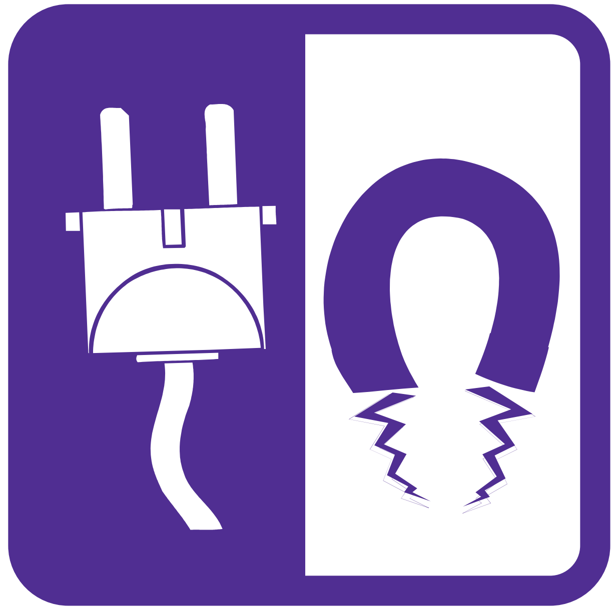


STOCK IT UP! ENERGY STORAGE SAMPLER

Activities Inside:

- Techno(logy) Pop Stars
- Battery Design Challenge
- Baseload Balance

Grade Levels:

Elem Elementary

Int Intermediate

Sec Secondary

Subject Areas:

Science

Math

Language Arts

Creative Arts

NEED

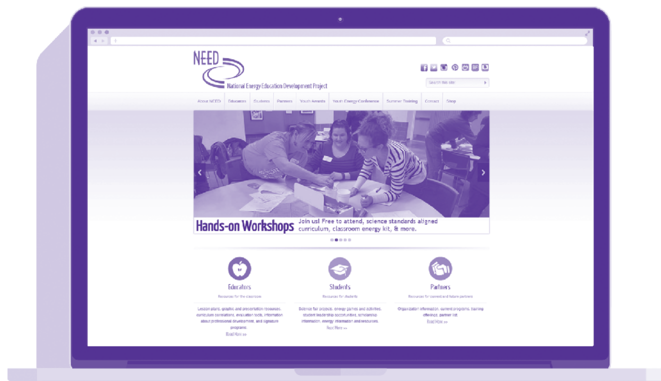
National Energy Education Development Project

TEACHER INFORMATION

Background

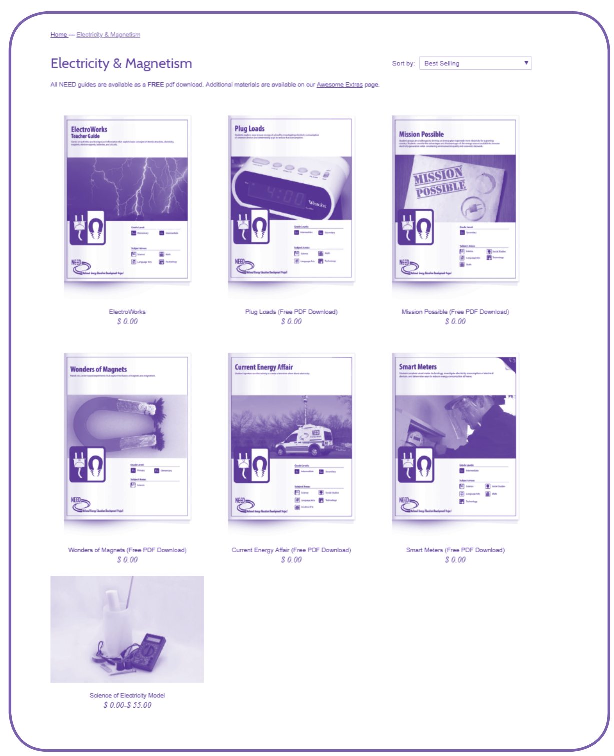
Energy storage is the hottest topic in energy research; renewable sources like solar and wind do not generate electricity at all hours of the day or year-round. When solar energy is at its peak, energy demand is not, and when energy demand is highest, the sun is starting to set. Wind energy is strongest overnight when most of us are sleeping. Scientists and engineers nation-wide are working to discover and perfect better technology to store the energy when it is produced so it is available when we need it. This curriculum sampler provides an introduction for students to explore the different ways energy can be stored and the technologies behind energy storage.

Each activity can be used as a stand-alone activity, or in conjunction with a larger energy unit. The *Energy Storage Infosheet* contains information for your students to read about energy storage and learn more about the technology involved in it. It can be used as a supplement to their *Energy Infobook* or by itself.



Techno(logy) Pop Stars is a fun Language Arts and creative arts activity where students write and perform a song about energy storage. Alternatively, we have provided a song that your students can perform if you do not have the time to devote to song writing. It is based on activities found in *Energy Live!,* which are similar songs featuring energy sources, electricity, and energy efficiency and conservation. If you wish, this activity lends itself nicely to cross-curricular involvement from the visual art and music teachers in your school.

Battery Design Challenge draws on concepts from chemistry and physics to help students understand how chemical reactions are harnessed to generate direct current (DC) electricity. The activity has been written such that intermediate level students can use it with a bit of scaffolding of some of the concepts from you, and secondary chemistry and physics students can use the activity as a culminating activity after studying heats of reaction, oxidation and reduction, electrochemistry, and simple DC electricity.



Perhaps you're familiar with NEED's activity, *Baseload Balance*. For this insert, we've given this popular NEED activity a fun twist where energy storage becomes an option. This activity demonstrates how electricity supply is transmitted on the electric grid to consumers. It also encourages students to explore the differences between baseload and peak demand power, and how power companies maintain supply to ensure customers have power as they need it. Students will act as loads, generators, and storage facilities as they aim to balance demand and generation.

The activities in this sampler can be incorporated into a larger energy unit that covers energy transformations, energy sources, electricity, transportation fuels, and energy efficiency and conservation. For more information, download NEED's catalog from www.NEED.org.

MATERIALS

The table below contains a list of materials needed to complete the activities in this suite. Many of the materials can be found in a common lab setting, or easily procured from a grocery, craft, or home improvement store. Refer to the activity instructions for more specifics about each item. Contact NEED if you have any questions or difficulty locating a certain item.

ACTIVITY	MATERIALS NEEDED
Techno(logy) Pop Stars	▪Construction paper ▪Scissors ▪Markers, colored pencils, crayons, and/or paints ▪Hand-held musical instruments, if available ▪Keyboard, piano, or other instrument, if desired
Battery Design Challenge	▪Assorted electrolytic solutions, such as dilute hydrochloric acid, citric acid, sodium sulfate, etc. - use what is on-hand, safe, and easy for you to access ▪Assorted solid, pure metals, such as copper, zinc, nickel, iron, etc. - use what is on-hand, safe, and easy for you to access (Pencil lead can be used for graphite) ▪Beakers or plastic cups ▪Alligator clips ▪LEDs ▪Digital multimeters ▪Thermometers ▪Stopwatches, timers, or a clock with a second hand visible to all students ▪Computer with internet access
Baseload Balance	▪Scissors ▪Tape ▪Rope ▪Colored paper ▪Individual marker boards with erasers and markers

ENERGY STORAGE INFOSHEET

When you need to see in the dark, do you turn on a flashlight? Energy storage to the rescue! A flashlight uses energy stored in a battery to generate electricity – and light – as you need it.

Energy is the ability to do work, or to make a change. How do you take the ability to make a change and put it in a box and store it on a shelf to use later? Energy storage has become an important problem for scientists. They are working hard to find and refine ways to store energy now to use later when it's needed.

Supply and Demand

But why exactly, do we need to store energy in the first place? Isn't energy always around, never created or destroyed? It comes down to the balancing act of supply and demand.

The process of generating electricity and getting it to customers who want to pay for it, is very complex. Generating electricity and consuming electricity happen almost instantaneously. Not using electricity as it is generated means it is lost, which wastes money and natural resources. Electricity, generated and ready to go to consumers, is called the supply. Having a way to store any extra supply so it doesn't go to waste is important when aiming to balance supply and demand.

When customers use electricity in homes, businesses, and industry, the amount of electricity being used is called the demand. If customers try to use more electricity than what's available, a blackout could occur. Having a way to make extra electricity available when demand is high is another important aspect of balancing supply and demand.

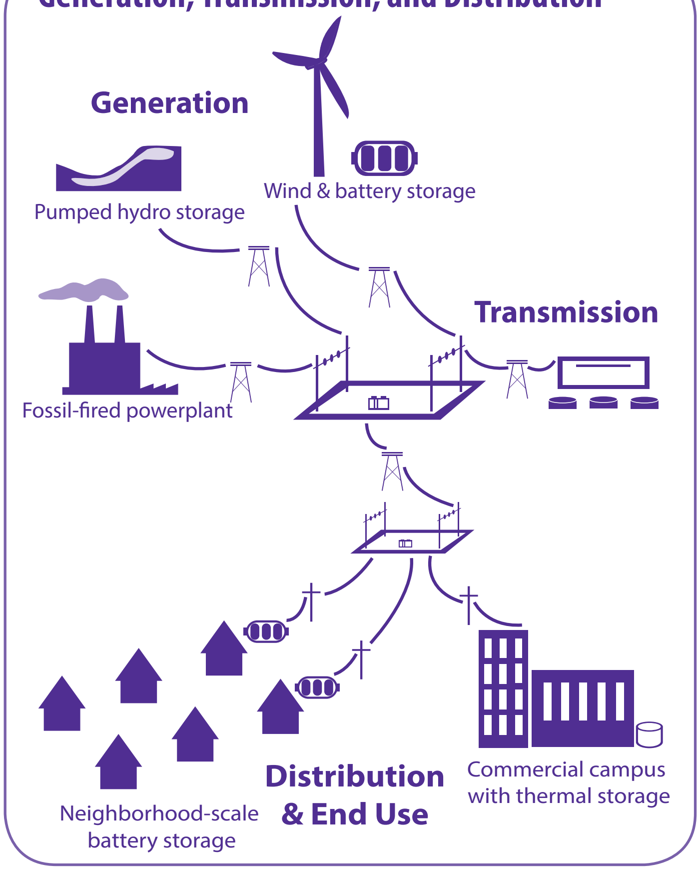
How do you predict the exact moment someone will turn on a dishwasher or plug in their electric car to charge? Balancing the supply and demand of electricity for customers is a critical job for electric power producers or utility companies. They must have the right amount of electricity available every second of every hour of every day. A tiny break in electricity flowing, or a surge of too much electricity flowing, could be disastrous to some electronic devices and it irritates paying customers.

The problem is, electricity itself can't be held in a wire or boxed up and set on a shelf until it is needed. So, scientists have developed a wide range of energy storage methods and technologies that change it into something else that can be stored. Electric power producers use these energy storage technologies to quickly supply energy when it is needed, and to consume energy when there is a surplus – helping to balance supply and demand instantaneously. Energy storage is continually at work, improving the way electricity is generated, delivered, and consumed in America.

Across the Grid

America's electric grid has three parts: generation, transmission, and distribution for end use. Energy storage technologies are in use across all parts of the grid. For example, during generation, we use pumped-storage hydropower and compressed air energy storage. These technologies generate electricity onto the grid when it's needed. During transmission, flywheels help regulate the flow of electricity. End users, such as neighborhoods and commercial buildings, hold surplus electricity distributed to them in battery storage and thermal storage devices.

Generation, Transmission, and Distribution



Using Energy Storage

Scientists are working to invent emerging technologies (new inventions – machines or methods - engineered by scientists to solve a problem) to improve energy storage. It's very expensive to engineer new technologies. High cost is one of the reasons energy storage technologies aren't used more often across the power grid.

Of course, there are many positive reasons to use energy storage though. Energy storage technology is safe. It does not give off direct emissions and may help cut emissions as it replaces the need for fossil fuel or biomass fired power plant generation. Energy storage systems work with both nonrenewable and renewable sources of energy. Having stored energy available to use instantly to balance the supply and demand for the electric grid makes the electricity system in America more reliable with less outages and more efficient. Ultimately, energy storage helps power producers save money, which results in consumers saving money, too.

Energy Storage Technologies

Many types of energy storage are in use today.

- **Pumped-Storage Hydropower** moves water from a lower elevation to a higher elevation, creating a large reservoir of gravitational potential energy.
- **Batteries** store energy in electrochemical storage.
- **Capacitors** store energy in an electric field.
- **Flywheels** are mechanical devices that store rotational energy.
- **Thermal** energy storage technologies capture and temporarily store thermal energy (as heat or ice).
- **Compressed Air** Energy Storage uses the force of compressed air as a powerful energy reserve.

Some technologies are small-scale while others are utility-scale; some are residential and others are industrial. Some technologies store energy for only a moment while some store energy for a long time. The many different energy storage options help us with different storage needs. These technologies use different approaches to store energy, to change energy from one form to another, and to generate electricity.

We categorize them into four types of storage: mechanical, chemical, thermal, and electrical. Pumped hydroelectric power, flywheels, and compressed air are examples of mechanical storage. Batteries are the most common type of chemical storage. Molten salt and ice are materials used for thermal storage. Finally, capacitors are also used for electrical storage.

Mechanical Energy Storage

Pumped-storage Hydropower

In the United States, almost all utility-scale energy storage is pumped-storage. It's a well-established way to store energy. We've been using this technology to generate electricity since the 1930s.

A pumped-storage facility has two functions working together in a loop. First, it generates electricity for the grid. Second, it pumps water into storage to use later for generating electricity.

To generate electricity, gravity pulls water from an upper reservoir, down through a penstock to a powerhouse. Inside the powerhouse, the moving water spins a turbine attached to a generator, which makes electricity for the grid. The water flows out of the powerhouse into a lower reservoir.

The turbine in the powerhouse is reversible, which means it can spin in both directions. When it is time to power the turbine as a pump, the facility must purchase electricity to run it – just like you do at home to run your appliances. The turbine spins in the opposite direction, working pumps that move water from the lower reservoir back to the upper reservoir. The water is held, or stored, in the upper reservoir. When more energy is needed on the grid, the facility lets the stored water rush down the penstock to spin the turbine again, generating electricity.

Some pumped-storage facilities have an open-loop system. These facilities are usually located on a river or creek allowing water to continually flow through the system. Some pumped-storage facilities have a lower reservoir that is not connected to a natural source of water. This type of system is called closed-loop, because the water flows from upper reservoir to lower reservoir and back to the upper reservoir again without ever leaving the system.

Remember, it takes electricity from the grid to run the turbines whenever they move water. A pumped-storage hydropower plant must consume electricity now in order to generate electricity later. To be cost effective, people working at the power plant pump water when they can purchase electricity at a low cost, usually at night or on weekends. During the day, when electricity costs are high, water is released to generate electricity. They sell the electricity to the grid at a higher, peak price.

About 40 pumped-storage hydropower plants generate power in the United States. They are typically large systems over 100 MW, utility owned, and connected to the transmission grid. The largest hydroelectric pumped-storage plant in the United States is owned by Dominion Energy, in Bath County, Virginia. It can generate over 3,000 MW of electricity.

A pumped-storage facility is very expensive to build. It requires many government permits and regulations. Facilities may impact the environment and need to be built at a site with specific topography that allow change in elevation between upper and lower reservoirs.

A benefit of using pumped-storage hydropower is that it can start and stop quickly. This helps balance the load on the grid and allows the facility to sell electricity when it is expensive and buy it when it's cheap.

You can watch a Department of Energy video about pumped-storage hydropower at: https://www.energy.gov/eere/videos/what-pumped-storage-hydropower.

BATH COUNTY PUMPED STORAGE FACILITY

Image courtesy of U.S. DOE

Flywheels

A flywheel is a mechanical device that consumes short bursts of electricity and stores it as rotational kinetic energy. Later, it instantly generates electricity as needed.

Traditionally, a flywheel is made of steel and rotates on bearings. A modern flywheel is made of carbon fiber materials and uses magnetic bearings. It is housed in a vacuum. This reduces friction in the form of drag as it rotates. It can spin up to 60,000 revolutions per minute.

When there is extra electricity, it is used to charge a flywheel. The electricity powers a motor that spins the flywheel, increasing its rotational speed. As it rotates, a mass inside the flywheel rotates. The stored kinetic energy is the force within the rotating mass. When electricity is needed, the flywheel is discharged, or generates electricity. The force of the rotating mass is used to power a device, similar to a turbine, that generates electricity. This process slows down the rotation of the flywheel. Then, when there is extra electricity available on the grid, it is used to charge the flywheel and increase its speed again. Flywheels are used to balance or regulate the frequency of electricity to keep the current as smooth as possible as it's transmitted over the power grid. Flywheels work well for this because they can start and stop generating electricity very quickly.

Almost all utility-scale flywheel energy storage in the U.S. is in New York and Pennsylvania. Two flywheel energy storage projects began operating in 2011 and 2014, respectively. They operate 400 flywheels, each weighing five tons. Altogether, they offer 40 MW of flywheel energy storage.

Flywheels pair well with sources of energy that produce electricity in an unreliable or unpredictable manner, such as solar and wind. They can also pair with ultracapacitors and battery systems to help those technologies perform better while providing energy storage.

Flywheels require little maintenance and don't wear out over time. They are safe, reliable, and energy efficient. They offer a high energy storage capacity and high power output. However, flywheels can take up a lot of space and they are expensive to manufacture. The carbon fiber materials used to build them can be a limitation.

CONVERGENT ENERGY + POWER FLYWHEEL PROJECT

Image courtesy of Energy Storage News

Compressed Air

A Compressed Air Energy Storage (CAES) system compresses air and pumps it into large storage tanks or a naturally occurring underground cavern. Energy is stored in the potential energy of a compressed gas. When electricity is needed, the pressurized air is released, heated, and expanded. This spins a generator to make electricity.

Cities in Europe have used CAES systems since the 1870s to power machinery for industry and to provide electricity for homes. In 1978, a utility-scale CAES system began operating in Germany.

PowerSouth Energy Cooperative began operating our nation's first CAES system in 1991. It's located in McIntosh, Alabama, at a power plant that also uses natural gas-powered turbines to generate electricity. According to PowerSouth, the CAES generator produces up to 110 megawatts of electric power within 14 minutes of starting up. It is enough electricity to power nearly 110,000 homes for up to 26 hours.

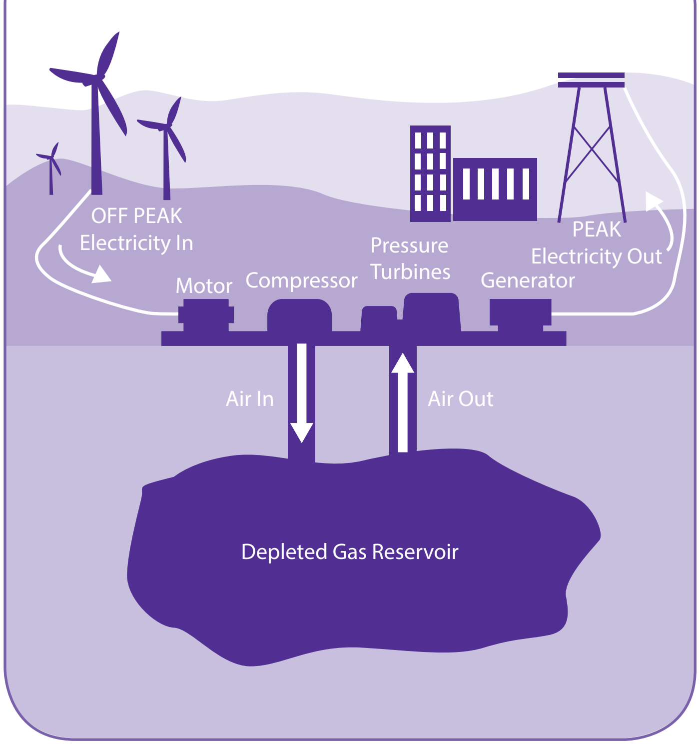
During off-peak hours, when energy is less expensive, the plant goes into "compression mode." Electricity is used to run air compressors that pump air into an underground salt cavern. The plant goes into "generation mode" during periods of peak demand. Air from the cavern is released and sent through pipes to a heat exchanger. The air is heated and expanded through a series of different processes, including a high-pressure combustion chamber, where natural gas is burned for heat. Air also moves through high- and low-pressure expanders, which work together to rotate the generator producing electricity for the grid. This electricity is sold to customers at more expensive daytime or peak prices.

Compressing air generates a lot of heat. Decompressing air requires a lot of heat. The CAES system burns natural gas in order to heat and expand the air. Even so, using the CAES system burns less natural gas than the combustion turbines at a natural gas-fired power plant, which means using CAES produces less pollutants, too.

CAES needs a stable, sealed underground geologic space, able to withstand pressurized gas. Some examples of future storage facilities could be underground salt caverns, underground rock caverns, porous rock formations, depleted natural gas reservoirs, abandoned mines, aquifers, and perhaps even plastic bags stored deep in lakes or the ocean.

In the future, CAES facilities might partner with intermittent sources of energy, like wind and solar. Wind energy is strong at night when electricity demands are low, making it a good CAES partner. Electricity generated by wind turbines at night can power the air compressors, storing the energy for later use during the day.

Compressed Air Energy Storage



Watch PowerSouth's YouTube video explaining their CAES system, at:

https://www.youtube.com/watch?v=sVDh_4ymcyY

Chemical Energy Storage

Batteries

In 1799, Italian physicist Alessandro Volta demonstrated the first battery. Today, we rely on batteries to power many of our modern conveniences. You've probably changed a battery in a favorite electronic toy or your TV's remote control, but have you thought about the large lead-acid battery that starts your family's car? Or the tiny button battery powering a hearing aid or watch?

There are many different types of batteries and they produce electricity in different ways depending on their technology. Basically, a charged battery stores electrical energy. When a load connects to the battery, an electrochemical reaction occurs that produces electrical energy as the battery discharges.

Modern batteries use a variety of chemicals to power their reactions. Some common batteries include zinc-carbon, alkaline, and button batteries. Some batteries are rechargeable, like the ones in your cell phone. The most common rechargeable batteries are lead-acid, lithium-ion, nickel-metal-hydride, and nickel-cadmium.

Batteries come in different sizes and can be wired together to store energy on a much larger scale. On the grid, batteries help balance electricity supply and demand by the second, minute, or hour. At a generating plant, batteries can be charged when energy is not in demand and electricity costs are low. When electricity is in demand and electricity costs are high, batteries can discharge, providing electricity. Batteries can also provide backup power during power outages for homes, businesses, and the grid.

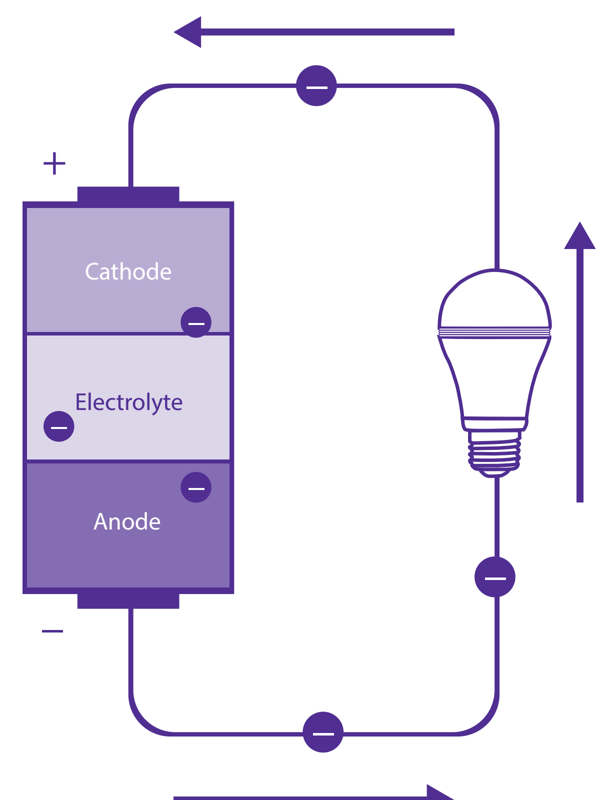
Commercial and industrial facilities that consume a lot of electricity save money by using battery storage at their facility. These customers are billed for electricity use based on the highest rate they consume electricity at during peak demands. If they charge batteries when energy prices are low, and discharge them during peak demand when utility rates are high, they reduce the amount they are consuming from the power plant, lowering their electricity bill. This is called peak shaving or discharge during peak demand time to avoid or reduce demand charges.

Homes can use energy stored in batteries, too. Tesla's Powerwall battery system is an example of a battery that is charged by solar panels or a solar roof during the day. The electricity is available to use at night or during a power outage.

Small islands and remote locations that aren't connected to our national grid are called microgrids. They must supply all their own power. Using a combination of renewable sources of energy and battery energy storage, some microgrids no longer need to rely on diesel fuel generators to have reliable power.

Electricity generated by wind turbines and solar panels is not always reliable. There could be a lot of energy one moment and little the next. It all depends of the amount of wind blowing or how the sun is shining. We call these intermittent sources, as their generation starts and stops. It's not very helpful for the workers at a power producer trying to balance supply and demand. However, using an energy storage device makes these renewable sources of energy an asset. When a wind turbine or solar panel is generating electricity, even sporadically, it can charge a battery. The battery holds the energy in chemical storage. Later, when a power producer needs electricity for the grid, the battery can generate electricity the moment it is needed.

How Batteries Work



Thermal Energy Storage

Thermal storage using molten salt is a technology in use at some commercial-scale concentrated solar power (CSP) plants. Since solar radiation is very spread out, CSP plants use mirrors to focus the sun's energy on a receiver, increasing its intensity. CSP facilities use different technologies to generate electricity. We'll look at two examples – one uses a parabolic trough system and the other uses a power tower. Both of these CSP power plants include energy storage with molten salt, but their storage technology is slightly different.

The Solana Solar Power Generating Station in Arizona uses a parabolic trough system to generate electricity. Curved mirrors focus sunlight onto a receiver tube running down the center of each trough. The receiver tube is filled with synthetic fuel. Sunlight heats the synthetic fuel up to 700°F. The heated fuel moves to a heat exchanger where it heats water into steam. The steam powers a steam turbine, generating electricity.

When the power plant wants to store energy to use later, the heated synthetic fuel flows into storage tanks filled with molten salt. Thermal energy transfers from the synthetic fuel to the molten salt. The storage tanks can hold the heat for about six hours. They use 12 massive storage tanks. Each is 145 feet across and 45 feet tall. When the sun isn't shining, the power plant can use the heat stored in the molten salts as a source of thermal energy for the heat exchanger, powering the turbine generators for six hours.

The Crescent Dunes Solar Energy Facility in Nevada uses a CSP molten salt tower. A 640-foot-tall tower stands inside rings of heliostats, large mirrors that track the sun. The 10,347 mirrors cover two miles. Molten salt flowing through pipes inside the tower reach 1,050°F. The molten salt, and all its thermal energy, is stored in a 3,600,000-gallon tank until needed. The molten salt flows through a steam generator, which makes steam that powers turbines, generating electricity. There is enough heat stored in the tank to power the turbine generators for ten hours.

These concentrated solar power plants use energy storage technologies to produce electricity when the sun isn't shining. It is clean, renewable power. Concentrated solar power plants are limited to the Southwest and Florida, in areas with high solar radiation. These power plants require a huge amount of land, access to water for cooling, and need to be located near high-voltage transmission lines.

Another thermal storage technology is a thermal battery, also called an ice battery. This type of thermal storage is widely used in commercial and industrial buildings in the U.S. today.

CRESCENT DUNES FACILITY

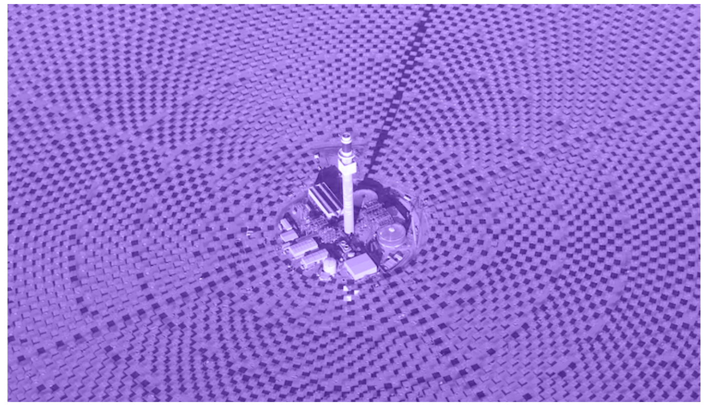


Image courtesy of U.S. DOE

Heating and cooling is the largest energy demand for buildings. Using a thermal storage system lowers a building's electricity costs by shifting the time of day when the building runs its cooling system. At night, when electricity rates are lower, the building will purchase electricity to run a cooling system that makes, and stores, ice. During the day, when electricity costs are high and building occupants are using the most energy, the system circulates air cooled by the ice through the building. Using this thermal storage system also helps reduce the afternoon load at the local utility.

Ice Energy in California develops thermal storage systems for commercial, industrial, and residential customers. They call their ice battery the Ice Bear. In the larger systems, stored ice provides buildings with cooling for up to six hours. The ice batteries are Smart Grid enabled, allowing a utility company to control when the ice battery charges (makes ice) and discharges (provides cooling). This helps the utility balance supply and demand during hot California days.

ICE BEAR SYSTEM

Image courtesy of U.S. DOE

Electrical Energy Storage

Capacitors

A capacitor is a device that stores electrical energy at one time, to be used at another time. Inside a capacitor are two conducting metal plates separated by an insulating layer called a dielectric. A dielectric is a non-conducting substance such as ceramic, plastic, glass, Mylar, paper, or air. This insulating layer blocks direct current from flowing through the capacitor. Instead, electrons flow onto the plates charging the capacitor. One plate has a positive charge and the other has a negative charge. The capacitor stores the energy of the electrons in an electrostatic field between the plates. When electricity is needed, current flows out of the capacitor, discharging it. The electrostatic field decreases as the energy moves out of the plates.

Capacitors come in a wide range of sizes depending on their function – from a tiny plastic capacitor inside a calculator to a supercapacitor powering a commuter bus.

A capacitor is not the same as a battery. They store electrical energy in very different ways. While a battery stores energy in a chemical reaction, a capacitor stores energy in an electric field. Capacitors charge and discharge much faster than a battery, are long lasting, lose less energy as heat, and are almost 100 percent efficient. They are lighter than batteries, low maintenance, and don't contain harmful chemicals or toxic metals. When you need a lot of energy fast – use a capacitor.

CAPACITORS

Image courtesy of Instructables

Electrochemical Capacitors (EC)

The capacitor was invented by European scientists in 1745, but it was English chemist Michael Faraday who made the first usable capacitor in the 1830s. Today, scientists continue to actively develop new capacitor technologies. One type capable of storing more electrical energy between their plates are electrochemical capacitors, also called ultracapacitors or supercapacitors. Ultracapacitors have large surface area conductive plates made from carbon. The plates are very close together. The dielectric material between them is a liquid electrolyte. An ultracapacitor is an electrochemical device, but no chemical reactions are occurring. Like a regular capacitor, electric energy is stored in an electric field between the two conducting plates.

One ultracapacitor is about 3 volts. To store larger amounts of energy, ultracapacitors are wired together.

The market is expanding rapidly with new applications for these technologies. A few ways they are being used today include portable electronics, medical devices, satellite technology, high performance race cars, electric vehicles, hybrid electric ships, powering cranes and electrical winches, and to capture electricity generated by ocean waves. Ultracapacitors are used in renewable energy systems to store energy, too.

Electrochemical capacitor technologies can hold a lot of stored energy, and they can instantly discharge it at high voltages. This makes ECs a reliable source of power for generating electricity on demand. The electrochemical capacitors can be recharged almost instantly and are ready to supply power again as needed. There are also ECs designed to slowly charge and slowly discharge. These technologies are well suited to bulk energy storage applications.

TECHNO(LOGY) POP STARS

This activity is adapted from NEED'S *Energy Live!*, which can be found by visiting shop.NEED.org.

Grade Levels

Elementary, grades 3-5

Intermediate, grades 6-8

Secondary, grades 9-12

Time

- 1-3 class periods

Additional Resources

- U.S. Department of Energy– https://www.energy.gov/science-innovation/electric-power/storage
- Energy Storage Association– http://energystorage.org/
- Sandia National Laboratories– https://energy.sandia.gov/energy/ssrei/energy-storage/
- U.S. Department of Energy, Office of Electricity– https://www.energy.gov/oe/information-center/library/fact-sheets#storage
- Electric Power Research Institute– http://eprijournal.com/

Background

Energy storage is continually at work, improving the way electricity is generated, delivered, and consumed in America. This cooperative learning activity tasks students with researching energy storage and then writing and performing their own energy storage song. Students will work in small groups, their new musical group, to create lyrics, album art, and an interview for a radio or TV spot. Students will quickly become creative and use popular tunes to create their own songs. However, for students who aren't feeling "charged up" or who are late-comers, you can easily assign them the task of performing the sample song.

Objectives

- Students will be able to describe energy storage and why we use it.
- Students will be able to describe balancing supply and demand on the grid.

Materials

- Construction paper
- Scissors
- Art supplies
- *Energy Storage Infosheet*
- Copies of *Energy Storage* song and interview for each student
- Original Pharrel Williams version of "Happy" (optional)
- Musical instruments (optional)

Preparation

- Decide how you will complete this activity - Unscripted or Scripted:
  - UNSCRIPTED – Assign students to small groups covering the energy storage technologies you want to explore from the infosheet. Allow time for students to research their technology, write their own song lyrics to a song of their choice that teaches about the technology, write interview parts, practice, and perform their song and interview. If you select this option, check out page 7 of NEED's *Energy Live* for a sample rubric and student guide. This guide and rubric can be viewed and downloaded by visiting shop.NEED.org.
  - SCRIPTED – Follow the procedure on page 11, using the lyrics and interview provided.
    - Make copies and gather supplies as needed.
    - Complete steps one through four.

Step One – Prepare, Practice, Perform

- Actors Needed: Assign speaking parts for one host and seven "band members" in the interview skit. Ask students to rehearse their lines.
- Artists Needed: Assign students to the role of artist. Task these students with helping the audience understand each speaking character's identity during the skit. Ask artists to create a sign for each character to hold, a hat to wear, a name tag, or other prop of their choosing. Include the character's name and decorate the sign/object to match the character's identity. Think about how the character represents energy storage. For example, Hip Hydro represents storing energy using pumped hydro-power. Hip Hydro's sign could be the shape of a water droplet or a picture of a reservoir behind a dam.
- Singers Needed: Assign students to practice and perform the *Energy Storage* song. If desired, have students practice singing the parody lyrics along with Pharrell Williams' music video or original song, in order to learn the speed of the music and timing of the lyrics. Practice, practice, practice, until everyone is comfortable singing, and the lyrics are clear and understandable for your audience.
- Musicians Needed: If possible, assign a student in the class to play Pharrell Williams' hit song, "Happy" on the piano or other instrument. Ask these musicians to accompany the singers as they practice and perform.

Step Two – Kids Teaching Kids

- Share what you've learned with others. Sing the *Energy Storage* song and perform the interview skit for another class.

Step Three – Compose Your Own Lyrics

- One energy storage technology not mentioned in this song is the flywheel energy storage system. Ask students to research how a flywheel stores energy and how it generates electricity when there is demand. Have students work in a small group to replace one verse in the song with new lyrics that describe a flywheel. Practice singing verses until comfortable performing.

Step Four – Questions for Discussion and Assessment

1. What does it mean to balance electricity supply and demand? Why is this important? *Balancing supply and demand means having enough electricity generated at any moment equal to the amount of electricity being consumed. If there is not enough electricity there could be a power outage. If there is extra electricity, it is wasted, which also wastes money and natural resources.*
2. What is energy storage? *Energy storage involves finding ways to store energy now to use later when it's needed.*
3. Why do we use energy storage? *There are many reasons, possible answers include: To instantly balance supply and demand across the electricity grid, to regulate the flow of electricity and avoid spikes or outages, to make an intermittent source of energy more reliable for generating electricity, to shift generating electricity from a peak time to a nonpeak time (load shifting), to lower the costs of generating electricity, to lower the cost of purchasing electricity for consumers during peak times (peak shaving), to provide power if there is a power outage.*

ENERGY STORAGE

Introduction

(The scene is a band stage. The host of the show addresses the audience.)

PAULY POWER: I hope you're ready to clap along with our next act. Please welcome, On Demand! They play advanced technology instruments and are very reliable during performances. They work with all the bands touring today. Thanks to them, there is music available on the grid whenever we demand it. On Demand! will be singing their latest hit, "Energy Storage," from their album, "Baseload Balance."

(On Demand! performs their song to the tune of "Happy" by Pharrell Williams.)

Original Lyrics to "Happy" by Pharrell Williams	NEED's lyrics to "Energy Storage"
It might seem crazy what I'm 'bout to say Sunshine she's here, you can take a break I'm a hot air balloon that could go to space With the air, like I don't care baby by the way	It might seem crazy what I'm 'bout to say Electric cars zipping 'round all day Need to recharge in their parking space To a wall, of batteries baby is the place
Huh, because I'm happy Clap along if you feel like a room without a roof Because I'm happy Clap along if you feel like happiness is the truth Because I'm happy Clap along if you know what happiness is to you Because I'm happy Clap along if you feel like that's what you wanna do	Huh, Energy storage Clap along **batteries that recharge** are really grand Energy storage Clap along charge off-peak then use during high demand Energy storage Clap along if you know stored chemical energy Energy storage Clap along converted into electricity
Here come bad news, talking this and that (Yeah) Well, give me all you got, and don't hold it back (Yeah) Well, I should probably warn you I'll be just fine (Yeah) No offense to you, don't waste your time Here's why	Here come bad news, talking this and that (Yeah) Well, there is high demand at the power plant (Yeah) Well, I should probably warn you it could black out (Yeah) Unless stored energy bails us out Here's why
Because I'm happy Clap along if you feel like a room without a roof Because I'm happy Clap along if you feel like happiness is the truth Because I'm happy Clap along if you know what happiness is to you Because I'm happy Clap along if you feel like that's what you wanna do	Energy storage Clap along because water held back in reservoirs Energy storage Clap along if you know it's called **pumped hydro-power** Energy storage Clap along the most common storage technology Energy storage Clap along use gravity make electricity
Hey, come on, uh Bring me down, can't nuthin' (happy) Bring me down My level is too high to bring me down (happy)	Hey, come on, uh Store it now, use later (storage) Store it now My energy is high so store it now (storage)
Can't nuthin', bring me down (happy) I said, let me tell you now, unh (happy) Bring me down, can't nuthin', bring me down (happy, happy, happy) My level is too high to bring me down (happy, happy, happy) Can't nuthin' bring me down (happy, happy, happy) I said	Use later, store it now (storage) I said, let me tell you now, unh (storage) Store it now, use later, store it now (storage, storage, storage) My energy is high so store it now (storage, storage, storage) Use later, store it now (storage, storage, storage) I said

NOTE: Bold words designate an energy storage technology

Because I'm happy Clap along if you feel like a room without a roof Because I'm happy Clap along if you feel like happiness is the truth Because I'm happy Clap along if you know what happiness is to you Because I'm happy Clap along if you feel like that's what you wanna do	Energy storage Clap along because the sun is up there shining bright Energy storage Clap along as molten salt stores heat from peak sunlight Energy storage Clap along use the sun to **store thermal energy** Energy storage Clap along when its dark heat makes electricity
Because I'm happy Clap along if you feel like a room without a roof Because I'm happy Clap along if you feel like happiness is the truth Because I'm happy Clap along if you know what happiness is to you Because I'm happy Clap along if you feel like that's what you wanna do	Energy storage Clap along because the wind is spinning a turbine Energy storage Clap along whenever it is windy you'll be fine Energy storage Clap along to use the wind to **charge a battery** Energy storage Clap along when its calm you'll have electricity
Come on, unh bring me down can't nuthin' (happy, happy, happy) Bring me down my level is too high (happy, happy, happy) Bring me down can't nuthin' (happy, happy, happy) Bring me down, I said	Come on, unh store it now use later (storage, storage, storage) Store it now my energy is high (storage, storage, storage) Store it now use later (storage, storage, storage) Store it now, I said
Because I'm happy Clap along if you feel like a room without a roof Because I'm happy Clap along if you feel like happiness is the truth Because I'm happy Clap along if you know what happiness is to you, eh eh eh Because I'm happy Clap along if you feel like that's what you wanna do	IEnergy storage Clap along when there is extra power to be found Energy storage Clap along **compress air under pressure underground** Energy storage Clap along when there's demand expands again with heat Energy storage Clap along expanding air makes electricity
Because I'm happy Clap along if you feel like a room without a roof Because I'm happy Clap along if you feel like happiness is the truth Because I'm happy Clap along if you know what happiness is to you, eh hey	Energy storage Clap along if you want to have power night and day Energy storage Clap along if you feel like storing it is the way Energy storage
Because I'm happy Clap along if you feel like that's what you wanna do, heh come on	Clap along if you know technologies that exist, eh hey Energy storage Clap along if you wanna be a cool scientist, heh come on

Songwriter: Pharrell Williams

Interview

PAULY POWER: It's great to have you here today. You are one of the most unique bands I've ever interviewed. I understand that you specialize in storing music. What does that mean?

BABY BATTERY: We store excess music when it is available and play it later when there is a demand for it.

ICY HOT: Sometimes, there is music available, but no one is listening. This happens a lot at night. We take advantage and grab as much as we can.

FUNKY FLYWHEEL: We store the music in our instruments using all the latest technologies. The music is safely stored away and ready to be played the instant it is needed.

PAULY POWER: How do you store the music?

DJ THERMAL: We have several different instruments. We use pumped hydro-power, rechargeable batteries, flywheels, thermal energy, and compressed air.

PAULY POWER: How long have you been playing these instruments?

LIL CHEM: Our band was started by Alessandro Volta, who invented the first battery to store music back around 1800. Today the rechargeable battery is a well-known instrument. All the kids are playing it.

HIP HYDRO: We've been pumping out the hydroelectric sound to the grid since the 1930s.

KING COMPRESSOR: Our compressed air storage sound has been listened to in small cities and industries since the 1870s. When I joined the band in the 1970s, we started playing it on a utility scale.

PAULY POWER: Your band is famous for storing music and providing it to electric utility companies whenever they need it to play songs on the music grid.

BABY BATTERY: Listeners might know that utilities depend on us during emergencies. For example, if there is a music outage during a storm. Or, if there is an equipment failure during a concert and a popular band, like Natural Gas, can't perform.

ICY HOT: But listeners might not realize how essential our band is to the music industry. Stored music allows a utility to balance the power supply and demand on the grid instantly - without any interruptions. The music never stops, keeping listeners happy. It's all because utilities use our stored music.

PAULY POWER: Have you partnered up with some of the other bands?

FUNKY FLYWHEEL: Yes, we work alongside every band performing today.

DJ THERMAL: Many of the young renewable energy bands play great while the sun is shining, or the wind is blowing. But their sound gets weak if it's cloudy or calm outside.

LIL CHEM: Everybody loves their sound, but they're just not very reliable when it comes to producing music consistently.

HIP HYDRO: Even though they aren't reliable enough to be a headliner show, we can capture their music whenever they're playing great. Then we store it until someone wants to hear it.

KING COMPRESSOR: Whenever music is needed – whenever there is a demand – our stored music is available.

PAULY POWER: Thanks, "On Demand!" Everyone appreciates having your music on the grid.

BATTERY DESIGN CHALLENGE

Background

The most prevalent use of energy storage is through what are commonly called batteries, but are more accurately described as electrochemical cells. Lithium-ion batteries are present in a host of electronic goods, from laptops and tablets to cell phones and other small electronic devices. Homes and commercial buildings with solar photovoltaics often include a bank of lead-acid batteries for storage of excess power generated when demand is low. This activity introduces students to electrochemical cells and provides an opportunity to consider some of the challenges in designing a good battery storage system.

This activity draws on several introductory chemistry and physics concepts: enthalpy; oxidation-reduction; reduction potential; voltage; current; and power, to name a few. These concepts are not discussed to the depth that a typical chemistry or physics class might to keep the activity accessible for students in younger grades; depending on the knowledge level of your students and your own comfort level, you may wish to teach those concepts before using this activity. However, a simple explanation of them as students encounter the terms in the activity is sufficient as mastery of those concepts is not necessary for successful completion of the activity.

Objectives

- Students will be able to describe the three basic parts of an electrolytic cell.
- Students will be able to construct a simple electrolytic cell.
- Students will be able to analyze an electrolytic cell for its potential use as a rechargeable battery or for energy storage.

Materials

- Assorted electrolytic solutions, such as dilute hydrochloric acid, citric acid, sodium sulfate, etc.*
- Assorted solid, pure metals, such as copper, zinc, nickel, iron, etc. (pencil lead can be used for graphite)*
- Beakers or plastic cups
- Alligator clips
- LEDs
- Digital multimeters
- Thermometers
- Stopwatches, timers, or a clock with a second hand visible to all students

NOTE: Use what is on-hand, safe, and easy to access.

Preparation

- Pre-teach any concepts with which your students may not be familiar, to the level you decide is best for your students.
- Review laboratory safety procedures as needed.
- Decide whether you will provide the information necessary to complete Part II, and make copies of the needed data for each student or group of students.
- Gather materials, preparing solutions as necessary.
- Make copies of student pages as needed for each student.

Grade Levels

Intermediate, grades 6-8

Secondary, grades 9-12

Time

- 1-2 class periods

✔ Procedure

1. Introduce the activity, explaining that students will be constructing electrochemical cells to maximize voltage. To ensure the challenge is authentic, do not provide a table of reduction potentials for students.
2. Allow time for students to complete Part I.
3. Introduce the concepts from the Background reading for Part II. Explain some of the challenges, emphasizing that this activity is on an introductory level and that actual research requires knowledge far beyond what they are exposed to in high school.
4. Allow students enough time to complete Part II.
5. Project or draw a simple Venn diagram for students to see. Label one side "Ideal Rechargeable Battery" and the other side "Electrochemical Cells Made in Class".
6. Ask students for concepts from their own Venn diagrams, and where on the diagram they should be written. Discuss the shortcomings of their own electrolytic cells as compared to ideal rechargeable batteries.

Extensions

- Have students construct two or more electrochemical cells identical to the one they completed in Part I, one time in series and another in parallel, and observe the effect on voltage and current in each case. This is a good way to introduce these concepts and branch off into electric circuits.
- Invite energy storage experts from a local utility, university, or materials company who can discuss the challenges of designing and constructing rechargeable batteries.
- For a cross-curricular collaboration, have students research which materials in their electrochemical cells as well as commercially available rechargeable batteries are obtainable domestically and which have to be imported. Have students identify the region(s) where these raw materials are found, and describe the political implications importing them may have.

BATTERY DESIGN CHALLENGE

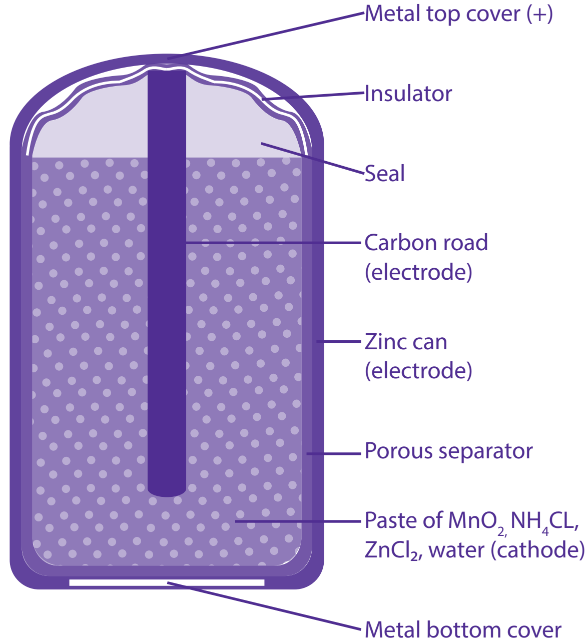
Background

Batteries, electrochemical cells, wet cells… help?

A battery is a device that stores energy for later use. So, technically, wind-up springs, hydropower pumped storage, and other similar energy storage devices could be called batteries. However, the way we use the word battery on an everyday basis is much more specific. Scientifically speaking, our everyday batteries are more accurately referred to as dry electrochemical cells. However, that's a mouthful, and if you continue referring to electrochemical cells as batteries nobody is going to mind.

An electrochemical cell is a device that harnesses chemical reactions to generate electricity. How is this possible, you ask? It relies on something called an element's reduction potential. When an atom gains electrons, there is a certain amount of energy, or potential, associated with the process. The potential, measured in volts, is the reduction potential; the atom has been reduced, or gained electrons. As you can well imagine, some elements are more willing to give up electrons, or be oxidized, while others are more amenable to being reduced, or gain electrons. Whenever an oxidation occurs, a reduction also occurs, because the electrons must go somewhere. In an electrochemical cell, we force the electrons through a circuit so they can do work for us.

Zinc-Carbon Dry Cell



All electrochemical cells have three parts: an anode, the site of oxidation; a cathode, the site of reduction; and an electrolyte, a substance able to conduct electrons. The anode is the source of electrons, and the cathode is the part of the cell that draws the electrons in. A wet cell uses a water-salt or water-acid solution as the electrolyte, while a dry cell contains a paste of electrolyte. Inside a typical dry cell battery you can purchase in any store is a paste of a mixture of compounds separated by a permeable barrier (see diagram of zinc-carbon dry cell). When the anode is connected to the cathode with a wire, electricity will flow through the wire. If you try this, be aware that the wire will quickly become quite warm! This is because there is almost no resistance against electricity in the wire, and the friction of the electrons moving is absorbed completely by the wire. When an electrical load is connected to the battery, the heat from the friction of the electrons is distributed in the load.

Electricity is a Load of Fun

Don't let the vocabulary of electricity trip you up. You've already read about potential and that it's measured in volts. Higher voltage from a battery just indicates that it will be able to power larger objects. Think about a AAA battery vs. a car battery. The AAA battery is only 1.5 volts, while a typical car battery is 12. It's much more difficult to start a vehicle than to operate a remote control for your DVD player.

However, potential is not the only thing that matters in batteries. Current is a measure of the number of electrons available to do the work. More current, more work gets done. AAA, AA, C, and D batteries are all the same voltage – 1.5 volts. So why are they different sizes? The D battery produces the most current, or has the most electrons available to do the work in the device it's powering (often a flashlight or portable radio). Because they are all made of the same materials, but in different amounts, they all have the same voltage. This is because the same materials in any given battery, regardless of size, always have the same reduction potential.

By combining different materials, batteries of varying voltages can be constructed. Chemists working on batteries are always looking for different materials that will yield higher voltages in smaller spaces and with less weight.

Getting a (Re)charge out of Life

One of the challenges associated with single-use alkaline batteries is that they must be properly disposed when they are no longer able to generate power to run devices. Most people just throw them in their municipal trash stream, but that creates a problem of heavy-metal and corrosive materials in a landfill. One solution to this problem has been to make batteries rechargeable.

In order to be rechargeable, the chemical reaction inside the battery has to be reversible. Not all chemical reactions are easily reversible, so it was a challenge for chemists to find a combination of materials that would be relatively safe to use in small amounts that would also provide a reversible reaction if sufficient electric current was applied. Some reversible reactions required much too high an electric current to be safely used in a residential setting. Others generated too much heat to be safe. The most common rechargeable battery is a lithium-ion battery.

Part I – Design a battery challenge

Question

Which materials make the best electrochemical cells?

Hypothesis

Write a hypothesis identifying which of the materials your teacher has provided will make the best battery in terms of voltage.

Materials

- Selected anode, a cathode, and electrolyte to test from the supplies provided by your teacher
- 1 Beaker or plastic cup
- 1 LED
- 3 Alligator clips
- Digital multimeter

Procedure

1. Place some of the electrolyte in a beaker or plastic cup.
2. Assemble your electrochemical cell by placing the anode and cathode in the electrolyte. Do not allow them to come into contact with each other.
3. Clip an alligator clip to the anode, and another to the cathode.
4. Clip one alligator clip to the end of an LED. Connect the other end of the LED to the digital multimeter with an alligator clip.
5. Connect the other end of the digital multimeter to the last alligator clip, completing the circuit.
6. Set the digital multimeter to measure DC voltage. You may have to adjust the scale to get the best reading.
7. Verify that current is flowing by observing the LED. If it does not light, reverse its connection in the circuit.
8. Record the voltage of your electrochemical cell.
9. Decide if you will improve your cell by replacing the anode or the cathode. Only replace one at a time, to keep control of the rest of your design.
10. Repeat steps 1-8, recording the voltage each time, until you have found a combination that results in the highest voltage.
11. Use the digital multimeter to record the current your electrolytic cell produces.
12. Make a diagram of your electrochemical cell, identifying the substance making the anode, cathode, and electrolyte.
13. Disconnect one alligator wire, but leave the cell assembled for Part II.

Data and Observations

Use the following table to record your electrochemical cell design and each modification.

Iteration	Anode	Cathode	Electrolyte	Observed Voltage
1				
What willl you modify?				
2				
What willl you modify?				
3				
What willl you modify?				
4				
What willl you modify?				

Diagram your best electrochemical cell below. Be sure to identify the anode, cathode, and electrolyte.

⁂ Conclusion

1. Explain the reasoning behind your first set of materials. Why did you think they would make a good electrochemical cell?

2. When you modified your design, did you improve your design, or did you take a step backward?

3. Based on the results of your classmates, which materials of those available in class make the best electrochemical cell? Justify your answer with evidence collected in the activity by you or one of your classmates.

4. An electrochemical cell will only provide a certain voltage, regardless of how large it is made. If a higher voltage is needed, batteries are connected positive-to-negative. This arrangement is referred to as "wired in series." Assume at least 6 volts is needed to power a device. How many of your electrochemical cells would be needed to provide at least 6 volts? Make a diagram of this setup below.

Part II – Ramp it up challenge

Background

The Storage Problem

You may already be aware that some kinds of batteries are used to store energy. The rechargeable batteries in your electronic devices store energy, and if those run low you can recharge them with a plug-in charging cord or an external battery pack. However, most of these batteries are measured in mAh (milliamp-hours) and would not provide the high numbers of kWh (kilowatt-hours) that we use in homes and commercial buildings. In short, rechargeable batteries with which you are already familiar will not be sufficient to provide power to your home overnight or in a power outage.

Some buildings with solar photovoltaic systems installed also have a battery bank of lead-acid batteries originally manufactured for vehicles. These batteries can be recharged relatively easily. However, they are very bulky, and as their name implies, the lead and acid inside are not exactly safe materials to have lying around the house. Most people do not have an extra-large closet or small room to use solely to store dozens of batteries, and in case of fire they are a serious hazard to firefighters.

Corporations, utilities, and government entities are all working toward developing a battery that is made of safe materials that do not take up much space and can be recharged and discharged over and over again without degradation of the materials inside.

Accepting the Challenge

It's one thing to assemble an electrochemical cell that maximizes voltage. It is quite another to assemble a cell that maximizes voltage and is also rechargeable. This part of the activity requires you to determine whether your electrochemical cell is, in fact, rechargeable.

Electrochemical cells, or batteries, are categorized into two types: primary and secondary. Primary batteries are the type with which you are most familiar. These batteries are single-use cells that cannot be recharged. Secondary batteries are rechargeable. Primary batteries will lose up to twenty percent of their available energy when not in use because some side reactions other than the desired redox reaction are taking place. Storing batteries in a cold place such as a freezer will slow down these side reactions and maximize the amount of available energy when the battery is needed.

Secondary batteries also have side reactions occurring, even when not in use. These batteries will lose about one-tenth of their available energy every month while not in use. This is why a device that was last charged two months ago will likely need recharging before you can use it.

When it comes to rechargeable batteries, energy density is key. Energy density is the amount of energy per unit of mass in the battery, measured in watt-hours per kilogram (Wh/kg). A watt-hour is one watt of power used in an hour. Nickel-cadmium (Ni-Cd) batteries have an energy density of 45-80 Wh/kg, a relatively low number. They also contain toxic substances; however, the advantage of Ni-Cd batteries is that they provide long life, so they are used in devices in the medical field and video cameras that are used for greater lengths of time.

Lead-acid batteries are used commonly in combination with solar photovoltaic installations to store power and use it at night. They have a relatively low energy density, 30-50 Wh/kg, but are reliable and can be discharged and recharged many, many times. The higher mass of these batteries is not a problem where they are used because they add little more weight to an already large vehicle, or remain stationary.

Lithium-ion batteries are most commonly used in small electronics because they have a high energy density of 100-130 Wh/kg. This allows a very small battery to power a device as large as a laptop computer or digital camera. The batteries on these devices are often built into the device and use a special charging cord to recharge the battery. Lithium-ion batteries use manganese and/or cobalt along with lithium. Under high heat conditions, manganese remains stable, but provides slightly less current than cobalt. Cobalt allows for the release of a higher current but can heat up quickly, which is not safe for any batteries. Batteries that overheat can rupture and are a fire hazard. Many lithium-ion batteries have a mixture of manganese and cobalt.

Predicting the amount of heat generated when a battery is discharged or recharged can be accomplished by knowing the change in enthalpy of the chemical reactions inside. Enthalpy is another way to represent the heat energy for a chemical change. For example, combining hydrogen and oxygen into water releases a lot of energy, so the value of the change in enthalpy is high. Scientists and engineers who design rechargeable batteries need to know the change in enthalpy for both the discharge reaction as well as the reverse reaction when recharging the battery.

Question

Is your electrochemical cell rechargeable?

Hypothesis

Write a statement explaining whether you believe your electrochemical cell from Part I is rechargeable.

Materials

- Electrochemical cell from Part I
- Thermometer
- Stopwatch, timer, or clock with second hand
- Computer with Internet access

Procedure

1. Place the thermometer tip into the electrolyte of your cell. Reconnect the alligator clip you had disconnected at the end of Part I. Observe the LED to verify that current is flowing.
2. Record the temperature of the electrolyte every 60 seconds. Use a time interval of fewer than 60 seconds if the temperature is rising rapidly. Use a time interval greater than 60 seconds if the temperature rises slowly. Record the temperature at regular intervals for a total of 15 minutes.
3. Disassemble the electrochemical cell. Clean the thermometer, anode, cathode, glassware, and alligator clips and clean up.

Data and Observations

Record your temperature data in the table below. Add more spaces if needed.

Time (s)															
Temp (°C)															

Conclusion

1. Does your electrochemical cell release a lot of heat energy? Use the evidence collected in your investigation to justify your answer.

2. Use online resources or materials provided by your teacher to determine the reaction occurring in your electrochemical cell. Write the equation, unbalanced, below:

3. Use online resources or materials provided by your teacher to determine whether the reaction occurring in your electrochemical cell is reversible. If it is, write the equation, unbalanced, below:

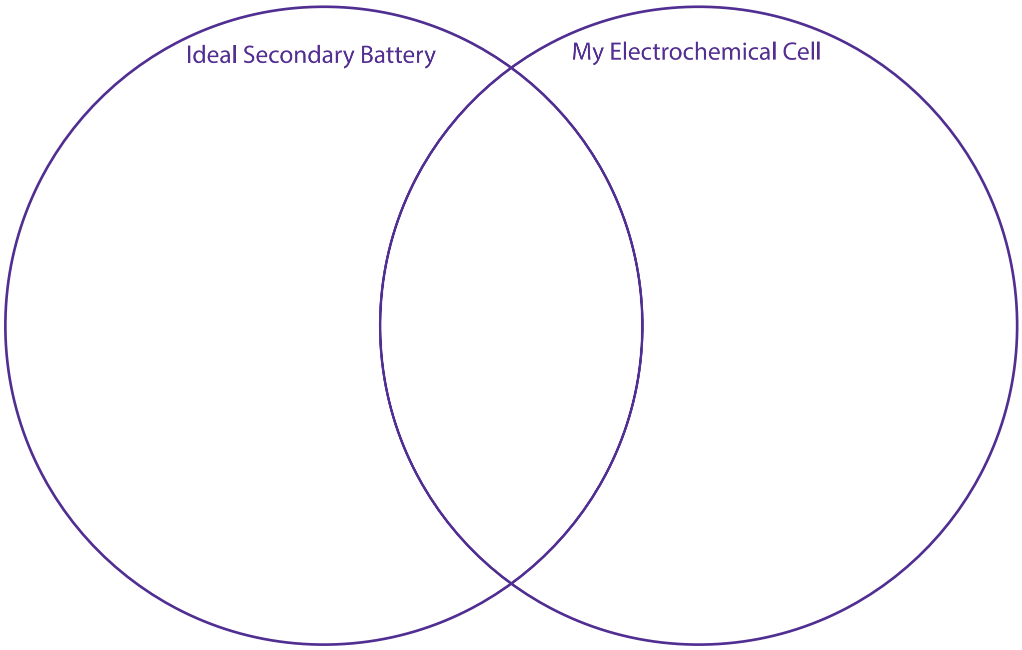
4. What was the maximum voltage your cell produced? What was the maximum current your cell produced? Use the formula Voltage × Current = Power to calculate the power produced by your cell.

5. Based on your calculation in question 4, how would you rate the energy density of your electrochemical cell? Use one of the other secondary batteries discussed in the text as a reference and estimate where your cell would align.

6. Design a method to determine the energy density of your cell. Describe the data you would need to collect and any calculations you must perform.

7. Use online resources or materials provided by your teacher to analyze the safety of the materials in your electrochemical cell. List the anode, cathode, and electrolyte and explain any hazards associated with each.

8. Fill the Venn diagram below with information you have gathered in both parts of this activity. Address energy density, enthalpy, and material safety as you fill in the diagram.



9. Is your electrochemical cell a good candidate for a secondary battery? Justify your answer with evidence collected in this entire activity.

BASELOAD BALANCE
WITH ADDED ENERGY STORAGE

Background

Most students don't give electric power much thought until the power goes out. Electricity plays a giant role in our day-to-day lives. This activity demonstrates how electricity supply is transmitted on the electric grid to consumers. It also encourages students to explore the differences between baseload and peak demand power, and how power companies maintain supply to ensure customers have power as they need it. This version of *Baseload Balance* has been augmented to showcase how energy storage can be added to benefit demand management.

Students will be introduced to the economics of electricity generation and supply and be able to see first-hand the financial challenges utilities must overcome to be able to provide the power demanded by consumers at the lowest cost. Figures, costs, and sources used in this activity are roughly based on current industry uses and costs, but have been made into round figures for ease of implementation. This simulation asks students to assume the roles of "loads" or "generation".

Objectives

- Students will be able to differentiate between baseload and peak demand power.
- Students will be able to explain the purpose of using a variety of sources to meet base and peak load power demand.
- Students will be able to describe the challenges of using certain sources to meet base and peak load power demand.
- Students will be able to describe how energy storage can be incorporated into demand management, and how it can benefit consumers and generators.

Suggested Materials

- Scissors
- Tape
- Rope
- Colored paper
- Individual marker boards with erasers and markers
- *Baseload Balance Cheat Sheet*
- *Baseload Balance Student Infosheet*
- *Baseload Balance Load and Generation Parameters*
- *Baseload Balance Hang Tag Template*
- *Baseload Balance Incident Cards*

Simulation Preparation

- Familiarize yourself with the activity instructions and student background information before facilitating the game with students. Make a copy of the *Cheat Sheet* information on page 26 for yourself.
- Copy the hang tags and cut them apart. Attach the tags to four colors of paper or color the cards so that the generation, the transmission, the load, and the storage cards are each a different color. Laminate, if desired, for future use.
- Prepare a copy of the *Student Infosheet* and *Load and Generation Parameters* for projection.

This activity was adapted to incorporate energy storage. The original version of this activity can also be found in the following NEED guides at shop.NEED.org:

Exploring Wind Energy

Energy From the Wind

Understanding Coal

Exploring Coal

Time

- 1-2 class periods

Grade Levels

Intermediate, grades 6-8

Secondary, grades 9-12

Number of Students

28+

Extensions

- RTOs usually require generation to be 15 percent above demand. Play the game again accounting for the prescribed demand plus the additional 15 percent. Hold a class discussion about why this extra generation is required.
- Have students brainstorm scenarios that could disrupt power on either end, and describe how they would respond on each side.
- Students could write a persuasive letter in support of a certain type of power plant after playing the game. Letters should include information gleaned about the plant's advantages and disadvantages, as well as the feasibility for use in generation of electricity at the lowest cost.

- Designate an area of the room to be the Regional Transmission Organization (RTO). On one side of this area will be the generation group, and the other side will be the load group. Each side should have its own marker board, eraser, and marker.
- Decide if a student will be the RTO leader, or if the teacher or another adult will assume this role. Having a student assume this position will create a more student-centered activity. Depending on the ability of the students in your group, using a student for this role may require more monitoring and time than if a teacher is in charge.
- Instruct students to read the infosheet prior to the activity.

Student Roles

- Baseload demand – 3 students
- Peak load demand – 8 students
- Baseload generation – 6 students
- Peak load generation – 7 students
- Transmission – 3-5 students
- RTO -- 1-3 students or a teacher
- Storage -- 1-3 students (optional)

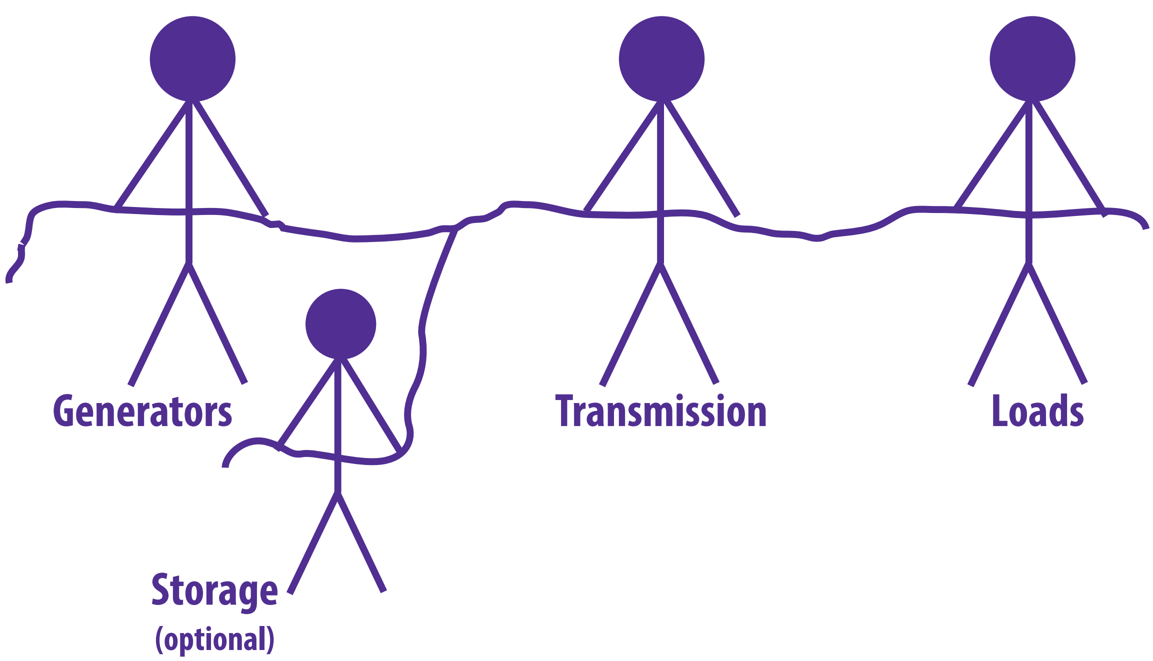
Vocabulary *SPECIFIC TO THE GAME*

- Baseload
- Generation
- Load
- Transmission
- Peak demand
- Megawatt

✔ Set-up Procedure

1. Assign each student a role that corresponds to each hang tag. If your class does not have enough students for each tag, the baseload tags can be tied to the rope because they are always in operation. A list of the roles can also be found above. The transmission roles are best assigned to students who are able to think quickly on their feet and have good math skills. Storage roles can be assigned after playing rounds one and two. If you do not have enough students to fill all required and optional roles, some baseload or storage roles can be "proxies" that are tied online as needed.
2. Allow time for students to research their roles and re-read the background information. Students should be familiar with the vocabulary and information on their hang tag, including generating capacity, energy source, and power demand. Depending on the level of your students, you may choose to have them skip the section of the background information that discusses regional transmission organizations and independent system operators.
3. Project the *Load and Generation Parameters* master for the class. Discuss the relative cost for each source and plant type as well as the suggested reasoning for the cost of each.
4. The activity begins with the transmission students gathering in the Regional Transmission Organization area, each holding onto the rope or string. The student on each end should have plenty of available rope or string onto which the generation students and load students will attach. These students will decide which peak load providers (plants) will be brought online to meet increasing demand as the activity progresses. They will also help the RTO by tabulating the current load or generation on their side of the line. They will display it on their marker board and update it as the activity progresses.
5. In the generation group, the residential baseload, commercial baseload, heavy industry baseload, and all baseload generation students all hold ends of the rope on their respective sides. They will be holding onto the rope during the entire activity because as baseload power or generation, they are providing or using power all the time.
6. At the appropriate time indicated on each hang tag, each load student will join the grid, increasing the load demand. Residential demand comes up (online) at about 7:00 a.m. as people begin to wake. Demand continues to rise as more residential, commercial, and industry come on the grid, pulling electricity or creating another load.

7. The transmission students will need to balance the generation against the load. They will choose the best generation students to come online to balance the load students. The RTO can monitor or assist the transmission group by announcing the time and reminding each load or role when to join on.
8. After going through the activity once (one complete 24-hour period), reset the activity to early morning and run through a second time balancing the generation against the load, but now using the cheapest available sources to run for the longest amount of time. You may also wish to reassign students to different roles, depending on their command of the activity in the first round.
9. Run the activity again, resetting as needed, and incorporate storage as a new way to manage demand. Select one of the incident cards to set the stage for using storage.
10. Hold a class discussion to recap the simulation, using the discussion questions below:
    - Roughly what time was the peak demand time? When is the least amount of power needed?
    - Why did we choose our particular sources we did when balancing generation and demand?
    - How would knowledge of historical data and weather forecasts help in making decisions about which sources to use?
    - How did storage make the balancing easier/harder? What challenges would there be if using storage types like those in the game? What factors were not addressed in our game play?



BASELOAD BALANCE CHEAT SHEET

	HANG TAGS
3	Baseload Demand
8	Peak Load Demand
6	Baseload Generation
7	Peak Load Generation
3 - 5	Transmission
1 - 3	RTO (Regional Transmission Organization)
28 - 32	**TOTAL**

LOADS

	BASELOAD DEMAND
Residential	35 MW
Heavy Industry	60 MW
Commercial	20 MW
TOTAL	**115 MW**

	PEAK LOAD/ DEMAND
7:00 a.m. - 12:00 a.m.	5 MW Residential
8:00 a.m. - 9:00 p.m.	5 MW Light Industry
8:00 a.m. - 11:00 p.m.	10 MW Residential
9:00 a.m. - 8:00 p.m.	5 MW Light Industry
9:00 a.m. - 9:00 p.m.	10 MW Commercial
10:00 a.m. - 8:00 p.m.	5 MW Light Industry
3:00 p.m. - 1:00 a.m.	10 MW Residential
5:00 p.m. - 11:00 p.m.	5 MW Commercial

GENERATORS

AVAILABLE GENERATION

BASELOAD GENERATION

Coal Baseload	40 MW	$60/MW
Natural Gas Baseload	20 MW	$30/MW
Nuclear Baseload	50 MW	$30/MW
Hydropower Baseload	5 MW	$30/MW
Solar Baseload	5 MW	$180/MW
Wind Baseload	5 MW	$40/MW
Waste-to-Energy Baseload	10 MW	$60/MW

PEAK GENERATION

Natural Gas Simple Cycle	10 MW	$90/MW
Natural Gas Simple Cycle	5 MW	$90/MW
Natural Gas Simple Cycle	10 MW	$150/MW
Natural Gas Simple Cycle	5 MW	$200/MW
Natural Gas Simple Cycle	5 MW	$600/MW
Hydropower Peak	5 MW	$50/MW
Hydropower Peak	10 MW	$70/MW

	TOTAL ONLINE
TOTAL BASELOAD DEMAND	115 MW

TOTAL ONLINE

PEAK LOAD COMING ONLINE

7:00 a.m. - 12:00 a.m.	5 MW	120 MW
8:00 a.m. - 9:00 p.m.	5 MW	125 MW
8:00 a.m. - 11:00 p.m.	10 MW	135 MW
9:00 a.m. - 8:00 p.m.	5 MW	140 MW
9:00 a.m. - 9:00 p.m.	10 MW	150 MW
10:00 a.m. - 8:00 p.m.	5 MW	155 MW
3:00 p.m. - 1:00 a.m.	10 MW	165 MW
5:00 p.m. - 11:00 p.m.	5 MW	170 MW

PEAK LOAD GOING OFFLINE

8:00 p.m.	Lose 10 MW (2 Tags)	160 MW
9:00 p.m.	Lose 15 MW (2 Tags)	145 MW
11:00 p.m.	Lose 15 MW (2 Tags)	130 MW
12:00 a.m.	Lose 5 MW (1 Tags)	125 MW
1:00 a.m.	Lose 10 MW (1 Tags)	115 MW

STORAGE OPTIONS	TOTAL AVAILABLE 45 MW
Compressed Air	10 MW
Pumped Storage Hydro	20 MW
Flywheel	5 MW
Solar Thermal	10 MW

BASELOAD BALANCE

STUDENT INFOSHEET

Introduction

Four kinds of power plants produce most of the electricity in the United States: coal, natural gas, nuclear, and hydropower. Coal plants generate about 30 percent of the electricity we use. There are also wind, geothermal, waste-to-energy, solar, and petroleum power plants, which together generate about ten percent of the electricity produced in the United States. All of this electricity is transmitted to customers, or loads, via the network of transmission lines we call the grid.

Fossil Fuel Power Plants

Fossil fuel plants burn coal, natural gas, or petroleum to produce electricity. These energy sources are called fossil fuels because they were formed from the remains of ancient sea plants and animals. Most of our electricity comes from fossil fuel plants in the form of coal and natural gas.

Power plants burn the fossil fuels and use the heat to boil water into steam. The steam is channeled through a pipe at high pressure to spin a turbine generator to make electricity. Fossil fuel power plants can produce emissions that pollute the air and contribute to global climate change. The amount and type of emissions can vary based upon the type of fossil fuel and technologies used within the plant.

Fossil fuel plants are sometimes called thermal power plants because they use heat energy to make electricity. (*Therme* is the Greek word for heat.) Coal is used by many power plants because it is inexpensive and abundant in the United States.

There are many other uses for petroleum and natural gas, but the main use of coal is to produce electricity. Over 90 percent of the coal mined in the United States is sent to power plants to make electricity.

Nuclear Power Plants

Nuclear power plants are called thermal power plants, too. They produce electricity in much the same way as fossil fuel plants, except that the fuel they use is uranium, which isn't burned. Uranium is a mineral found in rocks underground. Uranium atoms are split to make smaller atoms in a process called fission that produces enormous amounts of thermal energy. The thermal energy is used to turn water into steam, which drives a turbine generator.

Nuclear power plants do not produce carbon dioxide emissions, but their waste is radioactive. Nuclear waste must be stored carefully to prevent contamination of people and the environment.

Hydropower Plants

Hydropower plants use the energy in moving water to generate electricity. Fast-moving water is used to spin the blades of a turbine generator. Hydropower is called a renewable energy source because it is renewed by rainfall.

Waste-to-Energy (Biomass) Plants

Waste-to-energy facilities are thermal power plants that burn garbage and other waste to produce electricity. The heat from the incinerator creates steam in a boiler that drives a turbine generator. Facilities monitor and scrub their emissions and recycle ash to be environmentally friendly.

Cost of Electricity

How much does it cost to make electricity? Cost depends on several factors.

- **Fuel Cost**

The major cost of generating electricity is the cost of the fuel. Many energy sources can be used. There are also other factors that tie into the cost of a fuel, including production cost, manufacturing or refining costs, cost of transporting the fuel, and more. Hydropower is the cheapest energy source while solar cells are typically the most expensive way to generate power.

- **Building Cost**

Another factor is the cost of building the power plant itself. A plant may be very expensive to build, but the low cost of the fuel can make the electricity economical to produce. Nuclear power plants, for example, are very expensive to build, but their fuel—uranium—is inexpensive. Coal-fired plants, on the other hand, are cheaper to build, but the fuel (coal) is more expensive than uranium.

- **Efficiency**

When figuring cost, you must also consider a plant's efficiency. Efficiency is the amount of useful energy you get out of a system. A totally efficient machine would change all the energy put in it into useful work. Changing one form of energy into another always involves a loss of usable energy. Efficiency of a power plant does not take into account the energy lost in production or transportation, only the energy lost in the generation of electricity.

Combined Cycle vs. Simple Cycle

In the most simple of thermal power plants, a fuel is burned, and water is heated to form high-pressure steam. That steam is used to turn a single turbine. Thermal power plants running in this manner are about 35 percent efficient, meaning 35 percent of the energy in the fuel is actually transformed into useable electrical energy. The other 65 percent is "lost" to the surrounding environment as thermal energy.

Combined cycle power plants add a second turbine in the cycle, increasing the efficiency of the power plant to as much as 60 percent. By doing this, some of the energy that was being wasted to the environment is now being used to generate useful electricity.

In general, today's power plants use three units of fuel to produce one unit of electricity. Most of the lost energy is waste heat. You can see this waste heat in the great clouds of steam pouring out of giant cooling towers on some power plants. For example, a typical coal plant burns about 4,500 tons of coal each day. The chemical energy in about two-thirds of the coal (3,000 tons) is lost as it is converted first to thermal energy, and then to motion energy, and finally into electrical energy. This degree of efficiency is mirrored in most types of power plants. Thermal power plants typically have between a 30-40% efficiency rating. Wind is usually around the same range, with solar often falling below the 30% mark. The most efficient plant is a hydropower plant, which can operate with an efficiency of up to 95%.

Meeting Demand

We don't use electricity at the same rate at all times during the day. There is a certain amount of power that we need all the time called baseload power. It is the minimum amount of electricity that is needed 24 hours a day, 7 days a week, and is provided by a power company.

However, during the day at different times, and depending on the weather, the amount of power that we use increases by different amounts. We use more power during the week than on the weekends because it is needed for offices and schools. We use more electricity during the summer than the winter because we need to keep our buildings cool. An increase in demand during specific times of the day or year is called peak demand. This peak demand represents the additional power above baseload power that a power company must be able to produce when needed.

Power plants can be used to meet baseload power or peak demand, or both. Some power plants require a lot of time to be brought online – operating and producing power at full capacity. Others can be brought online and shut down fairly quickly.

Coal and nuclear power plants are slow, requiring 24 hours or more to reach full generating capacity, so they are used for baseload power generation. Natural gas is increasing in use for baseload generation because it is widely available, low in cost, and a clean-burning fuel.

Wind, hydropower, and solar can all be used to meet baseload capacity when the energy source is available. Wind is often best at night and drops down in its production just as the sun is rising. Solar power is not available at night, and is greatly diminished on cloudy days. Hydropower can produce electricity as long as there is enough water flow, which can be decreased in times of drought.

To meet peak demand, energy sources other than coal and uranium must be used. Natural gas is a good nonrenewable source to meet peak demand because it requires only 30 minutes to go from total shutdown to full capacity. Many hydropower stations have additional capacity using pumped storage. Some electricity is used to pump water into a storage tank or reservoir, where it can be released at a later time to generate additional electricity as needed. Pumped storage hydropower can be brought fully online in as little as five minutes.

Some power plants, because of regulations or agreements with utilities, suppliers, etc., do not run at full capacity or year-round. These power plants may produce as little as 50 percent of maximum generating capacity, but can increase their output if demand rises, supply from another source is suddenly reduced, or an emergency occurs.

Making Decisions

Someone needs to decide when, which, and how many additional generating locations need to be brought online when demand for electricity increases. This is the job of the Regional Transmission Organization (RTO) or Independent System Organization (ISO). ISOs and RTOs work together with generation facilities and transmission systems across many locations, matching generation to the load immediately so that supply and demand for electricity are balanced. The grid operators predict load and schedule generation to make sure that enough generation and back-up power are available in case demand rises or a power plant or power line is lost.

Transmission Organizations

Besides making decisions about generation, RTOs and ISOs also manage markets for wholesale electricity. Participants can buy and sell electricity from a day early to immediately as needed. These markets give electricity suppliers more options for meeting consumer needs for power at the lowest possible cost.

Ten RTOs operate bulk electric power systems across much of North America. More than half of the electricity produced is managed by RTOs, with the rest under the jurisdiction of individual utilities or utility holding companies.

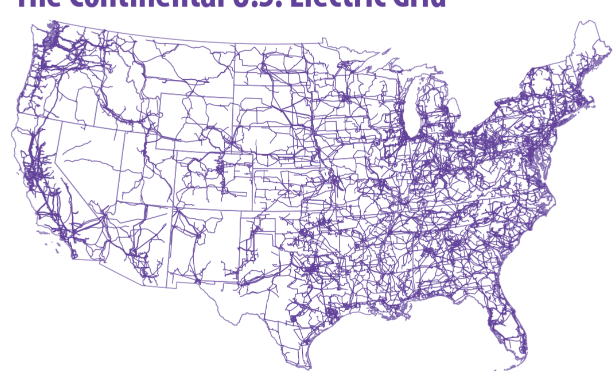
In the 1990s, the Federal Energy Regulatory Commission introduced a policy designed to increase competitive generation by requiring open access to transmission. Northeastern RTOs developed out of coordinated utility operations already in place. RTOs in other locations grew to meet new policies providing for open transmission access.

Members of RTOs include the following:

- Independent power generators
- Transmission companies
- Load-serving entities
- Integrated utilities that combine generation, transmission, and distribution functions
- Other entities such as power marketers and energy traders

RTOs monitor power supply, demand, and other factors such as weather and historical data. This information is input into complex software that optimizes for the best combination of generation and load. They then post large amounts of price data for thousands of locations on the system at time intervals as short as five minutes.

The Continental U.S. Electric Grid



Data: Energy Information Administration

BASELOAD BALANCE

LOAD AND GENERATION PARAMETERS

Load

Consumer	Capacity	Type
Heavy Industry	60 MW	Baseload
Commercial	20 MW	Baseload
Residential	35 MW	Baseload
Residential	5-10 MW	Peak Load
Commercial	5-10 MW	Peak Load
Light Industry	5 MW	Peak Load

Generation

Fuel	Capacity	Type of Generation	Time Required for Full Capacity	Cost per Megawatt-hour
Coal	40 MW	Baseload	24 hours	$60
Nuclear (Uranium)	50 MW	Baseload	24 hours +	$30
Natural Gas Combined Cycle (NGCC)	20 MW	Baseload	30 minutes +	$30
Wind	5 MW	Baseload	Immediate when wind speed is sufficient; primarily at night	$40
Solar	5 MW	Baseload	Immediate when solar intensity is sufficient; only during day	$180
Hydropower	5 MW	Baseload	5 minutes	$30
Waste-to-Energy (Biomass)	10 MW	Baseload	5 minutes	$60
Hydropower	5-10 MW each site	Peak load	5 minutes	$50-70
Natural Gas Simple Cycle (NGSC)	5-10 MW each site	Peak load	5 minutes	$90-$600

Baseload Balance Hang Tag Template

Generation

Baseload
Nuclear
50 MW
$30 / MW-hour

Generation

Baseload
Coal
40 MW
$60 / MW-hour

Generation

Baseload
Natural Gas CC
20 MW
$30 / MW-hour

Generation

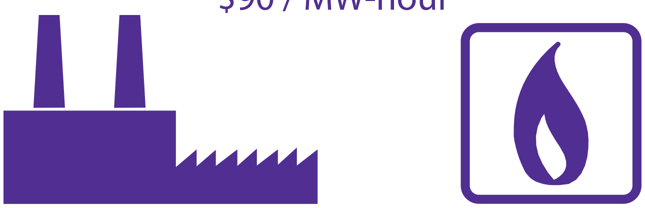
Baseload
Hydro
5 MW
$30 / MW-hour

Generation

Baseload
Wind
5 MW
$40 / MW-hour

Generation

Baseload
Solar
5 MW
$180 / MW-hour

Generation Baseload **Waste-to-Energy (Biomass)** 10 MW $60 / MW-hour 	**Generation** Peak Load **Natural Gas SC** 10 MW $90 / MW-hour 
Generation Peak Load **Natural Gas SC** 5 MW $90 / MW-hour 	**Generation** Peak Load **Natural Gas SC** 10 MW $150 / MW-hour 
Generation Peak Load **Natural Gas SC** 5 MW $200 / MW-hour 	**Generation** Peak Load **Natural Gas SC** 5 MW $600 / MW-hour 

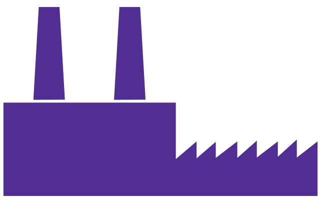
Generation

Peak Load

Hydro

5 MW

$50 / MW-hour



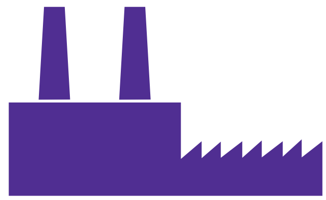
Generation

Peak Load

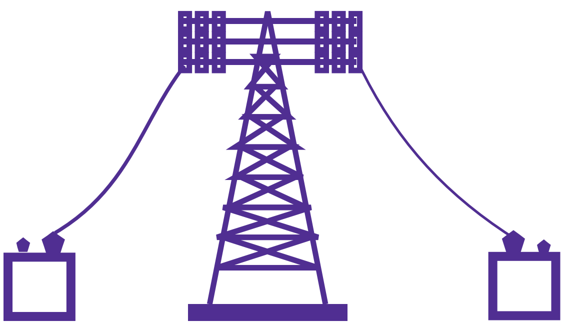
Hydro

10 MW

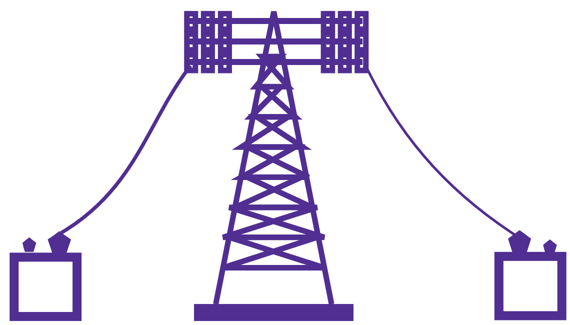
$70 / MW-hour



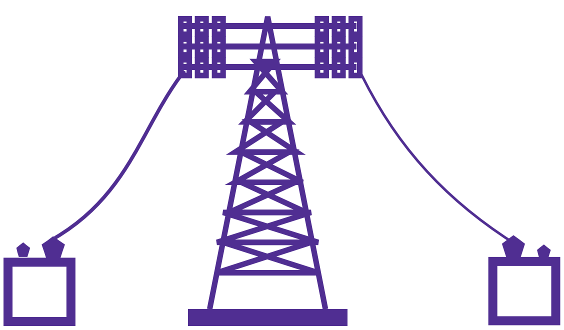
Transmission



Transmission



Transmission



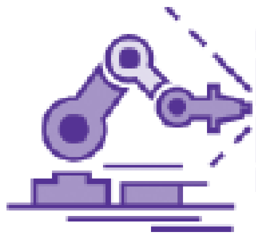
Load

Commercial

20 MW

Baseload

Load
Heavy Industry
60 MW
Baseload



Load
Residential
35 MW
Baseload

Load
Residential
5 MW
7:00 am – 12:00 am

Load
Residential
10 MW
8:00 am – 11:00 pm

Load
Commercial
10 MW
9:00 am –9:00 pm

Load
Commercial
5 MW
5:00 pm – 11:00 pm

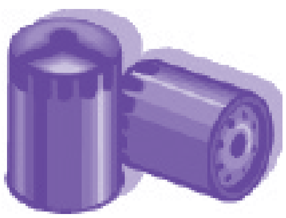
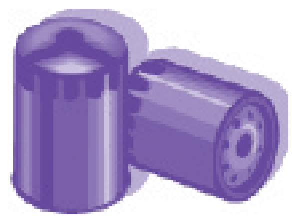
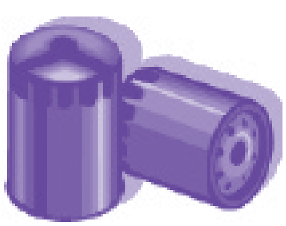
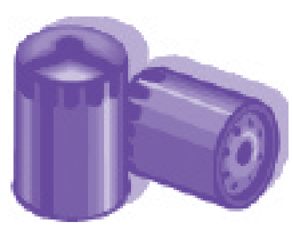
Load
Light Industry
5 MW
8:00 am – 9:00 pm

Load
Light Industry
5 MW
9:00 am – 8:00 pm

Load
Residential
10 MW
3:00 pm – 1:00 am

Load
Light Industry
5 MW
10:00 am – 8:00 pm

Regional Transmission Organization

Storage **Compressed Air** 10 MW 	**Storage** **Pumped Storage Hydro** 20 MW 
Storage **Flywheel** 5 MW 	**Storage** **Solar Thermal** 10 MW 

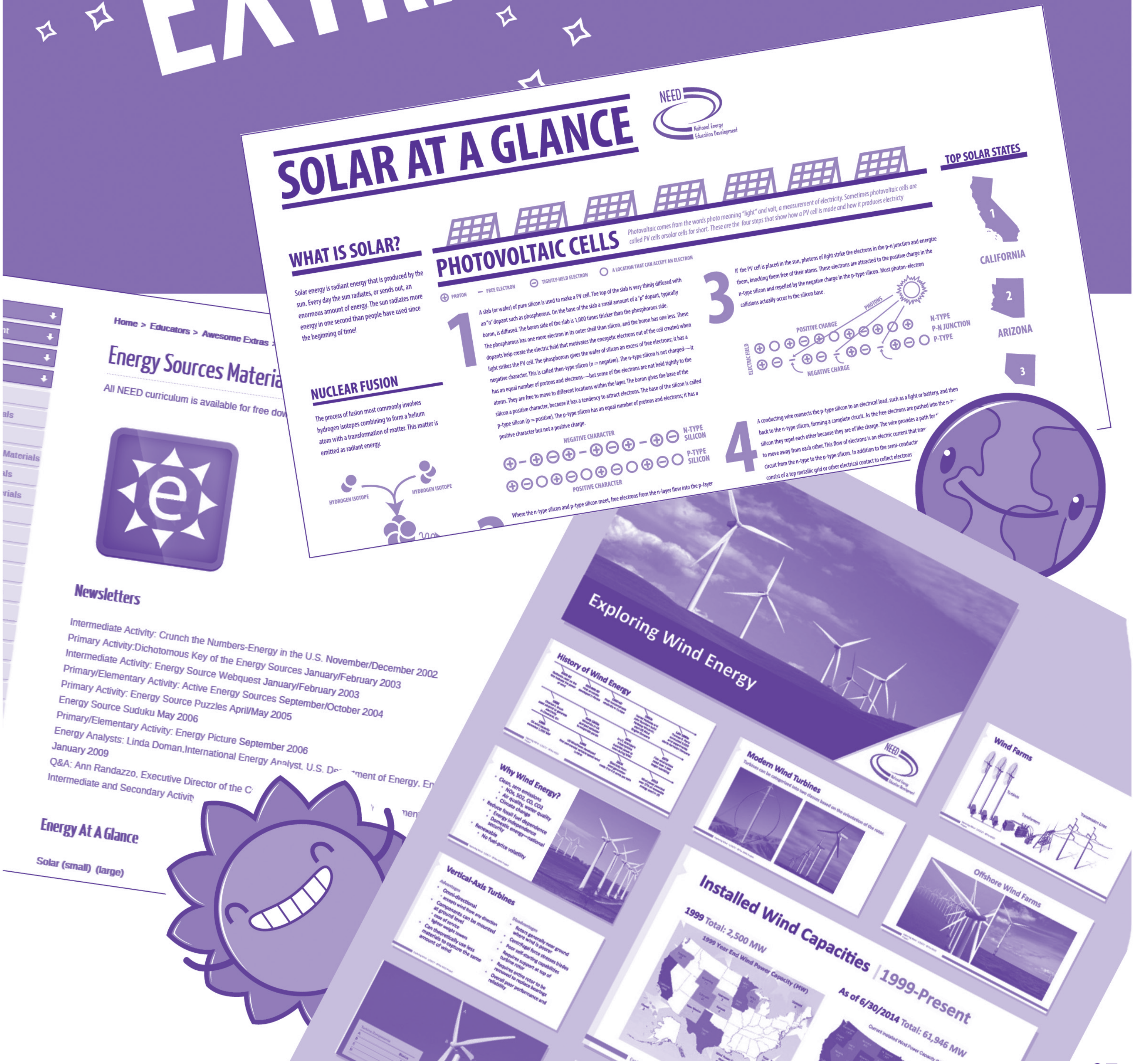
Baseload Balance Incident Cards

INCIDENT	At 3:00 p.m. heavy cloud cover moves over the region taking out your solar generation. If you can't provide enough power to meet the load, RTO must choose who will lose power and be in blackout. How could a blackout have been avoided?
INCIDENT	At 2:00 p.m. a baseload coal unit trips and you lose 10 MWs of baseload coal. If you can't provide enough power to meet the load, RTO must choose who will lose power and be in blackout. How could a blackout have been avoided?

AWESOME EXTRAS!

Our Awesome Extras page contains PowerPoints, animations, and other great resources to compliment what you are teaching!

www.NEED.org/awesomeextras

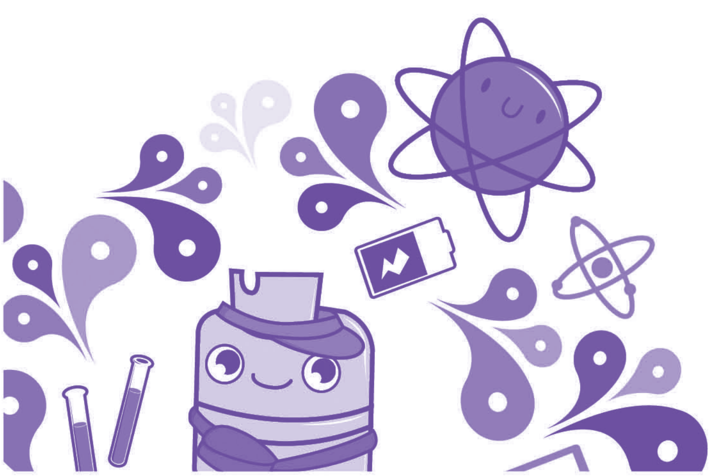


YOUTH ENERGY CONFERENCE & AWARDS

YOUTH ENERGY CONFERENCE AND AWARDS

The NEED Youth Energy Conference and Awards gives students more opportunities to learn about energy and to explore energy in STEM (science, technology, engineering, and math). The annual June conference has students from across the country working in groups on an Energy Challenge designed to stretch their minds and energy knowledge. A limited number of spaces are available for Full STEM Ahead, a special two-day pre-conference event, which allows students access to additional information, time to discuss energy with their peers, and access to industry professionals. The conference culminates with the Youth Awards Ceremony recognizing student work throughout the year and during the conference.

For More Info: www.youthenergyconference.org



YOUTH AWARDS PROGRAM FOR ENERGY ACHIEVEMENT

All NEED schools have outstanding classroom-based programs in which students learn about energy. Does your school have student leaders who extend these activities into their communities? To recognize outstanding achievement and reward student leadership, The NEED Project conducts the National Youth Awards Program for Energy Achievement.

Share Your Energy Outreach with The NEED Network!
This program combines academic competition with recognition to acknowledge everyone involved in NEED during the year—and to recognize those who achieve excellence in energy education in their schools and communities.

What's involved?

Students and teachers set goals and objectives and keep a record of their activities. Students create a digital project to submit for judging. In April, digital projects are uploaded to the online submission site.

Want more info? Check out **www.NEED.org/Youth-Awards** for more application and program information, previous winners, and photos of past events.

NEED

National Energy Education Development Project

National Sponsors and Partners

2019 Exelon Women's Leadership Summit
Association of Desk and Derrick Clubs Foundation
Alaska Electric Light & Power Company
American Electric Power Foundation
American Fuel & Petrochemical Manufacturers
Apex Clean Energy
Armstrong Energy Corporation
Association for Learning Environments
Robert L. Bayless, Producer, LLC
Baltimore Gas & Electric
BG Group/Shell
BP America Inc.
Blue Grass Energy
Bob Moran Charitable Giving Fund
Boys and Girls Club of Carson (CA)
Buckeye Supplies
Cape Light Compact–Massachusetts
Central Alabama Electric Cooperative
Citgo
CLEAResult
Clover Park School District
Clovis Unified School District
Colonial Pipeline
Columbia Gas of Massachusetts
ComEd
ConocoPhillips
Constellation
Cuesta College
Cumberland Valley Electric
David Petroleum Corporation
David Sorenson
Desk and Derrick of Roswell, NM
Desert Research Institute
Direct Energy
Dominion Energy, Inc.
Dominion Energy Foundation
DonorsChoose
Duke Energy
Duke Energy Foundation
East Kentucky Power
EduCon Educational Consulting
Edward David
E.M.G. Oil Properties
Energy Trust of Oregon
Ergodic Resources, LLC
Escambia County Public School Foundation
Eversource
Exelon
Exelon Foundation
Exelon Generation
First Roswell Company
Foundation for Environmental Education
FPL
The Franklin Institute
George Mason University – Environmental Science and Policy
Gerald Harrington, Geologist
Government of Thailand–Energy Ministry
Grayson RECC
Green Power EMC
Greenwired, Inc.
Guilford County Schools–North Carolina
Gulf Power
Harvard Petroleum
Hawaii Energy
Houston LULAC National Education Service Centers
Illinois Clean Energy Community Foundation
Illinois International Brotherhood of Electrical Workers Renewable Energy Fund
Illinois Institute of Technology
Independent Petroleum Association of New Mexico
Jackson Energy
James Madison University
Kansas Corporation Commission
Kentucky Office of Energy Policy
Kentucky Environmental Education Council
Kentucky Power–An AEP Company
Kentucky Utilities Company
League of United Latin American Citizens – National Educational Service Centers
Leidos
Linn County Rural Electric Cooperative
Llano Land and Exploration
Louisiana State University – Agricultural Center
Louisville Gas and Electric Company
Midwest Wind and Solar
Minneapolis Public Schools
Mississippi Development Authority–Energy Division
Mississippi Gulf Coast Community Foundation
National Fuel
National Grid
National Hydropower Association
National Ocean Industries Association
National Renewable Energy Laboratory
NC Green Power
Nebraskans for Solar
New Mexico Oil Corporation
New Mexico Landman's Association
NextEra Energy Resources
NEXTracker
Nicor Gas
Nisource Charitable Foundation
Noble Energy
North Carolina Department of Environmental Quality
North Shore Gas
Offshore Technology Conference
Ohio Energy Project
Oklahoma Gas and Electric Energy Corporation
Oxnard Union High School District
Pacific Gas and Electric Company
PECO
Pecos Valley Energy Committee
People's Electric Cooperative
Peoples Gas
Pepco
Performance Services, Inc.
Petroleum Equipment and Services Association
Permian Basin Petroleum Museum
Phillips 66
Pioneer Electric Cooperative
PNM
PowerSouth Energy Cooperative
Providence Public Schools
Quarto Publishing Group
Prince George's County (MD)
R.R. Hinkle Co
Read & Stevens, Inc.
Renewable Energy Alaska Project
Resource Central
Rhoades Energy
Rhode Island Office of Energy Resources
Rhode Island Energy Efficiency and Resource Management Council
Robert Armstrong
Roswell Geological Society
Salal Foundation/Salal Credit Union
Salt River Project
Salt River Rural Electric Cooperative
Sam Houston State University
Schlumberger
C.T. Seaver Trust
Secure Futures, LLC
Seneca Resources
Shell
Shell Carson
Shell Chemical
Shell Deer Park
Shell Eco-Marathon
Sigora Solar
Singapore Ministry of Education
Society of Petroleum Engineers
Sports Dimensions
South Kentucky RECC
South Orange County Community College District
SunTribe Solar
Sustainable Business Ventures Corp
Tesla
Tri-State Generation and Transmission
TXU Energy
United Way of Greater Philadelphia and Southern New Jersey
University of Kentucky
University of Maine
University of North Carolina
University of Rhode Island
University of Tennessee
University of Texas Permian Basin
University of Wisconsin – Platteville
U.S. Department of Energy
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy–Wind for Schools
U.S. Energy Information Administration
United States Virgin Islands Energy Office
Volusia County Schools
Western Massachusetts Electric Company - Eversource