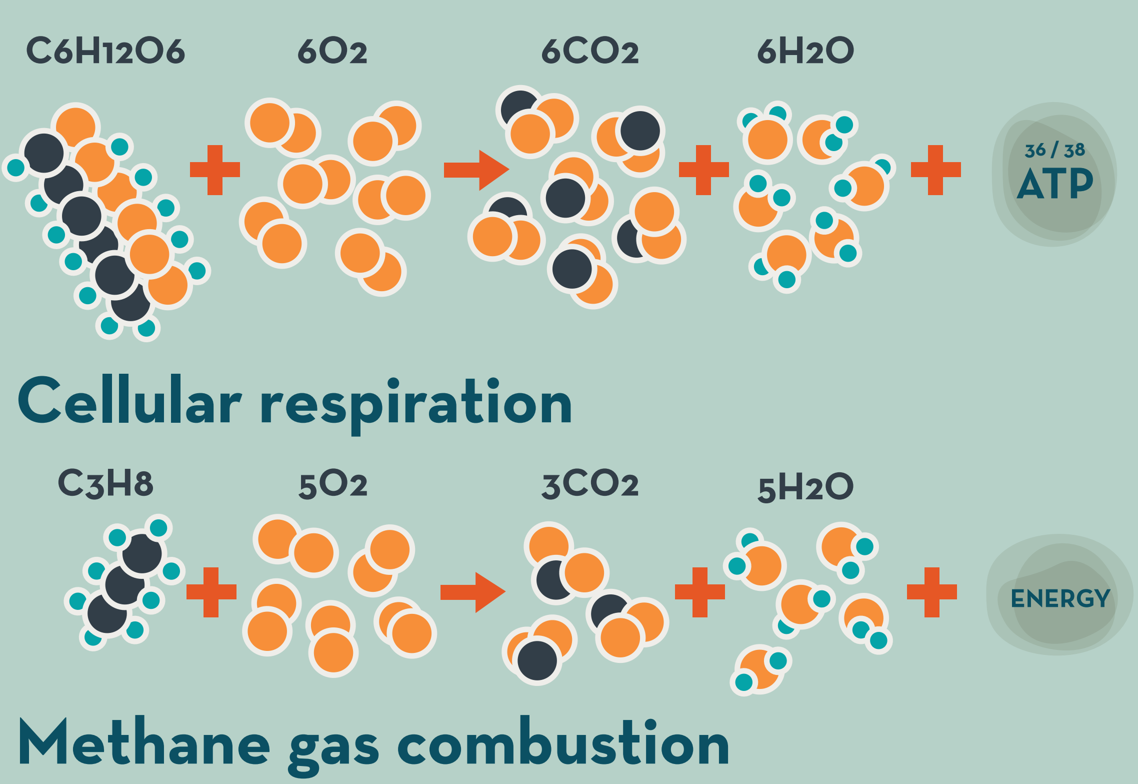


Migrating North Atlantic Right Whale
Florida Fish and Wildlife Conservation Commission (FWC)
Taken under NOAA research permit # 15488

## REVIEW

## Organisms and chemical energy

Organisms form and combust units of chemical energy in order to grow and reproduce. The process of photosynthesis transfers energy from solar photons into carbohydrates that contain chemical potential energy, while chemical digestion breaks down complex molecular compounds into carbohydrates that contain energy. Organisms then perform a process of cellular respiration to metabolize the carbohydrates and release the energy contained within their chemical bonds. This process forms adenosine triphosphate (ATP) molecules, which are used for all cellular processes that require energy.



Cellular respiration

Methane gas combustion

Cellular respiration is technically a combustion reaction, similar to the release of energy from a source like wood or oil. Carbon-based matter and oxygen combine in an exothermic (energy-releasing, in contrast to endothermic, or energy-consuming) reaction that causes the carbon to vaporize, becoming carbon dioxide. Thus the process of photosynthesis and the organic matter that results from it are the source of energy in both food sources and in energy sources like coal, oil, and gas. When humans want a source of energy to be available as needed, they often turn to chemical energy. Food, firewood, batteries, or gunpowder are a few examples of natural and human-made objects or substances with chemical energy.

## How do living things on Jones Beach use energy?

On Jones Beach, just like everywhere on Earth, living things require a constant input of energy to perform the biological work necessary for survival: the circulation of oxygen, the contraction of muscles, the formation of new cells, the transport of nutrients across cell membranes, and more. The source of this energy is the sun. What kind of sunlight is there in the Pollinator Garden, and how would different levels of light impact the plants and animals that live here?

Because the Earth rotates on a tilted axis, in the spring and summer months, Jones Beach is more directly exposed to the sun. More photons reach the plants in the Pollinator Garden during this time, powering more photosynthesis, which in turn allows growth and reproduction. Animals that rely on plant matter for energy find more food in the spring and summer, which means they also can grow and reproduce. In the winter months, solar energy is less available. Many plants cease to grow during this time; meanwhile, many animal species have evolved to store chemical energy in their bodies in the form of fat for digestion when external sources of energy are difficult to find.

Many plant and animal species have also evolved to conserve energy. Gulls, Osprey, Monarch Butterflies, and Green Darners floating on air currents are one example: these animals use the kinetic energy of the wind to supplement the chemical energy in their bodies in order to perform necessary functions for survival. Some animals slow down their internal metabolism during the winter months, becoming dormant and even going into hibernation in order to survive on the chemical energy they've stored in their bodies in the form of fat. Here are two mechanisms of energy efficiency that will be important in future discussions: using less energy, and storing energy for use when needed.

## How do humans use energy differently?

The answer to this question lies in the difference between the environment of the Jones Beach Energy & Nature Center, and that of Jones Beach itself. This building could not exist without another type energy — mechanical energy — and the unique human ability to engineer systems that intensify, transform, and direct energy for human purposes.

Humans create tools that combine different sources of energy to increase the mechanical energy of our bodies, or to intensify and direct the mechanical energy of the natural environment. Simple machines like wheels, gears, levers, and pulleys amplify the body's kinetic energy through the strategic activation of natural forces like gravity, adding up to a greater total mechanical energy. A gardener using a shovel to lever a rock or particularly tough root system out of the ground is an example of a simple tool multiplying the body's capacity to do work. The body and the tool function as one system, the mechanical energy of which is the sum of the body's chemical energy, kinetic energy, and gravitational potential energy, along with the gravitational potential energy and kinetic energy of the shovel. Meanwhile, a windmill uses the same tools to amplify the kinetic energy of the wind and transform it to accomplish mechanical processes like turning a millstone.

## AT THE CENTER

Location:
Pollinator Garden

Groups working on site can use the informational plaques distributed throughout the Pollinator Garden to identify individual plants and animals present in the ecosystem and learn about their relationships to one another.

Groups working off site can use materials from Unit 2 to learn about the various species and their relationships.

## LEARN MORE

See Unit 2 for discussion of how energy moves through the ecosystems of Jones Beach.

## REVIEW

## Mechanical energy

In physics, "mechanical energy" is the total combined kinetic and potential energy of an object, which amounts to the capacity of an object to do work on another. Over the course of a mechanical operation, potential energy is transformed into kinetic energy. The mechanical energy of a system can be increased through the intentional use of energy sources, like food or fuel, or as a result of natural energy transfer from the environment into the system. Humans have evolved to amplify the mechanical energy of their bodies through the use of tools and nutrients and to amplify the mechanical energy of tools through the use of fuels like firewood or oil, as well as other natural energy sources like sunlight and water.

When a wave breaks on the shore, it is doing work. Before the wave breaks, it contains mechanical energy equal to the sum of its kinetic energy and its potential energy. At the top of the swell, there is more potential energy than kinetic energy; in the moment just before the wave breaks, there is more kinetic energy than potential energy. But the sum of the energy remains the same until the work is accomplished, at which point the energy transfers into the surroundings.

How can the mechanical energy of the wave be increased? As previously discussed, energy transfer from sunlight can increase the total energy contained by the system. But there are more active ways to increase the mechanical energy of the water, as well. Consider the wake left by a motor boat or a big ship. The energy used to propel the boat forward is transferred into the surrounding water, where it increases the mechanical energy of those small waves.

## AT THE CENTER

Location:
Energy Classroom

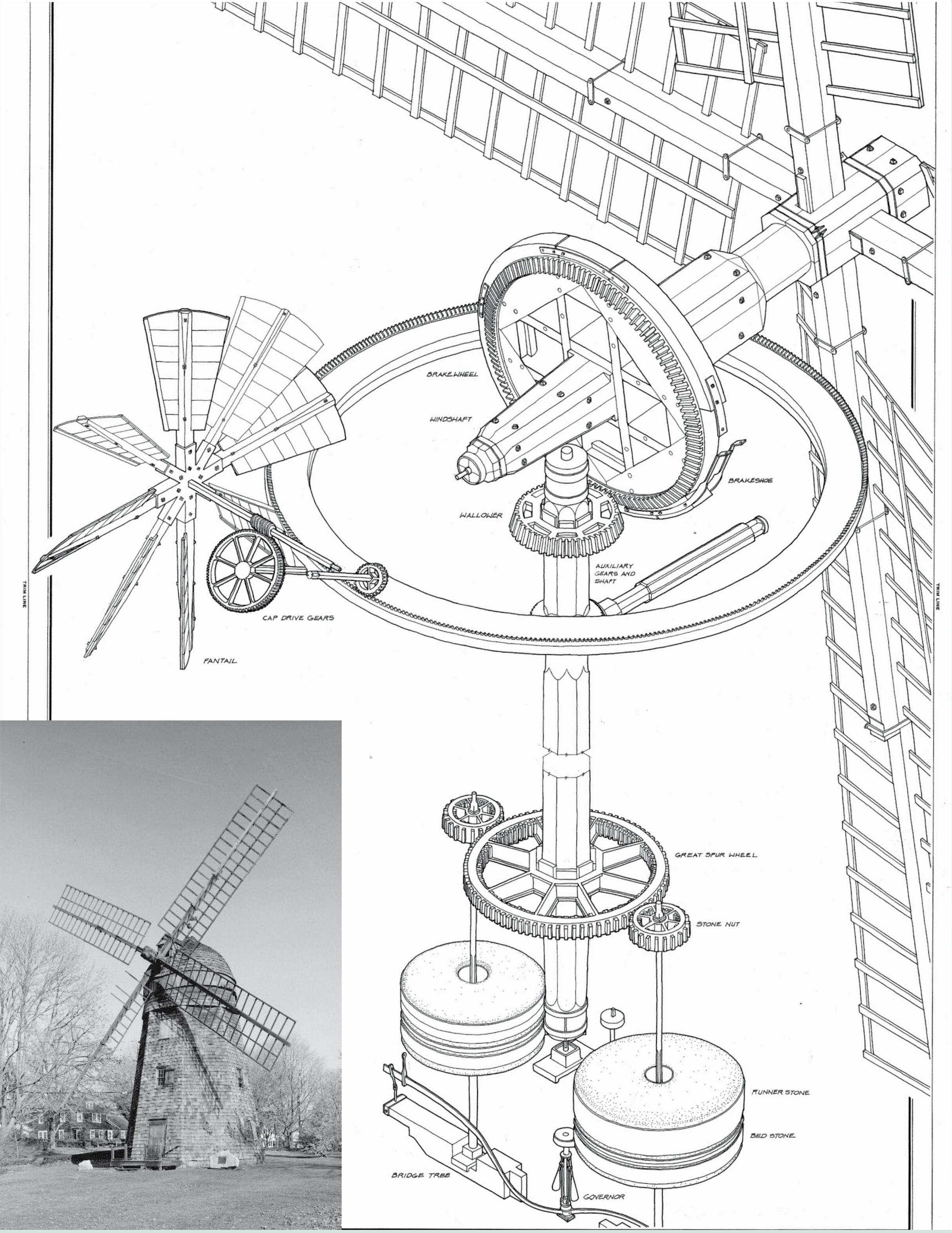
## LEARN MORE

See 1.2 for discussion of the processes and systems that convert natural energy sources to electricity.

The efficiency of energy conversion in a machine process determines how much of the energy going in is "lost" in the form of heat, light, friction, or even sound. (Remember, however, that energy is never actually lost.) For instance, poorly maintained gears on a bicycle may be less efficient than well-oiled gears because the friction caused by rust in the mechanism causes energy to be lost in the form of heat and sound (such as squeaking). A bicyclist would have to expend more energy to accomplish the same energy conversion.

Machines can also use fuel in order to convert one form of energy into another — for instance converting the chemical energy of firewood into thermal energy in water, or the potential energy of water into the kinetic energy of a millstone. In this case, efficiency describes how effectively the machine transfers energy from the one system to the other – how much energy is "captured" from the source. Many important machines today exist to convert energy from one form into electricity, while others use electricity itself as the source of their mechanical energy.

Keeping objects in motion, heated, or emitting light requires the continuous input of energy. Since the same amount of energy is always available in the universe, the challenge lies in creating machines that minimize the amount of energy that is "lost" in the course of conversion or transfer, or that can capture the lost energy for another use.



## Working the wind on Long Island

**SPOTLIGHT**

The Beebee Windmill was built in Bridgehampton, Long Island in 1820. The blades of the windmill turn a rotor, which is connected to a rotating shaft. The shaft causes a wheel to turn, which then operates a pair of toothed gears that control the rotation of two upper millstones ("runner stones"). Grain would be ground into flour or meal between the runner stones which rotated, and a pair of lower millstones ("bed stones"), which did not move.

## TAKE HOME: OBSERVE AND DOCUMENT

# Energy transfer in the environment

Energy transfer is always happening around us, but we don't always notice. In the search for new ways to generate electricity and run the machines that enable modern life, engineers are constantly on the lookout for opportunities to harness previously untapped natural energy sources.

### Instructions

For full activity materials, see:

Unit 1 Appendix
Pages 2-3

Locate four different places in or around your school and home where energy transfer between two systems occurs. Diagram each instance of energy transfer and describe it in a few sentences.

Consider:

**What can you see with your own eyes?**

**What do you hypothesize is happening at the atomic scale?**

**Is this an instance of conduction, radiation, or convection? Is potential energy being transformed into kinetic energy?**

**Where does the energy originate from and how does energy dissipate into the environment at the same time as it is transferred from one system to another?**

After documenting these observations, choose one of the instances of energy transfer that you observed and brainstorm:

**How could a machine capture energy from this natural source?**

**What could such a machine do?**

**How would such a machine be made most efficient?**

## CORE CONCEPT 2

# Energy from the environment can be used as a tool

Human use of energy depends on systems and technologies that transform sources of energy into fuel and electrical power, and deliver that power to end consumers.

Sean Hanley and G. Anthony Svatek

## From energy to power

With this Core Concept, students move from understanding energy as a natural occurrence to analyzing it as an object of human production and consumption, particularly in the generation of electricity. Using the Jones Beach Energy & Nature Center building itself as a case study, students explore how the physics and chemistry of energy transfer, electrical current, and circuits affect the engineered systems that distribute energy throughout the world.

First, students are prompted to reflect on their own daily experience as an energy user within a broader societal context. The discussion activity introduces students to the concepts of energy production, energy consumption, and the use of energy as a tool to accomplish work. Current data from the US Energy Information Administration frames a conversation about the social and environmental factors influencing energy use, allowing students to employ critical thinking and data interpretation skills.

Then, zooming in on the Center building, a two-part hands-on activity introduces students to the systems that generate and distribute electrical energy. Students grasp the basic building blocks of electrical currents, circuits, and systems at the building level, and then extrapolate these lessons to broader networks of energy production. A take-home research activity asks students to assess the efficiency of technologies that convert primary energy sources into electricity, and to begin to consider the environmental impacts of energy consumption at points of extraction, refinement, and distribution. These themes are a foundation for Core Concept 3.

Lisa Meiman, courtesy of Western Area Power Authority

## Everyday energy use

**What do I use energy for every day? How does my family use energy?**

**What kind of energy do we use?**

**How much energy do we use?**

**How do I define "energy efficiency"?**

Energy is everywhere in our daily lives, from the cars, buses, and trains we ride in, to the food we make with refrigerators and stoves, to the cellphones and computers we use for work, school, and entertainment. Especially note the prevalence of electricity and "invisible," or background, energy consumption like heat, hot water, refrigeration, WiFi, transportation, and lighting in spaces that individuals don't control themselves, like schools, businesses, or public transportation.

We can measure our energy consumption in terms of time or in terms of how much energy each activity or device consumes. Devices might use different amounts of energy under different circumstances, such as at different times of day, or when used for different purposes.

### PRIMER

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

## AT THE CENTER

Groups working with the curriculum on site can begin by viewing the Producing Power exhibit in the West Gallery.

# Production and consumption

### What are "energy sources" and how do we use them?

Energy sources are the naturally-occurring substances and forces we harness in order to accomplish anything that requires more energy than we have access to within our own bodies and immediate natural environments. In order to use an energy source to do work, typically the source must be transformed into electricity or refined through an industrial process.

Some examples of naturally-occurring substances include fuels like oil, coal, natural gas, or plant matter, which contain chemical energy that can be accessed through burning the energy source. An example of a naturally-occurring force could be the kinetic and gravitational potential energy of water, which can be accessed through hydroelectric power plants.

Energy sources can either be consumed directly, or transformed for indirect use, as in the case of a hydroelectric power plant using the kinetic energy of energy to produce electricity. When energy sources are used directly they are called "primary energy sources," and when they are used indirectly they are called "secondary energy sources." For example, the sun can be used to create electricity through the technology of solar panels. But we can also use the sun as a primary energy source – such as in this building, which is designed to maximize the sun's ability to warm the air.

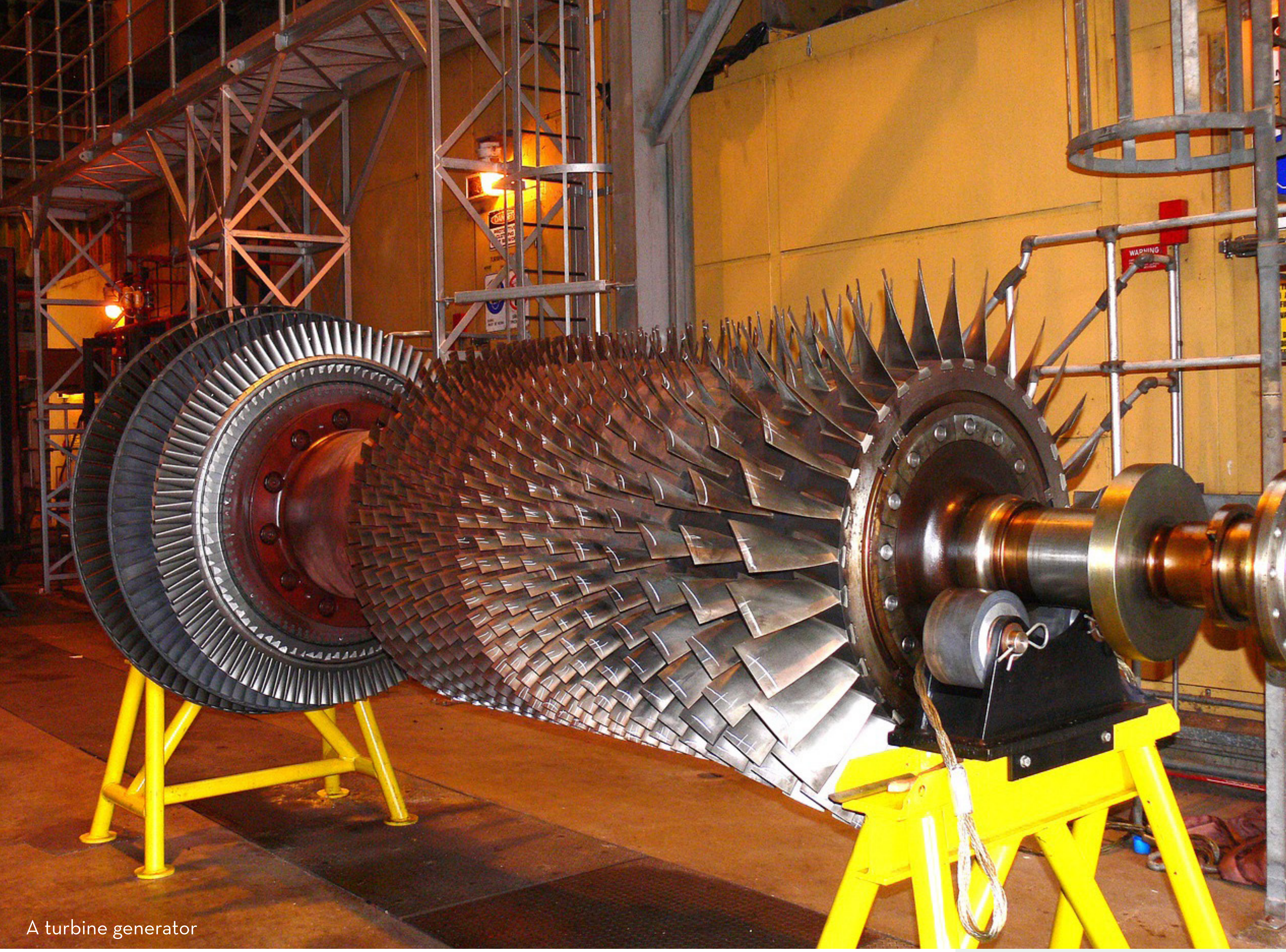
### When it comes to energy, who are the "producers"?

The majority of electrical power production relies on the use of turbine generators to transform the kinetic energy of gas, steam, wind, or water into electrical energy through electromagnetic induction. Producers therefore are often those entities – in the US usually private companies and utilities – that own the machinery required to make that transformation. (Photovoltaic solar panels work differently, but still require the use of machines.) They may also be companies that mine or harvest the fuel used to create steam or gas. Even energy sources that are used directly, like the oil and gas that we use in cars, stoves, and water heaters, have to be extracted and processed in some way before they reach consumers.

### When it comes to energy, who are the "consumers"?

Consumers are those who use energy to perform work beyond what they can do with their bodies and the natural environment alone. Consumers may be individual people and families, but they can also be business owners and companies that use energy for commercial or industrial purposes. They can even be the people and entities in charge of spaces like the Center, or your school.

Industrial manufacturing consumes energy through the machinery used in production, plus light, ventilation, and temperature control for buildings. Industrial agriculture consumes energy via machines used for planting, harvesting, and on-site processing.



A turbine generator

Commercial buildings consume energy through the light, heat, air conditioning, ventilation, and electronic devices in office buildings, stores, malls, warehouses. The transportation sector consumes energy through the fuel used to power trucks, boats, barges, freight trains, and planes.

## What are the challenges posed by an energy system?

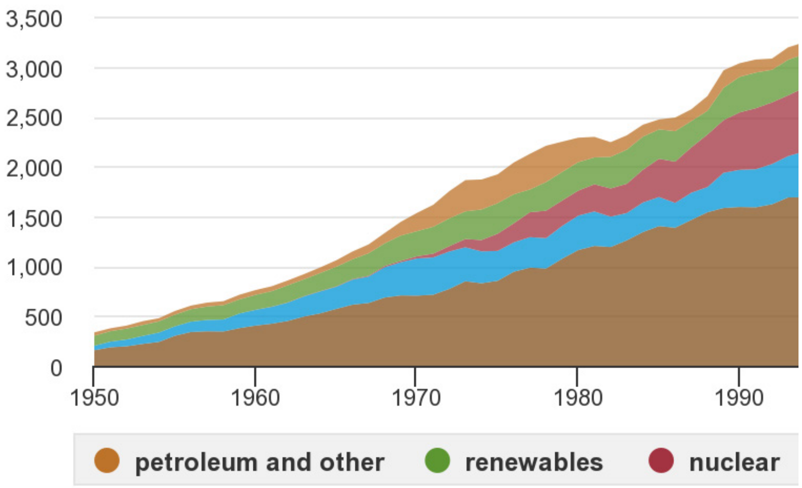
Distribution is a challenge. As access to energy increasingly determines quality of life and ability to participate in society, ensuring that everyone has equal and consistent access to energy is an important social issue.

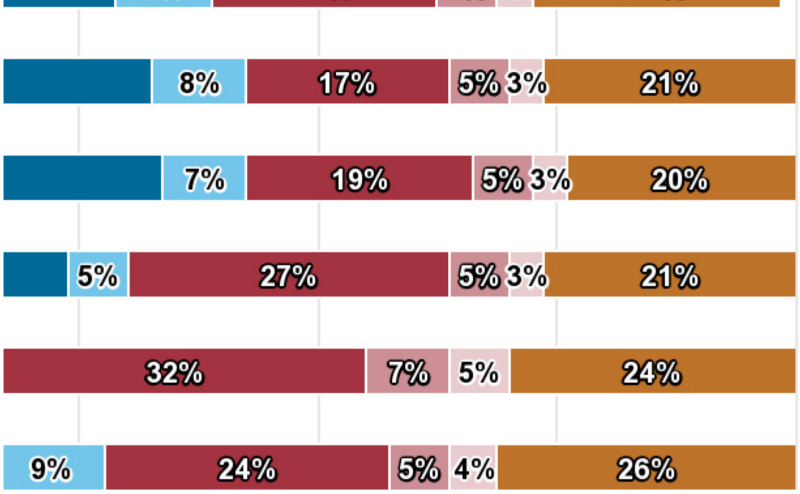
Efficiency, or the minimization of waste, is also a challenge. Waste here means the potential energy lost between the initial, natural energy source and the form of power provided to the consumer. Waste can occur in conversion processes, in transporting raw or converted energy sources, or in machines that fail to convert the entire source of energy into work.

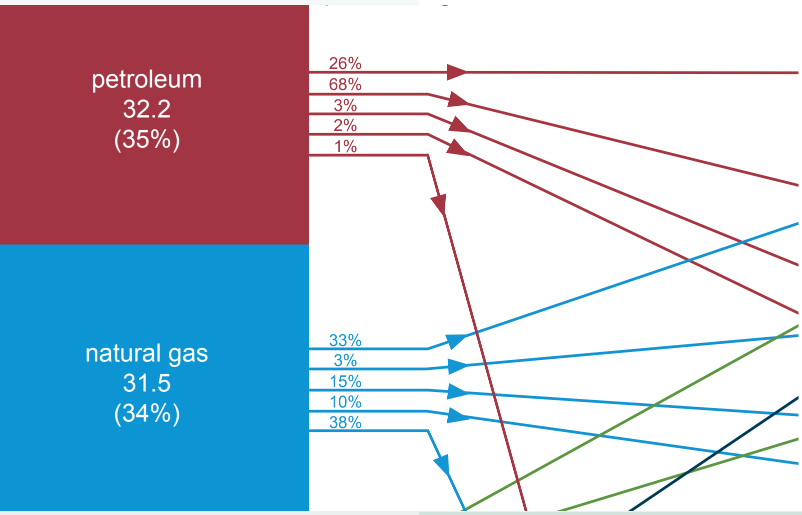
Lastly, managing the human impacts of energy systems is a challenge. Energy production and consumption can significantly impact the environment. Environmental impacts can occur at the extraction, conversion, delivery, or consumption stage.

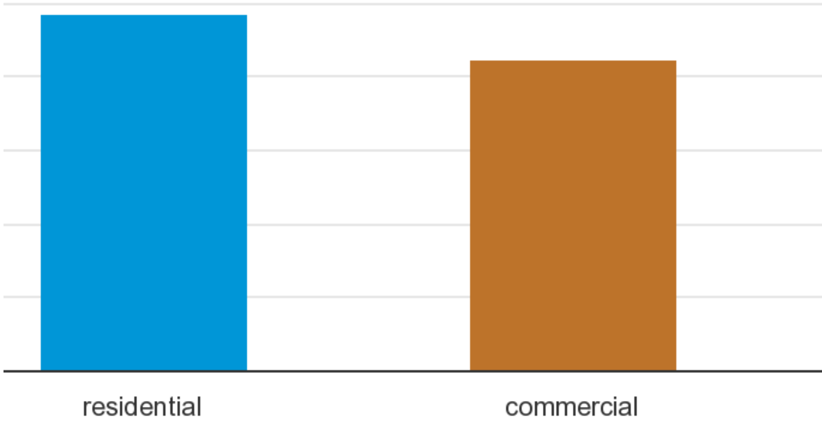
## LEARN MORE

See 1.3 and Unit 5 for discussion of the environmental impacts of different energy sources.









## BREAK OUT

Give students a few minutes to discuss in pairs or small groups. Then come back together as a class to debrief.

For full activity materials, see:

Unit 1 Appendix
Pages 4-8

## Data analysis

**What do these charts depict? What questions do they answer?**

**What do the charts not show? What questions do they raise?**

**Looking at these charts, what do you notice about how individuals, industry, and the commercial sector consume primary energy sources and electricity?**

Electricity is a greater portion of energy used by individual and commercial consumers. Industry uses far more petroleum than individual consumers and the retail sector. Natural gas is an increasingly common source of energy for both electricity generation and direct consumption.

### Source

US Energy Information Administration | Charts from "US energy facts explained"

eia.gov/energyexplained/us-energy-facts/

## Why is electricity a bigger part of individuals' energy use?

Most of our devices and home appliances run on electricity; a large proportion of energy used in interior spaces like homes and businesses goes to lighting and providing ventilation and temperature control (especially air conditioning) through electrical systems.

## Why does industry use more oil than individuals?

Oil is a highly efficient energy source that contains large quantities of chemical potential energy, which can be relatively easily converted into usable power, whether for electricity generation or combustion engines. However, oil impacts the immediate environment with toxic fumes during processing, potentially causing disease, and a risk of leaks during transport. These risks may be unacceptable in homes and businesses, but industrial entities have greater access to the kinds of equipment that can more safely transport, store, and use this energy source.

## Why might natural gas be an increasingly common energy source?

More efficient extraction techniques in recent years have increased the supply of natural gas. Meanwhile, the use of coal has been on the decline, in part due to the environmental effects of coal combustion. In the US, the majority of lost coal production has been replaced by natural gas. Since natural gas historically has been used both for electricity production and by direct consumers, there is an extensive existing network of infrastructure for transportation, storage, treatment, and delivery that can make the most of the new abundance of the resource.

## What are the advantages and disadvantages of powering devices with electricity versus other energy sources?

Electricity is delivered through wires: within buildings, these wires form circuits; across a larger area — like a city, state, or country — circuits are connected to other wires that form a network called the Electrical Grid. (Pipelines for oil and gas are often considered part of a broader Energy Grid. The Grid includes all the larger infrastructure that enables and controls the supply of energy.) What are differences and similarities between how electricity and other kinds of energy are moved across terrain, and what are the advantages and disadvantages of an electrical network versus other kinds of energy supply infrastructures?

Electricity delivered through the Grid is more or less always available on demand, whenever energy is needed. Electricity is versatile: it can power devices as small as a light bulb or as large as a supercomputer. And it is, largely, safe. In contrast to energy sources like oil and gas, which are volatile and must be handled carefully, the energy that courses through an electrical system can be cut off at a moment's notice. However, note the "electrical system losses" that account for a majority of the energy consumed by the electric power sector. Distributing electricity can be inefficient and electricity production must be carefully calibrated to anticipated demand, or else the larger system may fail.

Battery and Transformer outside the Jones Beach Energy & Nature Center
Barry Sloan

## SPOTLIGHT

### LEARN MORE

See 4.1 for discussion of the Grid and electrical infrastructure.

See 5.1 and 5.2 for discussion of the challenges of adapting the Grid to climate change, and transitioning to renewable energy sources.

## How electricity reaches us

Electricity arrives at the Jones Beach Energy & Nature Center much the same way it travels to any home, school, or business: through a network of wires and transformers called the Grid. Electrical power is generated at a central power station, usually by using a fuel like natural gas or another energy source like water power to turn a large turbine, which generates Alternating Current electricity. This travels to a transmission substation, which uses step-up transformers to produce a high-voltage current that can travel long distances with minimal power losses. The current travels along distribution lines, either strung between utility poles or buried underground. The lines eventually lead to another set of transformers, which reduce the current's voltage so it can be distributed to and safely used by end users.

In addition to the Grid, the Jones Beach Energy & Nature Center draws electricity generated on-site by 260 roof-mounted solar panels. Both the solar panels and the Grid connect to a large battery: the solar panels can charge the battery when they produce more electricity than is immediately consumed by the Center, and the Grid can recharge the battery if it is drained when the sun is not shining. When the electricity generated on site is more than that consumed by the Center or used to charge the battery, it is fed back into the Grid for use elsewhere.

# Electrical building blocks

Just like all other forms of energy in the universe, electrical energy relies on the interaction of matter and physical forces. Electrical currents are created when electromagnetic forces draw electrons away from atoms, creating a current along which charge flows. Electrical energy is a physical phenomenon: the strength of a current depends on the material characteristics of the conductor through which it flows, along with other physical factors.

## Part 1: Experiment

### Materials

**1 D cell battery**

**1 D cell battery holder**

**2 2.5 volt, 0.2 amp, or smaller mini bulb with a screw-type base**

**2 bulb holders**

**4 alligator clip cables**

**Safety goggles**

### Instructions

1. **Build a circuit that makes one bulb light up.**
2. **Build a circuit that powers two light bulbs, so that both bulbs can be turned on and off with the same action.**
3. **Build a circuit that powers two light bulbs, so that one bulb can be turned on and off without affecting the other.**

## AT THE CENTER

Kits for this part of the activity are available in the Energy Classroom.

To complete this activity off site, each group of 2-4 students will need either the listed materials, or access to an online circuit simulator, like the PhET Simulations Lab at the University of Colorado.

**phet.colorado.edu**

## Part 2: Group discussion

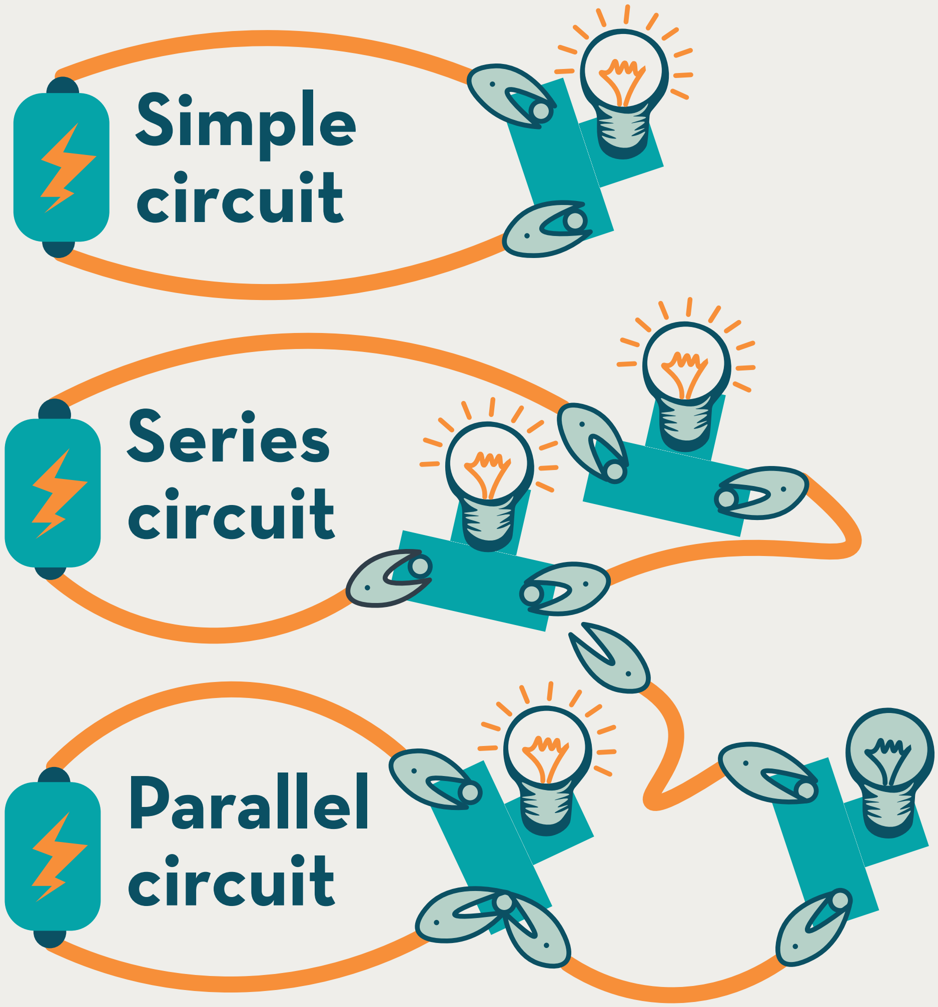
### What's happening here?

The bulbs light up because of electrical energy transferred along the circuit by an electric current.

Electrical energy is the potential energy of electrons. Recall that electrons are particles that comprise part of every atom. Electrical energy is similar to chemical energy in that the energy is released when component parts of matter are rearranged. But rather than bonds between atoms, the bonds that store electrical energy are between particles within atoms – between electrons and protons.

In a neutral, non-electrified state, atoms have the same number of negatively-charged electrons and positively-charged protons. Protons make up part of an atom's nucleus and the electrons orbit around the nucleus. The electromagnetic attraction between protons and electrons holds atoms together.

Electrons are held in different layers, or shells, around the nucleus: inner-shell electrons have the strongest attraction and are most firmly attached; outer-shell electrons have a weaker attraction and can become detached when an external force or source of energy is applied to the atom. This could be the impact of a wave, like a photon, or a strong electromagnetic attraction, as from a magnet.



## What is the difference between electrical energy and electricity?

When electrons move from one atom to another, this is the movement of electrical charge; when many electrons move in a stream in the same general direction through a material, this is an electric current. Simply put, electricity is electrical energy facilitated by a current. Energized electrons, which are negatively charged, naturally flow towards a positive charge and pull surrounding electrons along with them. A circuit can be made by creating an electromagnetic field that draws the flow of electrons towards a positive charge through a closed loop.

## When does current occur?

In their neutral state, with an equal number of electrons and protons, atoms have no charge. When an atom loses an electron, it becomes positively charged, which exerts an electromagnetic force on the electrons of surrounding atoms. As these electrons move in response to the force, their absence creates a positive charge that attracts electrons from surrounding atoms.

Electrons jump from atom to atom, changing the charge of each. They flow in the same general direction because the electromagnetic force attracts electrons towards the positively charged atoms in front and repels them away from the negatively charged atoms behind.

## What is a circuit?

If the electric current is the movement of electrons through a material, then in its simplest form, a circuit extends and directs that movement through a conductor. For example, think of the metal alligator clip leads in the circuit-building experiment. In a circuit, current is the measurement of how quickly charge flows past a fixed point; when the flow is fast, current is high, similar to water pressure in a pipe.

Electricity along a circuit is produced by a generator that uses an energy source to force electrons into a current that moves through a conductor. The conductive material, often metal, allows electrons to move easily from negative to positive charge.

In this case, the electric current is triggered by an energy source — a battery — that causes electrons to detach from atoms and flow through the conductor. In a turbine generator, like that employed in wind turbines and traditional power plants fueled by coal, oil, or gas, a current is produced by the movement of magnets around a conductive material, a principle called electromagnetic induction. In these generators, the kinetic energy of a substance in motion — flowing wind or water, or expanding gas or water vapor (steam) — propels the magnets, transforming into the magnets' kinetic energy. This is then transformed into electric current: the difficulty of moving the magnets around the conductor is proportional to the strength of the current that's produced.

As the electrons flow in the current, energy also "moves" through the material from one end to the other. More precisely, the movement of electrons and the shifting electromagnetic force that this movement creates changes the energetic potential of atoms in the material. When two points along a conductive material are at different electrical potentials — when there is a difference in charge between them, resulting in a difference in potential energy — this current of electrons and its shifting electromagnetic force flows from one point to the other. The energy of the circuit is proportional to this difference in charge, which can be quantified as its voltage.

The battery contains two parallel plates made of two different metallic materials, which are immersed in a special acidic solution called an electrolyte. The metallic material reacts chemically with the electrolyte and disintegrates, releasing the potential energy stored within the material's chemical bonds. This chemical potential energy is converted to electrical potential energy as electrons evacuate from one end of the battery, the positively charged cathode, and accumulate in the other end, the negatively charged anode.

The battery's energy remains potential so long as it is not part of a circuit. When a conductor (in this case, the alligator clips and wire) connects the negatively charged plate to the positively charged plate, the chemical reaction within the battery facilitates their movement through the battery and into the wire while the conductor material facilitates the movement of electrons from cathode to anode. There is also a need to insulate the circuit to minimize the natural dissipation of energy. A good insulator can keep electrons on their designated path and make sure they don't disperse. As the current flows through the circuit, electrical energy is converted into work — powering a device, like a light bulb, or causing the conductive material to heat up.

## How does the light bulb illuminate?

It can be tempting to think of energy as a substance that's contained in the battery and then "carried" to the light bulb by the electrons as they move through the circuit. This is not the case. When the circuit is closed — when

Solar panels on the roof of the Center
Barry Sloan

the anode and the cathode of the battery are connected by a conductor — energy is transferred at nearly the speed of light along the same route as the current of electrons, which move relatively slowly. If you were to create a closed circuit without any kind of energy-drawing device connected to the conductor, the result would be a short circuit: an equilibrium of charge would be established within an instant, and the battery would become very hot or even overheat, spark, or catch fire.

Devices like light bulbs are called "resistance" or "load" — they slow the current, avoiding a short circuit and allowing some of the energy in the circuit to be diverted towards specific purposes like light, heat, or mechanical motion. The circuit also loses energy to the environment, depending on the material characteristics of the circuit. (More on this below.) Because the circuit inevitably loses energy, the battery is a finite source of current.

The second and third example circuits demonstrate two different ways of incorporating multiple "loads" into the same circuit. Circuit #2 is a series circuit: the current is passing through the two light bulbs in series. Because the circuit needs to be closed in order for the electromagnetic force to carry through the cable clips, if one of the bulbs doesn't channel the current correctly, the entire circuit cuts out. Circuit #3 is a parallel circuit: one of the light bulbs can be taken out of the circuit without affecting the other.

## How does this all connect to our use of energy as a tool?

The systems that deliver electricity from a power plant to a building like this one, and those that distribute electricity throughout the Center, use electrical currents and circuits as building blocks. Our ability to improve the efficiency and power of circuits has far-reaching implications for our energy use overall.

## Turning sunlight into electricity

SPOTLIGHT

At the Center, just as the plants in the Pollinator Garden perform photosynthesis to transform radiant energy into chemical energy, 260 roof-mounted photovoltaic solar panels absorb energy from photons radiated by the sun and transform it energy of a different sort. Photovoltaics are made from materials called semiconductors that absorb a portion of the spectrum of wavelengths in sunlight. The Center's solar panels are composed of groups of photovoltaic cells, each of which contains two layers of silicon. The top layer, which absorbs photons from the sun, is made of "n-type" (negative) silicon: it contains atoms of elements with one more electron than silicon, like phosphorous. This creates chemical bonds between the two elements that leave one electron "loose." The bottom layer is made of "p-type" (positive) silicon. This layer contains atoms of elements with one fewer electron than silicon, like boron, resulting in bonds with electron "holes." When the energy absorbed from the impact of photons "excites" the loose electrons in the n-type silicon, they are attracted to the electron holes in the p-type silicon and flow toward the bottom layer. If the two layers are connected by a metallic wire to an electrical load, the electrons will then flow toward the load and then back to the newly created electron holes in the n-type silicon, resulting in a closed circuit.

## What determines the efficiency of electrical systems?

An “efficient” electrical system is one that can provide the right level of current at the right moment to all of the devices drawing energy from its circuits, while losing as little energy as possible in the process of distribution. But what factors determine a system’s efficiency?

### Energy source

An energy source, in this case the battery, facilitates the flow of electrons through the circuit by pulling negative charges away from positive charges. The strength of the resulting current is proportional to the potential energy contained in the energy source. For instance, a generator running on gasoline can create a stronger current than a D-cell battery in part because gasoline is more energy-dense. Technologies used to convert energy from the source into electricity can vary in efficiency as well. Hydroelectric power stations operate using dams and turbines that can capture up to 90 percent of the energy possessed by the energy source — water in motion. In contrast, solar panels capture only up to 25 percent of the radiant solar energy they receive. Steam turbine generators, the basis of all fossil fuel- and nuclear fuel-powered electrical power plants, capture about 30 percent of the energy possessed by their fuel source. The rest is “lost” in the form of heat and friction.

Despite the relative inefficiency of steam turbine power plants, fossil fuels remain popular as energy sources for electricity generation because as materials they are dense with chemical energy and can be held in reserve until power generation is necessary. (In contrast, wind and solar power plants rely on natural phenomena that can’t be turned on and off at will.) But these fuels exist only in finite amounts throughout the globe, and using them at our present rate damages the environment. Finding reliable renewable sources of energy and developing technologies that convert them into electrical current without “losing” energy in the process is key to sustaining our electricity consumption over the long term.

### Circuit resistance

Various physical characteristics of a circuit influence the level of current it carries. The quality of the conductor is very important. Metals are good conductors because electrons in metals already flow freely through the material. A good conductor is said to have low resistance, which is conceptually similar to friction. Resistance is what causes energy to be lost along a circuit in the form of light or heat. A wire that glows and grows hot when current passes through it has more resistance than one that doesn’t. A “superconductor” is a material that loses barely any energy in the form of light or heat when current flows through it.

The ability of the circuit to maintain the electron current and prevent energy from dissipating into the environment through insulation determines how much work the energy conveyed by the circuit can do. This is a matter of insulation. Meanwhile, conductors with larger cross-sectional areas — in other words, conductors that are wider or thicker — have less resistance. (Think of a heavy cable versus a thin wire.) Lastly, the distance that the current has to travel also affects the strength of the current: circuits have less resistance over shorter distances. These factors together determine the resistance of the circuit, or how much energy is lost as the current flows through the circuit; circuits with less resistance have a greater magnitude of current.

These factors impact the design of larger-scale electrical systems, too: the farther electricity has to travel between a power plant and an end user, the more energy is wasted. We can improve the efficiency of electricity production and consumption by designing circuits and Grids that minimize resistance through the selection of conductor and insulation materials, and the distribution of generators and transformers.

### Responsiveness

As electrons flow through a circuit, energy dissipates into the environment, and devices connected to the circuit use energy to perform work. Energy must be continuously applied to the circuit in order to keep charge flowing. Designing a circuit that draws on that energy only when necessary is a key part of efficiency. Consider the first circuit in the experiment: as long as the cables continue to connect the light bulb to either end of the battery, the chemical energy contained in the battery will eventually be used up and the light bulb will go dark. Within a circuit like this one, a switch can function to keep the circuit open and the conductor's electrons in place, not flowing in a current, until electricity is required to do work. The third circuit — called a parallel circuit — is an example: as long as the top circuit is open, the circuit is not losing the energy that would be used to light up the top light bulb. In a local system, switches can control entire circuits or individual devices, but some devices continue to draw electricity whenever they are connected to the circuit, regardless of whether they are "turned on."

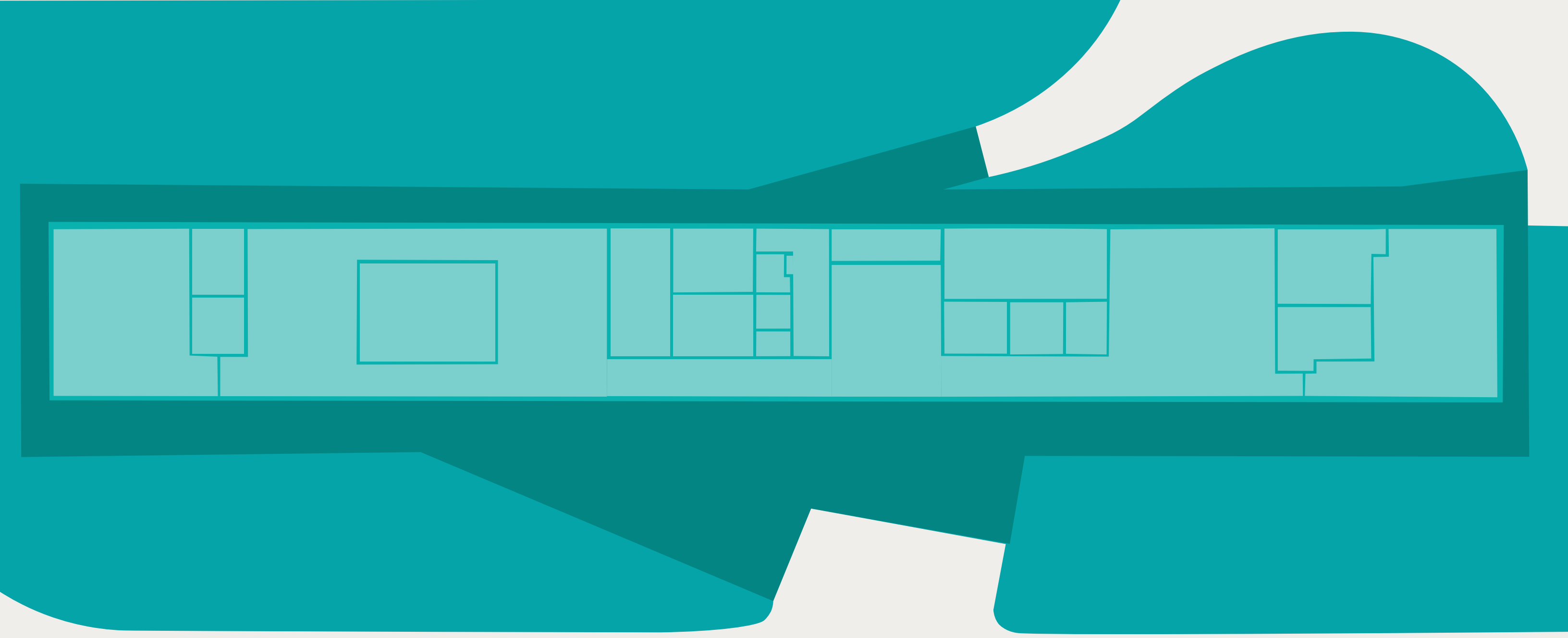
Within a larger electrical network, switches allow the power generator to send electricity only towards those parts of the network that require it. Large-scale batteries like the one outside the Center also perform an important function by storing electrical energy until it's needed to send electricity through a circuit.

Dean Hochman

## Electrical devices

The design of electrical devices also affects the circuit's efficiency. Different designs can accomplish different amounts of work using the same quantity of energy at the point of electricity generation. Take light bulbs as an example: their purpose is to produce light. Incandescent bulbs like the ones used in this experiment are considered inefficient because they produce heat along with light — every quantity of heat corresponds to light that can't be produced in another place along the circuit, so the energy that manifests as heat is "wasted." LED light bulbs are considered more efficient because they lose less energy to heat and their chemical lighting element requires less energy transfer than a typical incandescent filament to produce the same amount of light. The same principles hold true for computers, cars, water heaters, refrigerators, air conditioners, and anything else that runs on electricity: the less energy a device loses as it accomplishes its task and the less energy it requires to do that work, the more efficient the entire electrical network will be.

Michael Smith



## Part 3: Observation

### Instructions

Mark points of consumption on the Jones Beach Energy & Nature Center building plan (or draw a plan of the space you are analyzing). Make a list of what you observe. Don't forget to consider heating and cooling and other "background" energy consumption.

**Do devices with the largest loads consume the most electricity?**

**How might different devices' electricity consumption to change over the course of a year?**

**How does this building produce or conserve energy?**

**How does this building distribute energy?**

Look for evidence of circuits, devices that draw energy from the electrical system, and any evidence of where the system connects to a source of power.

**What parts of the building's electrical system might not be visible?**

**What devices are likely to have the largest loads?**

**How might the building reduce its overall energy consumption?**

**How might it reduce its electricity consumption?**

**Which of those reductions would be the most significant?**

## AT THE CENTER

Groups working with this curriculum on-site can begin by viewing the Center building model in the Lobby and the Energy Efficient House exhibit in the West Gallery.

Groups working with the curriculum off site can use their school building as the basis for the exercise.

For full activity materials, see:

Unit 1 Appendix
Pages 9-10

# Transforming natural energy sources

When designing or evaluating the electrical systems we rely on in daily life, it's important to consider how efficiently the system transforms primary energy sources into electrical energy. Efficiency is generally described in terms of the percentage of energy contained in an energy source that is successfully turned into electrical current. (For instance, if a given solar panel is exposed to 1,000 watts of sunlight and produces 200 watts of electricity, it will be said to be 20 percent efficient.) But we can also consider the waste produced in the process and the energy lost in distribution when assessing a conversion technology's efficiency.

For full activity materials, see:

Unit 1 Appendix
Page 11

## Instructions

Research two of the following technologies that is used to convert a primary energy source into electrical energy.

**Coal-powered steam turbine generator**

**Gas-powered combustion turbine generator**

**Geothermal power plant**

**Photovoltaic solar panel**

**Hydroelectric power plant**

**Wind turbine generator**

Prepare a research report that compares the two technologies, addressing the following questions for each:

**How does the technology work to transform a primary source of energy into electricity?**

**How efficient is it, on average? What factors affect its efficiency?**

**How is the resulting electricity delivered to consumers?**

**How much energy is lost in the process?**

**What waste is produced during electricity generation and distribution using these technologies? How else do these technologies impact their immediate environment?**

**What other factors do you think should be considered when assessing this technology?**

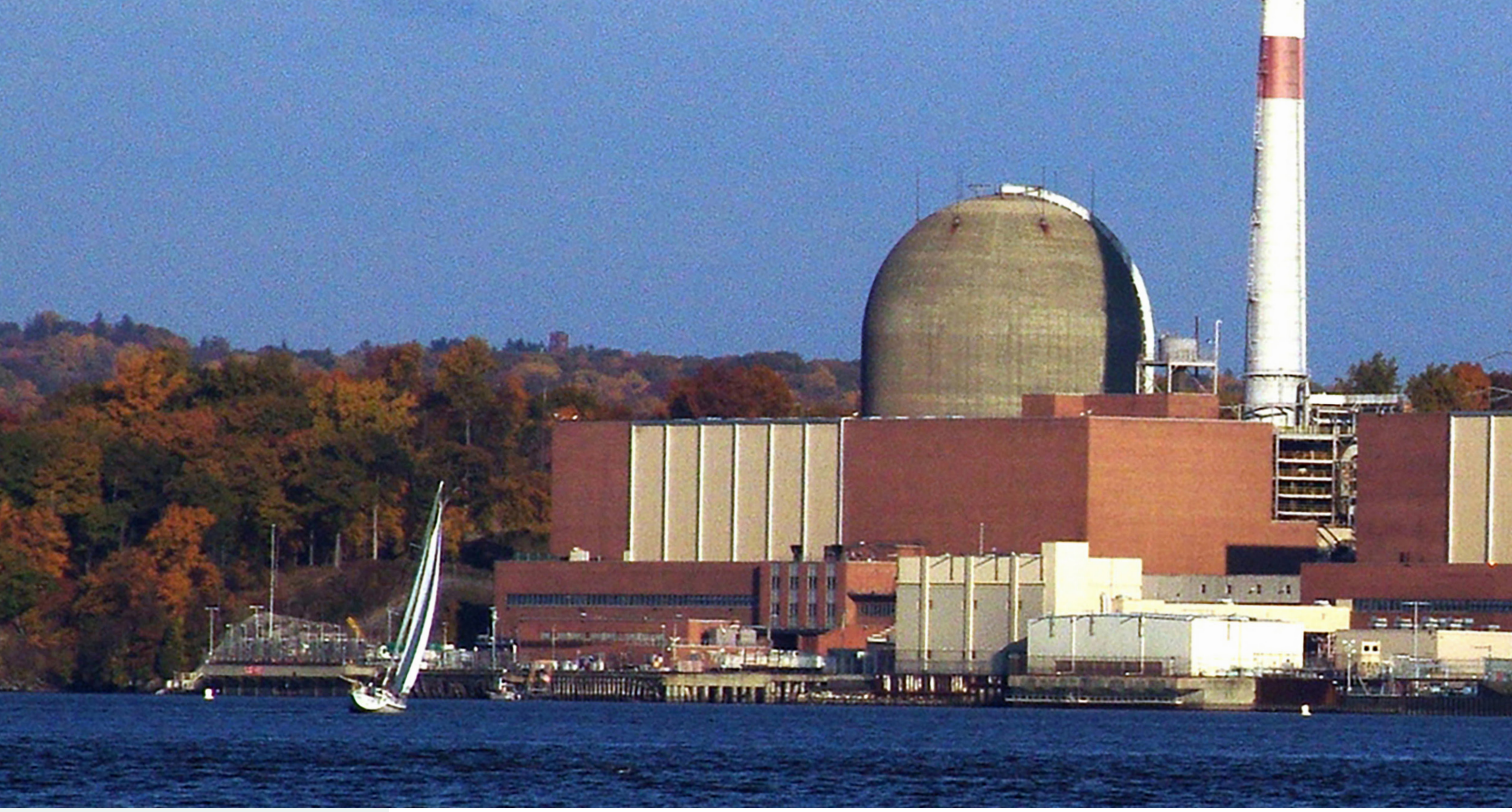
**Where are there opportunities to improve these technologies?**

## CORE CONCEPT 3

# Energy use impacts the environment in various ways

Extracting, refining, and converting primary energy sources into power for human use can impact the environment in many ways.

Landscape maintenance at Jones Beach
Sean Hanley and G. Anthony Svatek



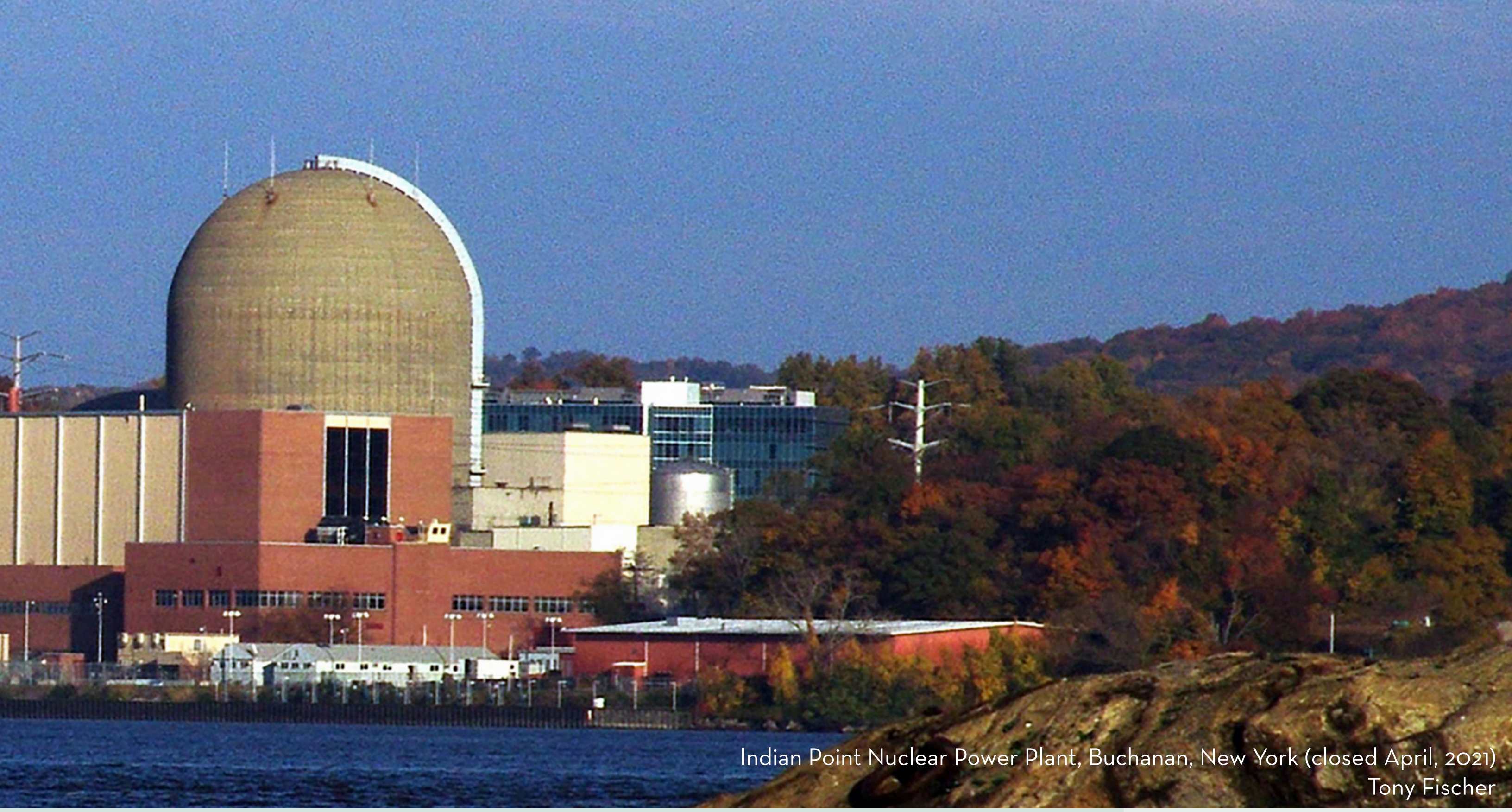
# Energy and human impacts

In Unit 1, energy has so far been a phenomenon that occurs naturally throughout the environment as well as an object of human consumption and utilization, moved from place to place within an environment by human-made systems. With this Core Concept, students begin to consider how energy systems themselves impact the environment. Climate change is introduced as a central issue at the intersection of human society, energy, and the environment, as extreme weather, sea level rise, and ecosystem disruption due to climate change, alongside pollution and habitat disruption from energy source extraction, are among the most significant environmental impacts of human energy use.

The initial discussion activity maintains focus on the materiality of daily energy use, exploring how physical characteristics and locations of different primary energy sources determine the environmental impacts of consuming them. The activity then transitions to an in-depth review the greenhouse effect and greenhouse gases, connecting the atomic-level chemical process of energy radiation and absorption to global climate change.

The subsequent role-play activity transitions from the micro to the societal level. Students adopt the roles of different stakeholders in the energy system, to explore the challenges of meeting society's energy needs while minimizing environmental impacts.

Lastly, as the take-home activity, students reflect on the unequal burden of energy systems' environmental impacts, developing a framework of environmental justice that they will use to critically assess different energy sources and systems in this and future Core Concepts.



Indian Point Nuclear Power Plant, Buchanan, New York (closed April, 2021)
Tony Fischer

# How do I fit into the energy system?

**What kinds of energy do I consume?**

**Where does the energy I consume come from?**

**How does the energy I use impact the environment?**

**What role can I play in determining how the energy system works?**

**What power do I have to make changes in the way my community uses energy?**

**What can I control, when it comes to my energy consumption and its environmental impacts?**

**What things are outside of my control?**

## PRIMER

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

# Our sources of energy

## Where does the energy we use come from?

Figuring out the origin of the energy we use isn't always simple. In 2019, the majority of energy produced in the state came not from fossil fuels but from nuclear power (468.5 trillion BTUs) and renewables like hydropower and wind (336.1 trillion BTUs). However, the majority of energy consumed in New York originated as the fossil fuel methane gas, also known as natural gas – in 2019, the state consumed 1,333 trillion BTUs of natural gas energy. How to account for the difference between production and consumption? Natural gas mining by hydraulic fracturing (also known as "fracking") was illegal in New York in 2019, so power companies imported natural gas from nearby states like Pennsylvania. But in 2019, the Climate Leadership and Community Protection Act commited New York to producing 100 percent carbon-free electricity by 2040. With the closure of the last coal-fired power plants in 2020 and the Indian Point nuclear power plant in 2021, the energy landscape of New York is in flux.

As of 2020, 81 percent of the energy consumed in the US came from so-called "fossil fuels," including liquid oil, coal, and methane gas, also known as natural gas. These fuels are used to power the motors and engines of vehicles and other machines, to generate electricity using steam turbine generators, and for household heating and cooking. Fossil fuels are derived from decayed organic matter—ancient plants and phytoplankton—that has been transformed by heat and pressure over millions of years into material dense with chemical potential energy contained in carbon molecule bonds. This energy can be released and transformed into kinetic energy or heat through combustion, but first the fuels must be located, extracted, and processed into a useable form. Then, the refined fuel must be transported to electrical power generators, or to end consumers. Electricity generated using fuels must also be conveyed to consumers through the network of infrastructure known as the Grid. At each of these steps, the environment is affected in a variety of ways.

Likewise, the petroleum products that power our cars, trucks, buses, and airplanes are produced elsewhere and imported via pipelines, trains, and trucks.

Fossil fuels are derived from decayed organic matter – ancient plants and phytoplankton – that has been transformed by heat and pressure over millions of years into material dense with chemical potential energy contained in carbon molecule bonds. This energy can be released and transformed into kinetic energy or heat through combustion, but first the fuels must be located, extracted, and processed into a usable form. Then, the refined fuel must be transported to electrical power generators, or to other consumers.

The environmental impacts of fossil fuels may be familiar to many students, but even renewable energy sources – those that generate heat or electricity using a functionally infinite resource like the wind, the sun, or the warmth of the Earth's crust – impact the environment. All sites of power

## AT THE CENTER

Groups working with the curriculum on-site can begin by viewing the Geography of Power exhibit in the South Gallery, and the Power of Seasons video, the Producing Power exhibit, and the Energy Sources Interactive in the West Gallery.

## LEARN MORE

See 1.2 for discussion of how different energy sources contribute to overall energy consumption in the US, including data from the Energy Information Administration.

See 4.1 for discussion of the network of energy supply known as the Grid.

Hydraulic fracturing in Inglewood, California
Erick Gustafson

generation have physical footprints that impact the ecosystems and human communities that surround them. Electricity generated using any energy source must also be conveyed to consumers through the network of infrastructure known as the Grid, which impacts the environment in turn. Extraction, processing, transport, and power generation: at each of these steps, our energy consumption impacts the environment in a variety of ways.

## How is the energy we use extracted?

The method by which energy sources are harvested depends on their phyiscal state and geographic location.

Fossil fuels are found in Earth's crust within and between layers of sedimentary rock. Like other geological phenomena, fossil fuel deposits are distributed unevenly across the planet, in patterns that reflect the movement of tectonic plates, the deposition of sediment, and the flow of water and ice over millions of years. The physical location of a given fuel deposit determines the processes required to extract it from the Earth. And as fuels become more scarce, more invasive methods are necessary to access the deposits that remain. Between 1949 and 2008, the average depth of oil well drilling increased from 3,635 feet below the surface to 5,964 feet below.

Oil and gas are often found together in underground reservoirs that can be accessed by drilling, and then pumped to the surface and piped to processing centers.

When gas deposits are small and diffuse, miners may use hydraulic fracturing to make them more accessible, injecting water, chemicals, and sand into bedrock at high pressure to open up larger cavities underground or consolidate reservoirs. Coal, meanwhile, is found in seams in sedimentary rock. It must be blasted out or otherwise separated from other solids by manual and machine labor, either in deep mines more than 200 feet underground or in mines at the surface.

Renewable energy sources like sunlight, wind, and geothermal energy can be found throughout the globe, but may be stronger in certain places than in others. For instance, off-shore winds are often stronger than winds on land, the power of which may be dampened by obstructions like mountains or buildings. Meanwhile solar energy is particularly plentiful in places closer to the equator.

## How are sources of energy converted to usable power?

Just as the physical state of a fossil fuel determines the method of its extraction, the location and surrounding geology of a given deposit determines its composition and the steps that must be taken after extraction to prepare the material for consumption as a fuel.

Coal seams often include clay and other kinds of rocks and minerals, like sulfur, that must be removed before the coal can be used as fuel. The cleaning process also includes sizing and sorting the coal into different categories based on quality and size. Coal is most often transported by train, first from the mine to a nearby processing plant, and then from the processing plant to a point of storage or distribution. It can also be shipped on barges or trucked over land.

CENEX oil refinery, Billings, Montana
Greg Goebel

Meanwhile, crude oil must be refined in order to separate out the various petroleum products and natural gas that consumers ultimately use. The refining process comprises two main steps. Separation isolates different hydrocarbons according to their volatility, or "heaviness." Meanwhile, conversion breaks heavier hydrocarbons down into lighter ones or induces chemical reactions to recompose light hydrocarbons into higher-value forms like gasoline. Pipelines, trucks, and barges convey crude oil from wellhead to refinery, and petroleum products from refineries to storage and distribution points.

Whether natural gas is found dissolved in a crude oil reservoir or isolated in a gas reservoir, it too must be processed to remove contaminating solids, water, mercury, gases like carbon dioxide and hydrogen sulfide, and other hydrocarbons. Gas is processed at the wellhead and transported via a network of "gathering pipes" to centralized plants for further processing. But the gas must be purified to meet quality standards before it can be transmitted to consumers or storage facilities through commercial distribution pipelines. Natural gas can also be liquefied for transportation in canisters over long distances. Gas can be stored in large quantities below ground in caverns and reservoirs, or in smaller amounts in above-ground tanks.

Though the vast majority of energy consumption by individuals and industry relies on fossil fuels, renewable energy sources make up an increasingly significant share of the energy consumed for electricity generation. Renewable energy sources are so called because, in contrast to fossil fuels that exist only in finite quantities on Earth, renewable technologies harness natural forces and phenomena that are functionally unlimited: the energy radiated to Earth by the sun, the energy radiated outward by Earth's core (geothermal energy), and the kinetic energy possessed by wind and water in motion.

Rather than mining fuel materials from Earth's crust, renewable energy production employs machines to transform naturally-occurring energy into electrical energy. In the case of wind energy and hydropower, these machines are turbines that use the kinetic energy of the wind and water to create an electrical current using electromagnetic induction. Solar panels are constructed from materials that absorb energy from photons, the impact of which pushes excited electrons within the panels into a current. Geothermal power plants use a system of pipes to draw energy from the ground into a conductive fluid, which is then used to power steam turbine generators similar to those employed in fossil fuel-powered electricity generation.

There are also non-fossil fuel primary energy sources that are not strictly speaking renewable. Nuclear power uses the chemical energy contained within the element uranium, a finite resource, to produce large quantities of heat that can then be used to run steam turbine generators. Biomass energy and biofuels derive fuel in either liquid or gas form from solid waste or crops like soy beans, corn, and algae. Farmed biomass is limited in quantity by the amount of land and nutrients available for cultivating crops; recycled biomass is limited by the amount of waste produced.

## How do different energy sources impact the environment?

The extraction of any energy source directly alters the landscape.

Fossil fuel extraction is particularly disruptive, as the crust must be mined, drilled, displaced, and fractured to access the underground deposits. Certain kinds of coal mining use explosives to remove entire mountaintops in order to access shallow coal deposits. Fracking to access natural gas can make land geologically unstable. Drilling for oil may induce seismic activity, setting off small earthquakes. But harnessing renewable energy sources also entails land disruption of some kind. Geothermal power plants also require drilling deep into the Earth, increasing the risk of earthquakes. Even extraction that happens at the surface can be disruptive. Hydroelectric power plants often require the construction of dams and large reservoirs of water, for which tracts of land are flooded, displacing human communities and disturbing or even destroying ecosystems. Growing biomass as fuel often relies on monoculture that can damage biodiversity by restricting production to just one plant species and thus denying food and habitat resources to animals that rely on other forms of plant life. Wind power plants and solar power plants that produce electricity at scale have large footprints, which can negatively affect ecosystems.

Consumption of some energy sources also impacts the environment by polluting the ground, water, and air. Pollution can occur at any point in the energy consumption process: extraction, refining, distribution, and consumption. Extracting geothermal energy can result in chemicals leaching into underground aquifers, for instance. Fracking, mining, and drilling for fossil fuels can release chemicals into the ground and groundwater, while mining coal in particular can release large quantities of methane into the atmosphere. Distilling crude oil to separate hydrocarbons of different weights produces chemical fumes that are toxic to humans and animals, while refining uranium for nuclear power production can pollute the surrounding land and water. The storage of waste material from uranium mining also introduces potential toxins into the environment. Indeed, all fuel extraction and refining processes produce waste, and especially wastewater, much of which is harmful to humans and animals.

The distribution and use of refined energy sources to generate electricity or accomplish other work frequently produces potentially toxic waste material and byproducts as well. Depleted uranium rods, which can no longer be used to run generators, remain dangerously radioactive for about ten thousand years. Combustion of many fossil fuels, especially coal and diesel, releases a range of air pollutants that are responsible for one in five deaths worldwide.

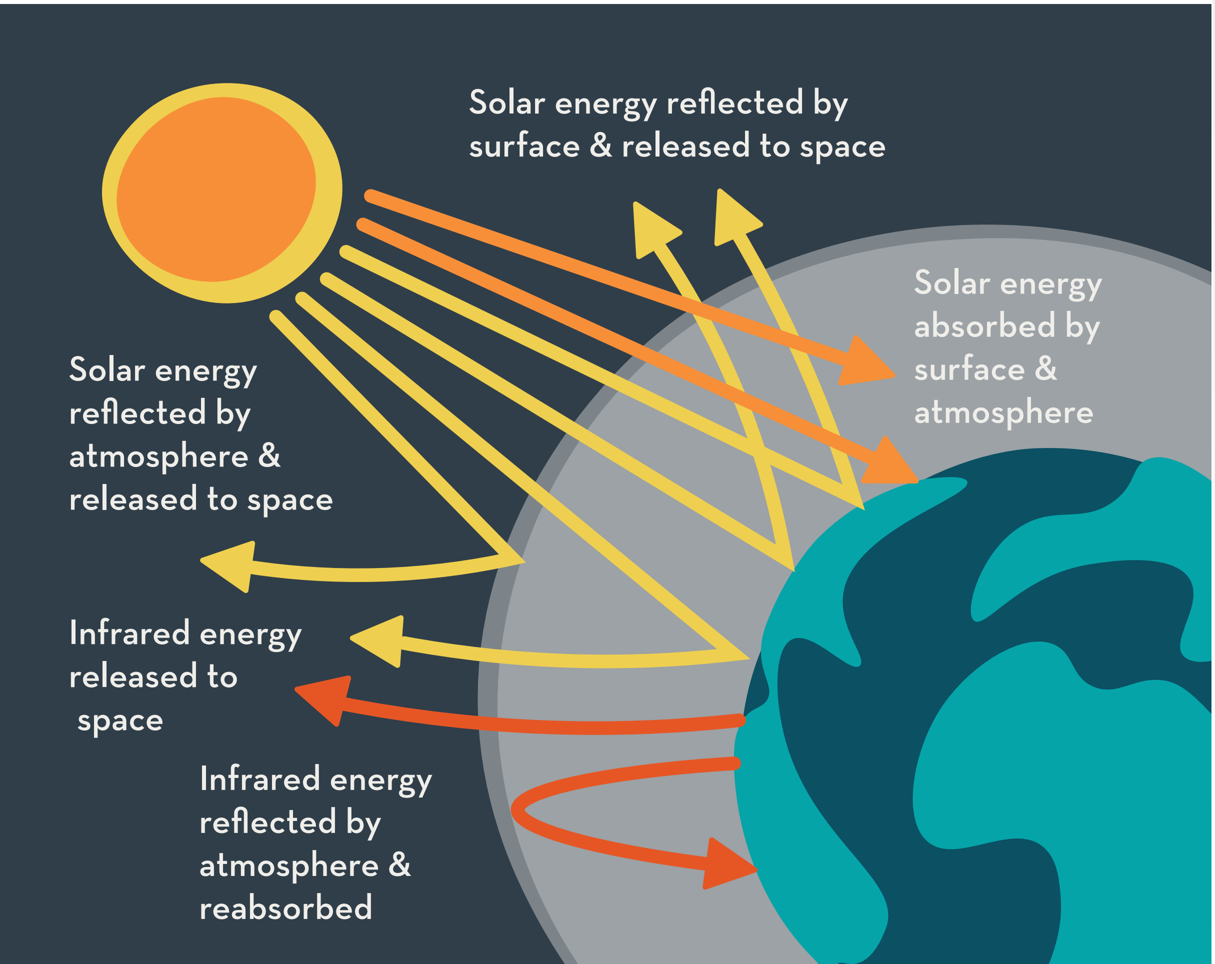
Of the fossil fuels, natural gas is the “cleanest” in that its combustion yields the least airborne toxic byproducts. However, gas wells and the pipelines that transmit gas over long distances are prone to leaks, which can infiltrate the ground and water or release airborne toxins that can trigger sickness in humans and animals. Oil wells and transmission routes are also prone to rupture, resulting in spills that can greatly harm surrounding ecosystems, especially at sea. Electricity produced by solar, hydro, and wind power plants does not have such direct, toxic byproducts. But it is important to note that renewable power plants are typically constructed from materials produced with fossil fuels, like concrete, or other materials that are extracted from the crust by invasive methods and refined with potentially toxic byproducts.

The infrastructure required to distribute an energy source can itself have a large environmental impact. How much space does the infrastructure of distribution require, and how does constructing that infrastructure disrupt habitats or impact public health? How much space does storage take up? How do the physical structures used to extract, refine, convert, and distribute a given energy source impact their surroundings? Does transporting raw materials cause pollution or emissions? All of these factors influence the environmental impact of energy consumption.

## What is the greenhouse effect?

The greenhouse effect is the mechanism by which certain kinds of gas molecules in Earth's atmosphere contain energy close to the planet's surface that would otherwise be released into space.

When photons radiating from the sun intersect with the planet, roughly 30 percent of the radiant energy they convey is reflected into outer space by the atmosphere and clouds, and about 20 percent is absorbed by the atmosphere. The rest is absorbed at the surface by the crust and oceans. Gradually, following the Second Law of Thermodynamics, the land and water lose the energy they have absorbed, radiating it outward in the form of infrared waves.



## LEARN MORE

The Climate Leadership and Community Protection Act (2019) commits New York State to transitioning to a cleaner energy future, with a focus on assisting the communities most effected by climate change. Among other goals, the Climate Act requires that that 70 percent of electricity consumed in the state be produced from renewable energy by 2030, and 100 percent zero-carbon electricity generation by 2040.

**climate.ny.gov/Our-Mission**

Ludovic Brucker, courtesy of NASA Goddard Space Flight Center

A greenhouse gas is any gas in the atmosphere that absorbs infrared radiation released by Earth.

The greenhouse effect occurs naturally on this planet and others. Naturally occurring levels of atmospheric greenhouse gases, produced by the decomposition of organic matter, are responsible for keeping the planet warm enough to support plant and animal life. Slightly more energy must come in than goes out of the planet's "energy budget" to drive the water cycle and keep ecosystems functioning. The natural greenhouse effect has maintained a habitable temperature on Earth for the last 10,000 years, about 33°C warmer than it would be otherwise. In that timespan, the temperature has varied only about 1°C thanks to changing light levels from the sun or events like major volcanic eruptions that add light-blocking debris to the atmosphere.

Ice cores extracted from polar ice record the gaseous makeup of the atmosphere at the time of freezing, and show that human activity since the 18th century has increased the concentration of greenhouse gases in the atmosphere rapidly and significantly. This in turn has rapidly increased the amount of radiation energy contained by the atmosphere through a phenomenon called the enhanced greenhouse effect. Additional greenhouse gases emissions that are the result of human activity including — but not limited to — fossil fuel energy consumption have increased the capacity of the atmosphere to retain radiation energy by the atmosphere, which is known as "radiative forcing." Radiative forcing shifts the energy budget and causes global average temperatures to increase. The overall result is the warming of average global temperatures over time, which ultimately accelerates the water cycle and changes the direction of ocean and air currents, producing anthropogenic climate change. "Anthropogenic" — derived from the Greek *anthropos*, meaning human, and *genus*, meaning origin — means that human activity is the source. Water vapor has by far the largest effect on radiative forcing of any greenhouse gas, so the increased evaporation driven by warming makes the greenhouse effect stronger too.

## What are the primary greenhouse gases and where do they come from?

The ability of gases to absorb energy from infrared radiation depends on their chemical structure. Energy is absorbed when the impact of the radiative waves causes the molecules to vibrate and electrical charge to shift, alongside electrons, between their component atoms. The majority of the atmosphere is made up of nitrogen (N2), oxygen (O2), and argon (Ar), but these are not greenhouse gases because molecules composed of two atoms of the same element do not undergo a shift in electrical charge when they vibrate, and single-atom molecules cannot vibrate.

Often, people use "carbon" as a stand-in for greenhouse gases in general, and indeed, carbon dioxide is the most prevalent naturally-occurring greenhouse gas besides water vapor. It also makes up the vast majority of human greenhouse gas emissions. (In 2019, carbon dioxide was 80 percent of US greenhouse gas emissions.) But several other gases also contribute significantly to the greenhouse effect and have a greater relative warming effect, pound for pound, than carbon dioxide. This relative warming effect is called Global Warming Potential (GWP). Carbon dioxide has a GWP of 1, and a molecule that absorbs twice as much radiation as carbon dioxide over the same time period has a GWP of 2.

It is challenging to quantify the relative impact of different gases on the greenhouse effect and global warming. Higher-GWP substances may have a lower absolute effect on global warming because they are present in the atmosphere in smaller amounts. In addition, when gases mix with other molecules in the atmosphere, their chemical structure and their effect on radiative forcing change, meaning that the presence of any given gas may change the warming impact of another, and vice versa. Additionally, the GWP of non-carbon greenhouse gases changes over time, and some gases may be removed from the atmosphere at variable rates over time through precipitation and other processes. But most greenhouse gases, once emitted into the atmosphere, remain there for hundreds or thousands of years.

### Carbon Dioxide (CO2)

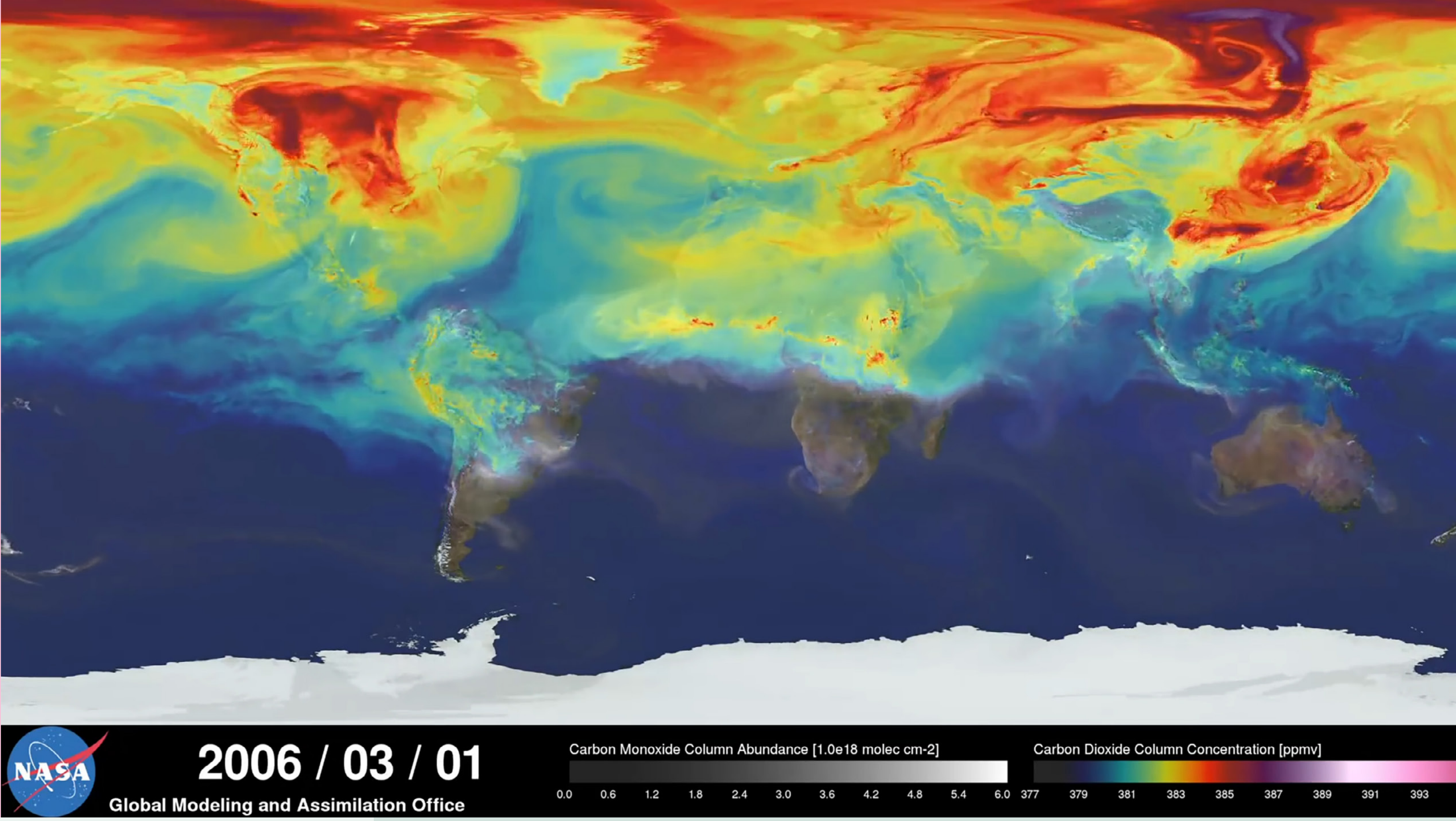
Outside of the context of anthropogenic climate change, carbon dioxide enters the atmosphere as dead plants and animals decompose. Combustion of fossil fuels, wood, or other biomass breaks the chemical bonds in matter, releasing the potential energy contained in the bonds that would otherwise be released by decay.

Since the beginning of the Industrial Revolution in the second half of the 18th century, carbon dioxide has been responsible for the majority of the increase in radiative forcing.. Primarily due to industrial activity, the concentration of carbon dioxide in the atmosphere has increased 45 percent since 1750, from about 280 ppm (parts per million) to 412.5 ppm in 2020, the highest concentration in 800,000 years. This increase only reflects half of the total emissions in that time, as carbon "sinks" like forests and oceans have absorbed the other half.

## LEARN MORE

See 1.1 for discussion of radiation and energy transfer between molecules.

See 1.1 for discussion of the chemical energy contained in hydrocarbon bonds.



## BREAK OUT

Give students a few minutes to view the video and discuss in pairs or small groups. Then come back together as a class to debrief.

## Discussion

View the video from the NASA Goddard Space Flight Center shows the atmospheric concentration of carbon dioxide over the course of a year.

**What do you notice about how carbon moves around in the atmosphere?**

Because carbon dioxide emissions are a direct result of hydrocarbon combustion, the emissions themselves are unevenly distributed throughout the world. Countries with extensive, fossil-fuel-driven industrial sectors emit much more carbon, creating a greater local atmospheric concentration over those regions. Meanwhile, extensive carbon sinks reduce local concentrations during their growing seasons. And the global circulation of air spreads the gas around the globe.

### Source

NASA | A year in the life of the world's CO2

**youtube.com/watch?v=x1SgmFa0r04&ab_channel=NASAGoddard**

### Methane ($CH_4$)

After carbon dioxide, the second-most significant greenhouse gas is methane. Methane has about 28 to 36 times the warming potential of carbon dioxide over 100 years. In 2019, methane comprised 10 percent of US anthropogenic greenhouse gas emissions, and anthropogenic emissions from fossil fuel extraction and consumption, landfills, and industrial agricultural practices like cattle farming, accounted for about 60 percent of total methane emissions worldwide. The energy source known as “natural gas” is in fact methane gas, so leaky gas pipelines, besides carrying the risk of dangerous explosions, also contribute to the atmospheric concentration of greenhouse gases. Methane can also enter the atmosphere through evaporation from natural sources like wetlands, bodies of water, and the ocean floor.

The concentration of methane in the atmosphere has increased about 150 percent since 1750, more than double its atmospheric concentration at any point in the last 800,000 years. Methane often indirectly impacts the greenhouse effect by facilitating the combination of other molecules into low-lying air pollution, including tropospheric ozone, which has a significant warming effect.

### Nitrous Oxide ($N_2O$)

The relative warming potential of nitrous oxide is roughly 265-298 times that of carbon dioxide over 100 years. In 2019, it represented 7 percent of US anthropogenic greenhouse gas emissions, and anthropogenic emissions comprised 40 percent of total nitrous oxide emissions across the globe.

Natural sources of nitrous oxide include oceans, forests, and soils, as nitrogen cycles through these ecosystems. The main source of nitrous oxide in human activity is the use of nitrogen fertilizers in agricultural production, as well as the combustion of fossil fuels. Wastewater treatment also contributes significantly to nitrous oxide emissions.

### Fluorinated gases

This group of gases includes hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride ($SF_6$), and nitrogen trifluoride ($NF_3$). The relative warming potential of each type of fluorinated gas is different, but as a group they have thousands or tens of thousands of times the warming potential of carbon dioxide.

There are no natural sources of fluorinated gases; they are exclusively man-made and used in industrial processes. Hydrofluorocarbons were manufactured as alternatives to commonly-used chemicals that were found to be depleting the stratospheric ozone layer. They are used in the manufacture of refrigerants, aerosols, foams, solvents, and fire retardants. The primary source of hydrofluorocarbon emissions is refrigeration, especially air conditioning. Other fluorinated gases are produced as byproducts or used in industrial manufacturing, electricity generation and transmission, and electronics. As well as having a high GWP, fluorinated gases stay in the atmosphere for hundreds or thousands of years — PFCs have an atmospheric lifetime of 50,000 years.

## LEARN MORE

See 5.1 for further discussion of the greenhouse effect, climate change, and feedback loops.

See 1.1 for discussion of how radiated energy drives evaporation and climate processes on a molecular level.

See 2.3, 5.2, and 5.3 for discussion of how sea level rise due to climate change impacts human communities and ecosystems.

### Black Carbon

While not technically a gas, black carbon is now recognized as another major airborne contributor to climate change. A byproduct of the incomplete combustion of biomass and fossil fuels including wood, coal, and municipal waste, this fine particulate solid gives soot its black color and texture. Black carbon has a 100-year GWP of 1,055-2,240, but only stays in the atmosphere for up to two weeks. It is especially important to consider black carbon as a driver of the greenhouse effect because its short atmospheric lifetime means it would be relatively easy to affect its atmospheric concentration, compared to other greenhouse gases. Black carbon also has significant impacts on human health, causing lung and heart diseases.

The greenhouse effect is a molecular phenomenon with global results. Climate change has major implications for every ecosystem on Earth. Global warming impacts local temperatures, altering seasonal weather patterns, plant growth cycles, and animal habitat and migration. Warming even causes some species to go extinct, permanently impacting food webs on which humans and other living beings depend. For human beings, extreme weather is one of the most significant effects of climate change. An increased quantity of energy contained inside the Earth's atmosphere alters evaporation patterns, ocean currents, and winds, giving rise to stronger storms, more intense heat waves, and droughts that impact where humans can live and where we can grow food. Sea level rise is another major environmental impact of climate change, particularly for coastal communities like the ones around Jones Beach, which will have to make hard decisions in the coming years about how to respond to the encroaching ocean. Globally, hundreds of millions of people live in areas that may become uninhabitable due to flooding within the next century.

## BREAK OUT

Give students a few minutes to discuss in pairs or small groups. Then come back together as a class to debrief.

## Discussion: Clean, sustainable, both, or neither?

**What does it mean for an energy source to be "sustainable"?**

**What does it mean for an energy source to be "clean"?**

"Sustainable" and "clean" are value judgments, rather than technical terms, and their application to different energy sources is the subject of considerable debate. An energy source may be considered sustainable if it is functionally unlimited (like solar power), if its production has a neutral or positive effect on the environment (like certain kinds of biomass), or if it is energy-dense enough to meet energy needs in the long term with relatively small environmental impact (like nuclear power). An energy source may be considered unsustainable if demand far outstrips availability, or if the negative environmental effects of extracting, processing, and distributing it pose a serious threat in the short or long term. By contrast, "clean" energy sources might carry relatively few of those negative effects, but may not necessarily be more sustainable as a way to meet energy needs in the long term. Regardless, the extraction, processing, distribution, and consumption of any energy source, even one described as "sustainable" or "clean," necessarily has some impact on the environment.

# Energy and environmental impacts

There are always trade-offs when choosing between different sources of energy. In this activity, each group of five represents a national energy council tasked with choosing which natural energy sources to extract, refine, and use for industrial power production. Together, the council must come to a decision about how to allocate ten units of funding for industrial electricity production. The council can allocate all of its funding to one source or divide its funding between sources. Each council includes one Council Member to advocate on behalf of Energy Consumers, one for Energy Producers, one for the Environment, and two Government Adjudicators.

## Part 1: Debate

### Instructions

Designate a Council Chairperson to moderate the debate.

Read through the Energy Source Information Sheets and get familiar with the assigned Council Member profiles.

> **What are your goals?**
>
> **What do you want to avoid?**

Formulate initial proposals.

> **Each Council Member should choose up to three energy sources among which the ten units of funding will be divided, then write their proposal on a piece of paper and submit it to the Chairperson.**

Vote on initial proposals. Council Members should not vote for their own proposals, but instead choose their top two of the other Members' proposals.

Debate the top three proposals. At the end of the allotted debate time, vote again.

For full activity materials, see:

Unit 1 Appendix
Pages 12-16

### Debrief

> **What was easy and what was hard about choosing how to allocate this funding?**
>
> **What things did groups tend to prioritize highest? What didn't seem to matter as much?**
>
> **How did the dynamic of the debate change when the participants' interests were revealed?**

### Energy Source A

Of the non-renewable energy sources, Energy Source A is one of the least energy-dense. Historically, it has been widely available within the country's borders, and was one of the first energy sources used in industry. A large infrastructure and economy...

### Profile: Consumer Advocate

Your priorities are to keep prices low, and to distribute control towards energy consumers. You do not want to have to change your consumption habits. You are concerned about service reliability and long-term availability of power....

### Energy Source B

This non-renewable Energy Source is more than twice as energy-dense as Energy Source A by weight, but it is much less concentrated in natural deposits, so extracting the same quantity of energy requires more effort and expense...

### Profile: Producer Advocate

Your priority is to maximize profit by minimizing the cost of material extraction and delivery infrastructure. You want to keep prices low to encourage consumption, but not so low that you don't make money. You are not concerned about...

### Energy Source C

This non-renewable material is the most energy-dense material on Earth, containing more than 70,000 times more energy by weight than Energy Sources A and B. This energy source is also very rare and quite dangerous. Accidents in extraction...

### Profile: Environmental Advocate

Your priority is to minimize the impacts of energy production and consumption on the environment. You are concerned about pricing insofar as it affects production and consumption choices. You are concerned about reliability...

### Energy Source D

This energy source is one of the most widely available on Earth and exists in virtually unlimited quantities. However Energy Source D is not always available, and humans cannot control how consistently or powerfully it is available....

### Profile: Government Adjudicator

Your priority is to find a solution that works for everyone such that you are not targeted for removal by an organized interest group during the next election. You are concerned about environmental impacts insofar as they affect your constituents....

# Environmental justice

What is the spatial relationship between of the environmental impacts of the energy system and the places people live? For low-income people and people of color, these geographies can be too closely intertwined. These groups disproportionately suffer from the environmental impacts of the energy system: potentially hazardous energy infrastructures like mines, power stations, pipelines, and highways are disproportionately sited in poor, segregated communities, exposing members of those communities to greater risk of disease and injury. Meanwhile, as global climate change accelerates, poor and marginalized communities are among the first to feel the impacts of changing weather patterns, rising sea levels, and increasing water scarcity. But how should the burden of energy consumption's environmental impacts be distributed?

## Instructions

Read and summarize the two attached articles.

**What problem does each article describe? Who or what is responsible? Who is most affected? Who avoids being affected?**

**How are the stories similar? How are they different?**

**Where do you locate injustice in each story?**

**What is your definition of "environmental justice"? How should an environmentally just society should be organized, and why is environmental justice important?**

**What stands in the way of environmental justice in your community and society at large? What can you do to help bring about environmental justice?**

## Sources

"Postcard From Thermal: Surviving the Climate Gap in Eastern Coachella Valley," Elizabeth Weil and Mauricio Rodríguez Pons, ProPublica, August 17, 2021. Excerpted in Appendix and available online.

**propublica.org/article/postcard-from-thermal-surviving-the-climate-gap-in-eastern-coachella-valley**

"As Houston plots a sustainable path forward, it's leaving this neighborhood behind," Raj Mankad, *Grist* and *Texas Tribune*, August 15, 2017. Excerpted in Appendix and available online.

**texastribune.org/2017/08/23/houston-plots-sustainable-path-forward-its-leaving-neighborhood-behind/**

## LEARN MORE

See 2.3 and 5.1 for discussion of the greenhouse effect and its role in climate change.

See Unit 5 for discussion of the origins, impacts, and ethics of anthropogenic climate change, and 5.3 specifically for discussion of frontline communities and climate migration.

For full activity materials, see:

Unit 1 Appendix
Pages 17-33

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