What Is Renewable Energy?

Energy comes from natural resources that are either renewable or nonrenewable. Nonrenewable resources exist in fixed amounts within the earth and once they are used up, they are either gone forever or they take an extreme amount of time to regenerate. Renewable resources are different. They can be replaced through natural and/or human processes in a comparatively short time. Examples of renewable energy sources are:

Solar
Energy from the Sun

Wind
Energy Caused by the Sun's Uneven Heating of the Earth's Surface

Hydropower
Energy from Moving Water, Ocean Waves, Tides and Temperatures

Biomass
Energy from Plants and Animals

Geothermal
Energy from Heat Within the Earth

Pros, Cons and Savings

Renewable energy offers important advantages. It helps the environment by reducing human caused greenhouse gas emissions that are produced from burning fossil fuels. Renewable energy contributes to our economic security because it can be gathered within the U.S., or even state boundaries. Vast amounts of renewable energy can also help supply the world's growing demand for energy sources that generate electricity, create heat and power transportation.

Renewable energy sources can have drawbacks. They may require conditions that are not always present, like a strong wind blowing or a sunny day. Some renewable energy sources rely on new technologies or infrastructures that are not fully developed.

However, we are learning to store renewable energy for times when it is needed and the cost of these technologies is decreasing rapidly.

While renewable energy is more sustainable because it will not completely "run out," both renewable and nonrenewable sources require time, money and resources to use. Energy efficiency and being smart with the ways we use energy help us save all energy sources. We can be energy efficient by managing consumption through the use of efficient technologies like low flow water devices or a smart thermostat. We can also be smart with our energy behaviors by taking a short shower or turning off the lights.

Using Renewable Energy: Past and Present

The U.S. has always relied on renewable energy, but the sources and amounts we use have changed over time.

Early History

The sun is used for warmth and to dry food. Wind is used to push boat sails and turn mills to grind grain. Wood (biomass) is widely used for energy needs.

Mid-1800s to 1990s

New technologies are created to use renewable sources for heat and to convert them to electricity. Hydropower and (solid) biomass are the most used renewable energy resources.

1990s and Beyond

Biofuel (liquid biomass), solar and wind energy use increased. By 2021, renewable energy provided about 12% of the energy used in the U.S., most of it for generating electricity.

The Ultimate Energy Source

The sun is the ultimate source of energy, emitting light and heat energy at a tremendous rate. Solar technologies include photovoltaics, solar thermal electric systems and solar heating and cooling systems. All of these capture the sun's energy to produce electricity or heat.

Heat from the Sun

Solar energy has been used for a long time to heat and cool buildings. Solar collectors gather heat from the sun when it strikes an absorber. That heat can be stored until it is needed. In a passive solar building, the building itself serves as the collector. Sunlight enters through the windows or sunspaces and is stored inside the building. Active solar relies on pumps, fans or solar collectors to collect and distribute heat.

Solar energy can also heat water. Passive water heating systems work like a water filled garden hose that has been left in the sun. Panels containing water pipes may be located on a roof where sun hits and warms water to be used in the building.

Active Solar Heating

Concentrating the Sun

Solar energy can generate high temperatures for use in industrial processes or for generating electricity. Concentrating solar power systems use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat. Thermal energy can then be used to produce electricity with a turbine or heat engine driving a generator.

Parabolic Solar Trough

Photovoltaics

Sunlight can generate electricity directly through photovoltaic (PV) cells. You may have seen small PV cells on a calculator or a traffic sign. Most solar cells are made of layers of semiconductors such as silicon, a material that conducts electricity (but not as well as a metal). When sunlight strikes the PV cells, it is changed directly into electricity without other steps such as heat generation.

Many PV cells can be arranged together in a module, or panel, like one seen on a home. Multiple panels can be arranged in an array of any size. Larger arrays can be used by a utility company to produce electricity for thousands of buildings. PV systems can be created to produce more electricity by use of tracking systems that move them to constantly face the sun. Photovoltaics are amazing. They:

- Power spacecraft, cellular phone towers and weather stations
- Supply electricity in places where power lines do not exist
- Are placed in beneficial areas like fields (to produce energy and reduce heat stress livestock) or on pontoons that float on water (reducing evaporation and undesirable algae growth)
- Can be developed with thin-film solar cells that are flexible and lightweight, making them portable (like on a backpack) and useable on products like windows
- Are becoming more efficient and less expensive
- Will be made in the future from organic materials and other technologies that could lower costs and be easier to manufacture.

Cells

Panel

Array

Sensational Renewables

Around one billion people worldwide experience energy poverty that changes the ability to learn, be safe or earn money.

Renewable technologies are part of the solution. After a 2010 earthquake in Haiti, a lightweight, solar-powered inflatable light was developed to help those affected. In developing countries, flexible PV cells are woven into cloth to collect solar energy for light at night. Visit *un.org/sustainabledevelopment/energy/* to find other ways that renewable energy is making a difference.

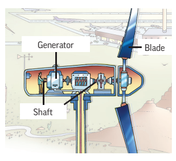
Solar PV Madagascar

Something in the Air

Today, most wind energy is used to generate electricity. We harness the power of the wind and convert it into electricity with wind turbines. They usually have two or three blades and either a vertical or horizontal axis. One small turbine can power part of a home. Turbines can be combined to create wind farms, or wind power plants, to provide electricity for hundreds of buildings. Small wind turbines must be placed where the wind is at least 9 miles per hour (mph) and large turbines where it is at least 13 mph. Good places for turbines are in open plains and water, in mountain gaps that channel the wind and at higher elevations. Wind blows at different times depending on location and season. In general, offshore winds are stronger in the day and on land they are stronger at night.

Energy Transformations and Wind Generation

When electricity is generated with wind, it involves several energy transformations.



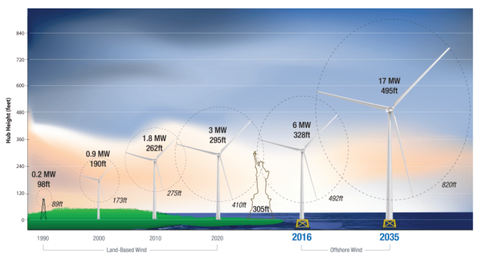
- Wind is kinetic energy caused by the thermal energy of the sun when it heats the earth's surface unevenly.
- The kinetic energy of wind turns the blades of a wind turbine.
- The mechanical energy in the rotating turbine blades and shaft is converted to electrical energy in the turbine's generator.
- Electricity may be transformed to another type of energy by the end user. For example, a toaster changes electricity back to thermal energy.

New Technologies

Technology has increased the effectiveness, and decreased the cost, of generating electricity from wind. For this and other reasons, U.S. electrical generation with wind grew from less than 1% in 1990 to more than 9% in 2021! Wind technology continues to develop:

- New, lightweight materials to build turbines as tall as 900 feet
- Better designs and materials for longer or more durable blades
- Performance optimizing systems to better forecast how and when the wind will blow
- Offshore wind turbines that float on platforms in deep ocean waters.

Vertical-axis Wind Turbine
(Photo courtesy of eia.gov/kids/energy-sources.)



Wind Turbine Size
(Source: energy.gov/eere/articles/wind-turbines-bigger-better, accessed July 2022)

Sensational Renewables

Build and test a wind-powered boat. You will need a small foam tray, a small foam craft ball, a straw, paper, a hole punch, a hot glue gun, a large, shallow pan of water and a fan.

1. Cut the foam ball in half and glue it to the center of the tray.
2. Draw a symmetrical triangle or other shape on the paper. You may need a ruler.
3. Cut the shape out and punch a hole in the center top and bottom of the shape
4. Place the straw through each hole to make a sail.

Time the number of seconds it takes the fan to push the boat across the water. Did you notice problems with your boat design? Might the design of a wind turbine have some of those same issues? Improve the design and test the boat again.

The Balancing Act

There is a constant challenge in the electric power grid. The amount of electricity that it generates is about the same during short periods of time. However, the demand for electricity varies greatly throughout the day. Fortunately, technologies are developing to balance supply and demand. They store electricity generated at times of high generation and low demand to be used at peak times when demand is greatest.

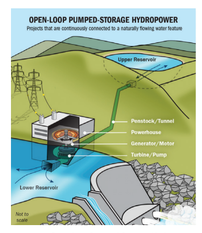
Batteries

Batteries can store electricity for devices in your home. Did you know that many types of batteries can store electricity on a large scale for the grid? One example, the lithium-ion battery, was initially developed for consumer products. A large number of them can be housed together on a rack to power a home or the electric grid. Lithium-ion batteries take up a relatively small amount of space for the energy they store. Flow batteries work differently. They store energy in electrolyte fluids and are well suited for longer duration storage.

Battery Storage Facility

Pumped Hydro Power

Pumped hydroelectric facilities are the most common energy storage on the grid. During off-peak hours, turbines pump water to an elevated reservoir. When electricity is needed, the reservoir opens to allow the water to flow through turbines and produce electricity.



Open-loop Pumped Storage Hydropower
(Source: Sandia National Lab Electricity Storage Handbook)

Thermal Storage

Thermal systems use heating and cooling methods to store and release energy. For example, molten salt can store heat from the sun for later use. Other systems use chilled water or hot water heaters, to store excess energy.

Compressed Air Energy Storage

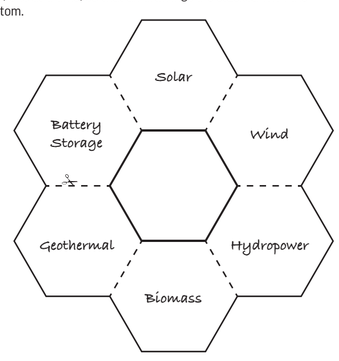
When electricity is off-peak (not in demand) it can be used to compress air. The air is stored underground or aboveground in pipes. When electricity is needed, the pressurized air is released to generate electricity through an expansion turbine generator.

Electricity Storage and Renewable Energy

Renewable energy, like wind and PV, are more available at certain times of the day or the year. Storage technologies make electricity generated by these sources available when we need it. Increased use of renewable energy has helped to push the development of storage technologies. In the future, we will benefit from other emerging storage technologies like superconducting magnets, underground pumped storage hydropower and solid oxide fuel cells.

Sensational Renewables

1. Download the octagon image from *nef1.org/renewable-poster.pdf*.
2. On outside octagons on front, write the names of seven renewable energy sources or technologies.
3. On the reverse side, write a fact about each source or technology (e.g. Biomass = energy from plants and animals).
4. Cut along the dotted lines and fold inward on the bold lines.
5. Turn each octagon inward, one at a time, so that all drawings are stacked with the center octagon at the bottom.
6. Trade projects to quiz another student.



A Variety of Renewables

Geothermal

Geothermal energy is heat from deep in the earth. Low and moderate temperature geothermal resources can be used directly or used by ground source heat pumps. These take the relative heat just below the surface of the earth and pump it into a building. In the summer, it works backward, pumping warm air from the building into the ground.

Highest temperature geothermal resources are generally used for electric generation. Hot water is brought to the surface through production wells. The steam is separated from the liquid and fed to a turbine, which turns a generator. The steam then gets cooled in a cooling tower. The cooled water is injected back into peripheral parts of the reservoir to be reheated and help maintain reservoir pressure.

Marine and Hydrokinetic Energy

A plentiful renewable resource covers over 75% of our earth - water!

- The kinetic energy of moving water has been used to generate electricity since the early 1880s. Hydroelectric power has usually involved river water or water stored behind a dam. It flowed through a pipe called a penstock and turned the blades in a turbine. The turbine spun a generator to produce electricity.
- Marine and hydrokinetic technologies harness energy in the ocean's waves, tides and currents and generate electricity in different ways. They can involve a turbine in the ocean or a buoy that captures up and down, or side to side, ocean water movement.

Hydroelectric Dam

Hydrokinetic Buoy
(Photo courtesy of energy.gov, accessed June 2020)

Biomass

Biomass is stored solar energy found in living organisms such as trees, grasses, corn, manure (digested plants) or algae. It can even include trash, paper products and other waste. Producing energy from biomass can be as simple as burning wood. It can be more complicated, like using feedstocks to produce ethanol or other alcohol fuels for transportation. Biomass can be converted to combustible gases for electricity production.

Renewable Hydrogen

The hydrogen on earth is combined with other elements in liquids, gasses or solids. Electrolysis is the process of using electricity to split water into hydrogen and oxygen. Renewable energy sources like wind, solar, geothermal or biomass can supply this electricity. There are many exciting possibilities for combining renewable electric generation and hydrogen production. For example, when a wind farm is producing too much electricity, the excess can produce hydrogen.

Sensational Renewables

Electricity can be used to separate hydrogen and oxygen atoms in water, so the hydrogen gas can be used as a fuel. Try this process called electrolysis.

Materials

9 Volt battery

Small, clear cup

1/2 Teaspoon baking soda or salt

2 Pencils, sharpened on both ends (copper wire or a straightened paper clip can replace one or both pencils)

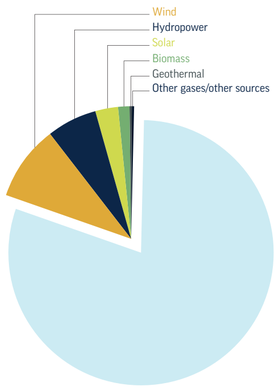
3 x 5 Inch index card

Fill the cup half full with water and add the salt or soda. Push the pencils through the card about an inch apart. Put one point of each pencil in the water and the other point on the terminals of the battery. Observe what happens. Are the results the same for both pencils? How can you explain the difference?

Electricity and the Environment

Currently, renewable energy sources generate nearly 20% of electricity in the United States. Cost and inability to provide base load power (the minimum amount of electric power delivered or required over a given period of time at a steady rate) have been traditional roadblocks to the use of some renewables for generation. However, innovative technologies are now making renewable electricity generation cost competitive. According to the U.S. Energy Information Administration electricity generation from renewable sources has surpassed nuclear and coal and is projected to surpass natural gas in 2045.

Why is this important? Electricity is an essential part of our modern lives and economy. We use electricity for lighting, heating, cooling, refrigeration, appliances, machinery, transportation and our many electronics. In 2021, we used 13 times more electricity than we did in 1950. Renewable energy sources help electricity companies meet this demand while producing electricity in a more sustainable way with environmental benefits.



U.S. Electricity Generation by Energy Source
(Source: eia.gov/tools/faqs/faq.php?id=427&t=3, accessed July 2022)

Sensational Renewables

You will need a 2 liter bottle with cap, tape, water and a nail.

1. Make three, small holes with the nail at equal intervals down the bottle from the top to the bottom.
2. Place pieces of tape over the holes. Fill the bottle with water.
3. Remove the tape and observe. Which stream of water is under the greatest pressure?

Does the pressure affect the rate of water flow? Where would you place a penstock and turbine if you were designing a hydroelectric dam?

For the Earth

Renewable energy sources are not without an environmental footprint when they are used for energy or to generate electricity. For instance, the creation of a solar panel or wind turbine uses natural resources. However, renewable energy sources have the potential for a smaller footprint than their nonrenewable counterparts.

Solar energy systems themselves do not generally produce air pollution, water pollution or greenhouse gasses. When electricity is produced with solar energy, it has much lower greenhouse gas emissions from start to finish of the system's life cycle than electricity generated by a resource like coal.

Wind turbines do not generally release emissions. They do not require water for cooling. When electricity is generated using wind, it can reduce fossil fuel generation, resulting in lower total air pollution and carbon dioxide emissions.

Biofuels may reduce some pollutant emissions and several types could yield lower lifecycle greenhouse gas emissions than gasoline. Ethanol, in particular, can ensure complete combustion, reducing carbon monoxide emissions. Using biomass for energy that is also used for food can create higher crop prices.

Direct use geothermal systems, like geothermal heat pumps, have almost no negative effects on the environment. Geothermal power plants do not burn fuel to generate electricity, so the levels of air pollutants they emit are very low. They emit nearly 100% less carbon dioxide than fossil fuel power plants of similar size.

Hydroelectricity produced with accumulation reservoirs can provide electricity to the grid immediately. This can increase the use of other renewables that cannot act as base load sources for generation. Hydroelectricity will not pollute the air like power plants that burn fossil fuels. Although hydroelectric dams can disrupt their environment and the natural flow of water, they also provide recreational activities, flood control, irrigation and water supply.

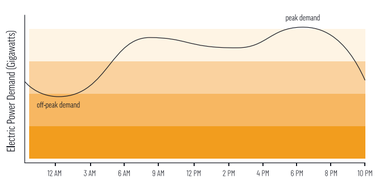
Get Smart

The grid is the complex system of power plants, transformers and transmission lines that deliver electricity to your home. We are beginning to use technology to provide better and increased communication between providers and consumers of electricity in the grid. Our electrical devices, solar panels or plug-in electric vehicles can even be a part of this enhanced communication by using, supplying or storing energy when it is most beneficial to the overall system. When parts of the grid communicate, disruptions like a downed power line can be identified and responded to more quickly. Our increasingly "smarter" grid will use electricity with more flexibility, reliability, affordability and efficiency. It will also allow for more effective and increased use of renewable energy sources for generation.

A Tricky Job

Electricity companies must match electricity supply to demand in real time. We tend to use more electricity in the summer and winter months when homes need to be cooled and heated. Did you know that our demand for electricity also changes throughout the day?

Generation with renewable energy sources has been difficult in the past because sources like solar or wind are easiest to capture when demand for electricity is off-peak. Additionally, renewables like wind, solar and geothermal are usually collected in large amounts in remote places, while most of the demand for electricity is in urban areas. The smart grid provides solutions! It gives grid operators tools to reduce power demand quickly when wind or solar power dips. It stores excess renewable power to release when the sun is not shining. When the wind is not blowing in one area, it may be blowing in another. The smart grid helps ship electricity to where it is needed, resulting in a steadier supply of wind power to the grid. In short, the smart grid makes renewable energy sources easier to use.



(Source: eia.gov/todayinenergy/, accessed July 2022)

Driving Smart with Renewables

The smart grid will support the efficient use of plug-in electric vehicles (PEVs). They reduce our dependence on oil and emit no air pollutants when running in all-electric modes. When a PEV, or another form of electric transportation, is charged with electricity generated with renewables, there are opportunities to reduce transportation pollution.

Smart grid technologies interact with a PEV to charge it at the time when power demand is at its lowest. This is an obvious benefit to the grid and may also provide cheaper electricity rates to the customer. PEVs will play other important roles in the smart grid. They will store electricity to provide extra power at critical peak times and integrating variable power sources, like wind and solar.

Visit *nef1.org/renewable-poster.pdf* for full project details on the Sensational Renewables activity. Adult assistance may be required.

Sensational Renewables

You will need copies of "Fermentation Challenge" from *nef1.org/renewable-poster.pdf*, two snack-size resealable zipper bags, sugar, yeast, a thermometer and warm tap water.

- Combine 1 teaspoon of sugar and 1 teaspoon of yeast in the bag.
- Add 1/4 cup of warm tap water (approximately 104 F) and seal the bag, removing as much air as possible. Mix the contents of the bag gently.
- Start a timer. What happened after 20 minutes?
- The sugar is plant-based biomass that is "fuel" metabolized by the yeast. How would the experiment differ if you used another form of biomass, like corn meal?

Moving Forward

New ways and ideas to harness or use these renewable energy sources are continually being researched and developed. Some are inexpensive and have been used for centuries. Others will require more research and development before they can be provided to the public at a reasonable cost. In the future, renewables will play an even larger role in our lives.

Nada. Nothing. Zilch.

Zero energy buildings combine energy efficiency and renewable energy use to consume only as much energy as they can produce. Achieving zero energy use is a lofty goal that buildings are beginning to meet. A zero energy building commonly has on-site renewable energy system(s) like solar PV, solar water heating, geothermal heat pumps or small wind turbines or hydroelectric systems. It also uses little energy due to efficiency achieved through:

- A tight building envelope that uses insulation, airtight windows and doors, and other methods to keep the desired temperature inside
- Building and window orientation that lets in sun when needed and keep it out otherwise
- Building materials in colors that reflect the sun's heat and light or absorb it where needed
- Triple glazed or low-E windows that have a thin coating to reflect heat
- Windows that can darken automatically when sunlight hits them to keep its heat and light out when not needed
- Efficient lighting, appliances and electronics
- Proper ventilation

Zero Energy Building

A Future Career in Renewable Energy

As new technologies increase our use of renewable energy, careers in renewables will also increase. These could be any job that helps capture, use or conserve renewable energy. Check out the careers in renewable energy listed below or visit *energy.gov/eere/education*. Which sounds most interesting?

- Clean Car Engineer
- Biofuel Farmer
- Solar Fabricator/Installer
- Wind Farm Developer
- Geologist
- Architect
- Civil Engineer

Acknowledgments

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