ESSENTIAL LENS

ANALYZING PHOTOGRAPHS ACROSS THE CURRICULUM

Energy: Capture, Storage, and Transformation

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Energy: Capture, Storage, and Transformation

Standards

The content is in accordance with the Next Generation Science Standards (NGSS), specifically:

- Physical Sciences PS3: Energy
- Life Sciences LS1: Structures and Processes
- HS ETS1.B: Developing Possible Solutions
- HS ETS1.A: Defining and Delimiting an Engineering Problem.

Other sections that might be relevant are:

- MS ESS3.A: Natural Resources
- MS ESS3.C: Human Impacts on Earth Systems
- The crosscutting concept of Energy and matter: Flows, cycles, and conservation, from the *2012 Framework for K-12 Science Education* from the National Research Council of the National Academy of Science (see References and Further Reading).

Prerequisite Knowledge

Before doing these activities, students should be familiar with the conservation of energy—that it is not created or destroyed, but can be stored and released. Students should recognize that photos of light or motion represent effects of energy.

Introduction

Energy. We know it when we see its effects but have a hard time explaining it. If you ask students to picture the concept of energy, they might conjure up the images in this collection. They might have difficulty explaining how the photographs represent energy, however. Students can understand that images of food, gasoline, and sunlight represent energy, but they might not know how humans have, for millennia, engineered ways to store energy and use energy transformation to do work.

Some of the photographs in this collection illustrate the impact of energy as movement, light, or heat; others show mechanisms engineered to capture, store, and distribute energy. Ask students to consider the costs and benefits of different energy-capturing systems. In addition to the physical science concept of energy, science, and engineering topics directly and indirectly related to the photographs, include natural resources, human impact on earth, and defining and delimiting engineering problems.

Curriculum Snapshot

- Using photographs to recognize energy effects in the natural world
- Examining ways to capture, store, and use energy for work

Grade Level

High school and possibly middle school

Classroom Connections

Physical Science, Life Science, Earth and Space Science, Engineering

Note: In talking about energy, it is easy to use language that suggests that energy is created or destroyed. Strictly speaking, however, energy is conserved in our universe, according to the first law of thermodynamics. Terms such as "generated" or "lost" are common in conversations about energy. When teaching about energy, however, use terms such as convert, flow, distribute, store, release, transfer, transform, input, and outflow. "Heat energy" is a common conversational term. To be accurate, however, "heat" should be used to describe the transfer of thermal energy.

Key Learning Targets

Students will:

- Think and talk about energy and visual depictions of energy using appropriate terms.
- Observe and consider different systems that humans use to capture, store, and transfer energy—including the efficiencies and inefficiencies of different systems.
- Follow energy transfer through systems by analyzing photos and making flow charts.

Essential Questions

- What are society's energy needs and how have we traditionally met them?
- What are the advantages and disadvantages of different ways of meeting our energy needs? (For example, how do energy-capturing systems differ in their impact on the land and in their efficiency or inefficiency?)

ACTIVITY 1
Activating Students' Prior Knowledge

Begin the Activity

In pairs or small groups, ask students to talk—and possibly write about—what they picture when they hear the word "energy." Then have the students look at the photos (projected or on handouts) and talk about how the photos represent energy. Have students identify the types of energy involved in each photographed system and the inputs, processes, and outputs they see. Students might notice energy types, inputs and outputs (such as movement or light), and processes (such as cranks or wheels). Some students might know terms such as kinetic, thermal, or chemical bond energy. Have students brainstorm other examples of systems for capturing and using energy. Depending on the photos used, they might think of traditional or modern windmills, or new methods, such as solar panels.

Emphasize that, at this point, no ideas are considered right or wrong. Some discussion points might be to note the movement energy of water, waves, and wind; thermal and light energy of sunlight; and stored chemical energy in organic matter such as wood. Human metabolism releases stored chemical energy in food. That energy can be used for movement, such as riding a bicycle. A point to raise in discussions is how photographers visually convey energy: for example, how the water photos emphasize waves and motion rather than tranquility.

Photographs for This Activity (Appendix, pgs. 14-27)

2503, 2511, 2529, 2544, 2553, 2559, 2567, 2569, 2573, 2574, 2575, 2581, 2592, 2596

ACTIVITY 2
Energy Systems

Learning Targets

- I can use accurate terminology to talk about images that represent energy transfer, storage, and use.
- I can follow the transfer of energy through a system; for example, by making a flow chart or other diagram.
- I can describe different technologies and engineering solutions for capturing, storing, and using energy.

Photographs for This Activity
(Appendix, pgs. 28-40)

2528, 2544, 2548, 2576, 2578, 2582, 2587, 2589, 2591, 2593, 2595, 2597, 2598

Background

This information is not for classroom content, but to prepare teachers for the photographs, activities, and potential questions from students.

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (p. 128–129) has background material for these activities:

In ordinary language, people speak of "producing" or "using" energy. This refers to the fact that energy in concentrated form is useful for generating electricity, moving or heating objects, and producing light, whereas diffuse energy in the environment is not readily captured for practical use. Therefore, to produce energy typically means to convert some stored energy into a desired form—for example, the stored energy of water behind a dam is released as the water flows downhill and drives a turbine generator to produce electricity, which is then delivered to users through distribution systems. Food, fuel, and batteries are especially convenient energy resources because they can be moved from place to place to provide processes that release energy where needed. A system does not destroy energy when carrying out any process. However, the process cannot occur without energy being available. The energy is also not destroyed by the end of the process. Most often some or all of it has been transferred to heat the surrounding environment; in the same sense that paper is not destroyed when it is written on, it still exists but is not readily available for further use.

Naturally occurring food and fuel contain complex carbon-based molecules, chiefly derived from plant matter that has been formed by photosynthesis. The chemical reaction of these molecules with oxygen releases energy; such reactions provide energy for most animal life and for residential, commercial, and industrial activities.

Electric power generation is based on fossil fuels (i.e., coal, oil, and natural gas), nuclear fission, or renewable resources (e.g., solar, wind, tidal, geothermal, and hydro power). Transportation today chiefly depends on fossil fuels, but the use of electric and alternative fuel (e.g., hydrogen, biofuel) vehicles is increasing.

All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. Technological advances and regulatory decisions can change the balance of those costs and benefits.

Although energy cannot be destroyed, it can be converted to less useful forms. In designing a system for energy storage, for energy distribution, or to perform some practical task (e.g., to power an airplane), it is important to design for maximum efficiency—thereby ensuring that the largest possible fraction of the energy is used for the desired purpose rather than being transferred out of the system in unwanted ways (e.g., through friction, which eventually results in heat energy transfer to the surrounding environment). Improving efficiency reduces costs, waste materials, and many unintended environmental impacts.

Begin the Activity

In small groups or pairs, have students choose a photo to examine and explain how energy is being captured, stored, or transferred in the system in the photograph. Students should discuss the state of the energy and the system before and after the situation shown in the photo. (Note that this exercise is mainly designed for high school students, so middle school students might use less sophisticated terms. High school students with more science experience might use more advanced terms. For example, they might discuss if they are seeing the capture of kinetic energy, or the release of chemical bond energy as heat.) In small groups or pairs, have students select a series of related photos and assemble them to portray a designed energy system. If the photos are not adequate to show a complete system, have the students identify the missing step. Remind students to try to use words that emphasize transfer and conservation of energy in the universe, rather than terms that suggest creation, generation, or loss of energy.

Have students make a diagram—for example, a flow chart or systems diagram—that shows the transformation of energy in each photo.

Questions to Consider

Engineers work to design practical solutions to real-world problems by breaking them down into smaller, solvable problems. Spend a few minutes thinking like an engineer, considering a solution to a problem based on priorities and thinking about trade-offs and limitations. Use this type of thinking to describe ways that humans do or could take advantage of the energy source shown in one of the photographs and use it to do work.

- How could the energy source be tapped and what could it be used to do?
- Systems developed for capturing energy from a particular source often have similar design elements; however, the designs for individual energy-capturing systems vary, depending on a variety of factors.
- For photographs that show a mechanism designed to harness an energy source, how could elements of the mechanism be used to harness a different energy source? (What design elements do windmills and waterwheels have in common, for example?)

ACTIVITY 3
Designing Energy-Capturing Systems

Learning Targets

- I can critically examine photographs and identify details of competing design solutions based on the priorities and constraints of the problem.
- I can weigh the efficiencies and inefficiencies of different systems to meet human energy needs.

Photographs for This Activity (Appendix, pgs. 41-48)

2500, 2506, 2543, 2554, 2555, 2564, 2594, 2599

Background

This information is not for classroom content, but to prepare teachers for the photographs, activities, and potential questions from students.

Any system designed to capture energy for work has associated criteria and constraints that are defined by a variety of factors. Consideration of scientific principles and other relevant knowledge may limit possible solutions. For example, extracting, processing, transporting, and using fossil fuels have environmental impacts. Hydroelectric and nuclear power plants create risks and benefits for a region. Renewable energy sources, such as wind turbines, solar panels, and biofuel production, have production costs and demands and require space. Costs and requirements change as technology advances but are often limited by geographic constraints or situations.

In this activity, students will focus on one of the energy sources highlighted in the second activity. Students will use photographs showing different systems designed to capture, store, and transfer wind energy to analyze different design features of wind energy systems, thinking about the environmental factors involved in different solutions. Small group and class discussions will consider the design benefits of different systems that take advantage of energy sources. Students will have the opportunity to apply engineering design strategies to locations and situations in their own community.

Begin the Activity

Part 1

Give students a photograph to work on, possibly in pairs. (Optional: Start by making a diagram, as in Activity 2: Energy Systems, to show the flow of energy in the system in the photograph.) Show the energy flow from the source through the processing equipment to a specific use, such as a home, car, or school.

Next, consider the space required for the energy-capturing system in the photograph. If the photo has an associated scale, for example 1 cm = 5 m, calculate the dimensions of the energy-capturing system. If the photo does not have an associated scale, use a familiar item in the photo (such as a person or vehicle) to estimate the dimensions. For example, use an average height of 170 cm per person, or guess that a tree might be 5 or 10 meters high to calculate the length and width of solar panels or wind turbines.

Have students look at the background features of the photographs and note the general geographical features and the expected climate of the region.

As a class, share the footprint—the dimensions—of each energy-capturing system. Discuss the amount of space required for the different systems as well as requirements.

Thinking about the space and other requirements, discuss the advantages and disadvantages, such as environmental impact, risks to the surrounding community, sustainability of the energy source, or aesthetic impact. For example, if this system were installed in your state or region, what ecosystems might be affected? What else might the space be used for?

> *Note: Using the activity results, students will be able to discuss the space requirements. For the other features, they could generate hypotheses about advantages and disadvantages of the energy-harnessing systems, such as the sustainability of a system that requires a steady supply of wind or sun, or complaints that people might have about the aesthetics of various systems. For a more in-depth activity, have students choose one of the systems and research its advantages and disadvantages more fully.*

Part 2

Using the estimates from Part 1, based on the photos of the solar array and wind turbine, have students go outside and plot or map out their estimates of the size of the energy-capturing systems. Back in the classroom, have students discuss and identify factors besides size that would be required to using the systems in their community.

Materials:

- Rulers, pencils and paper

Although energy cannot be destroyed, it can be converted to less useful forms.

Part 3

In this part of the activity:

1. Students work in pairs or small groups to analyze different wind turbine and blade designs and discuss possible reasons for the different design components.

2. Student teams select a possible local site for installing a wind energy system and identify the relevant environmental factors to be considered.

3. Student teams create a model of a wind energy system with a design based on real local data.

Give students photos of wind turbines. Based on the variety of designs shown in the photos, have students make one or more models that explore options for blade design and turbine structure. After they have sketched or described their own models, have the students research and design a option that might work locally. (Option: an Internet search might find directions for building and testing a mock wind turbine.)

Compare the advantages and disadvantages that the class came up with for the energy-capturing systems in the photographs to the pros and cons of the predominant systems in your area. Do you think your region has the optimal energy option? Why or why not? (Interactive maps and tables from the U.S. Energy Information Administration can answer questions about energy capacity and consumption in different regions and by different sources, see References and Further Reading.)

What sources of energy are we not yet using effectively? What is needed to use or improve our use of these energy sources?

Questions to Consider

Look at the background features of all the photographs.

- What general geographical or climate features do you see?

- Where in the United States or in the world might this type of energy-capturing system work well?

- Is the system suited for developed or developing countries?

- Would this be a good option for your community? Why or why not?

Extensions Activites

1. Research different energy options in your area using the U.S. Energy Information Administration interactive map in References and Further Reading. Prepare a presentation or a paper, using the photographs from the first activity, presenting the pros and cons of different options for your community.

2. As a persuasive writing exercise, write a letter to a politician that makes a case for supporting a particular energy option for your region. Support your case with images.

3. Prepare a presentation or paper using the resources and imagery on biomimicry at asknature.org. Show how natural features of organisms can be used to design energy-capturing systems, such as wave turbines.

Essential Lens Video Connection

- Watch ***A Closer Look*** to learn more about analyzing photographs.

References and Further Reading

Framework for Science Education
A Framework for K-12 Science Education. Practices, Crosscutting Concepts, and Core Ideas.
http://www.nap.edu/catalog.php?record_id=13165

Additional energy-related educational materials and activities from the Department of Energy
http://energy.gov/science-innovation/science-education

Additional energy-related educational materials and activities from the National Renewable Energy Laboratory
http://www.nrel.gov/education/educational_resources.html

Interactive map of energy sources in the United States from the U.S. Energy Information Administration
http://www.eia.gov/state/maps.cfm?src=home-f3

Interactive tables with numbers for production, capacity, and other features of different energy sources, by country, adjustable for different units and years from the U.S. Energy Information Administration
http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

Ask Nature resources on biomimicry
http://www.asknature.org

Production statistics from the U.S. Energy Information AdministrationUsing the interactive tables, teachers and students can get current data on how much energy comes from various sources such as nuclear, fossil fuels or renewables.
http://www.eia.gov/countries/data.cfm

Renewable energy cost comparisons
http://www.renewable-energysources.com/

Additional Photographs and Digital Images

Alternative energy system
http://moberismoothies.com/#/id/i7221112

Maya Pedal
http://mayapedal.org

Bike-powered gym
http://inhabitat.com/human-powered-gyms-in-hong-kong/

APPENDIX

Activity 1

pgs. 1-27

2503, 2511, 2529, 2544, 2553, 2559, 2567, 2569, 2573, 2574, 2575, 2581, 2592, 2596

Activity 2

pgs. 28-40

2528, 2544, 2548, 2576, 2578, 2582, 2587, 2589, 2591, 2593, 2595, 2597, 2598

Activity 3

pgs. 41-48

2500, 2506, 2543, 2554, 2555, 2564, 2594, 2599

Activity 1 - **2503** - *The 63-MW Dry Lake Wind Power Project is the first utility-scale power project. The Salt River Project is purchasing 100% of the power from the phase one of this project for the next 20 years. January 13, 2011. Salt River, Arizona. (Iberdrola Renewables/NREL 16702)*

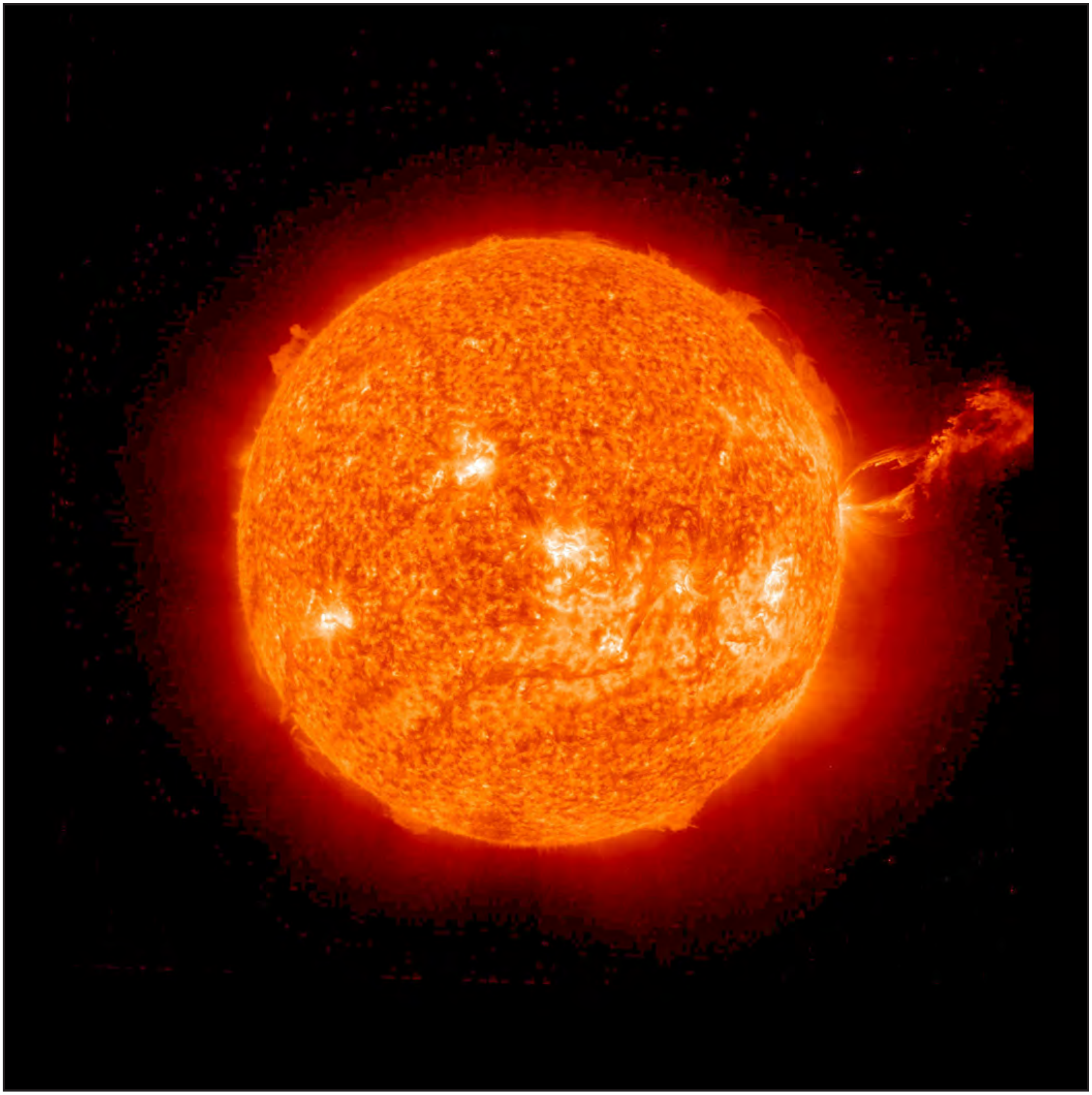
Activity 1 - **2511** - *NREL contractors Brian Lawson and Kenesaw Burwell work on panels that DOE is using to leverage a Power Purchase Agreement with Sun Edison and Xcel Energy to absorb the upfront installation costs. August 19, 2010. Golden, Colorado. (Dennis Schroeder/NREL 17842)*

Activity 1 - **2529** - *Traffic signal powered by solar power. 2010. Yokohama, Japan. (iStock)*

Activity 1

2544

Onshore wind farm. Date unknown. Westereems, Netherlands. (RWE Innogy UK)



Activity 1 - **2553** - *The Sun is constantly roiling with nuclear heat and intense magnetism that make sunspots, flares, coronal mass ejections, and all sorts of space weather. When directed toward Earth, those solar blasts can disrupt satellite and radio communications, damage our electric-powered tools and toys, and create auroras. October 14, 2012. (NASA image courtesy of the STEREO science team.)*

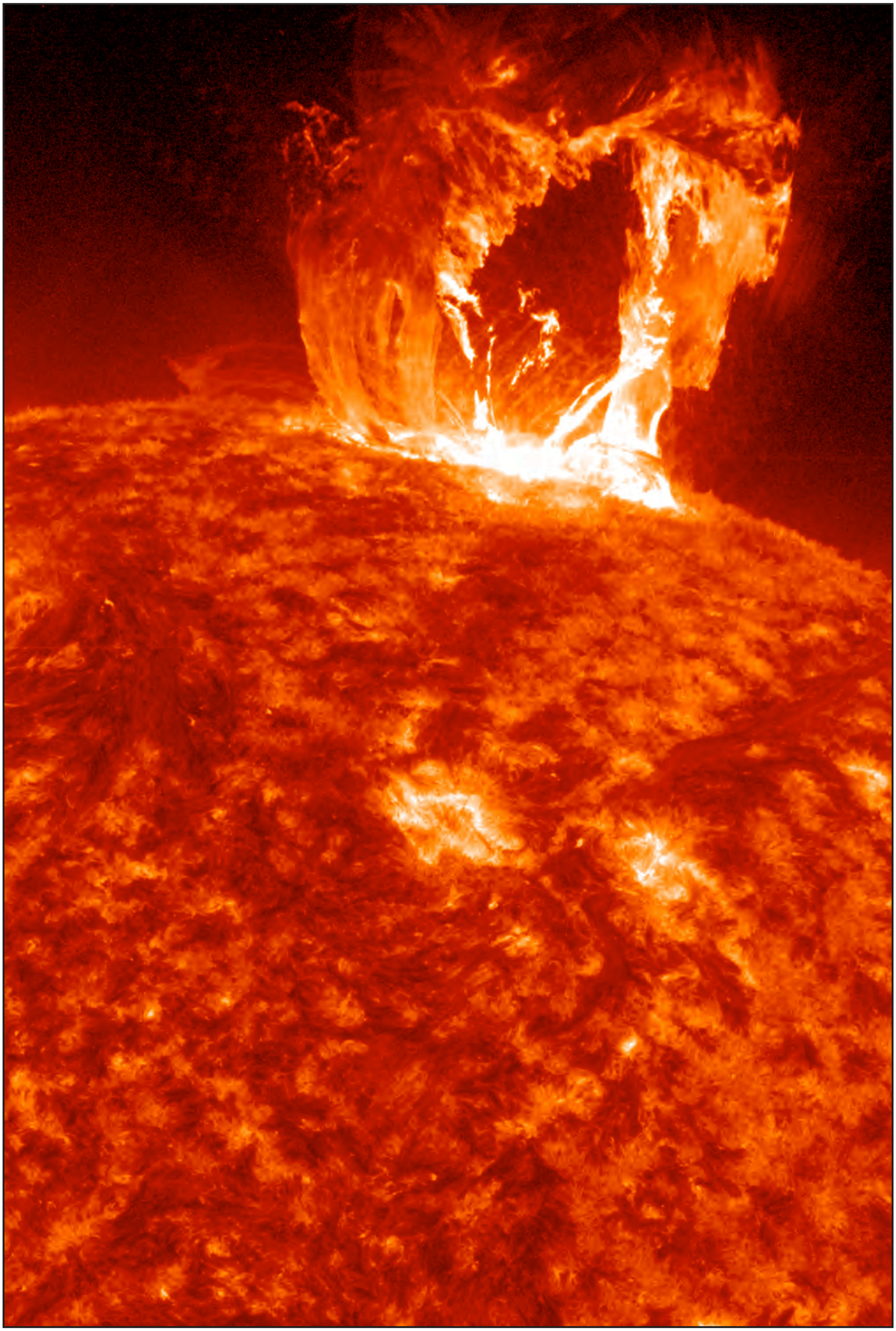
Activity 1 - **2559** - *A miner pushes a cart loaded with coal at Bagou village in China's southwest Sichuan province. Coal mined in the area is transported by steam train to the nearby city of Qiangwei. The Shibanxi passenger train, in operation since 1958, is one of a handful of steam trains left in the world. The area, blanketed much of the year by clouds and drizzle, is inaccessible by car, and villagers rely on the seven-car train to get to work, take pigs and vegetables to market, and take kids to school. Despite frequent rumors that it's headed for retirement, the train keeps chugging through the lush green mountains of Sichuan province. April 13, 2006. Bagou, China. (AP Photo)*

Activity 1 - **2567** - *The Bonneville Dam on the Columbia River near Cascade Locks, Oregon. The Bonneville Power Administration has ordered Pacific Northwest wind farms to cut production twice in recent days because it has a surplus of power from hydroelectric dams. The action renews a dispute from last spring, when the BPA curtailed wind turbines because the water from a large mountain snowpack left the region with more hydropower than the electrical grid could handle. June 3, 2011. Cascade Locks, Oregon. (Rick Bowmer/AP Photo)*

Activity 1 - **2569** - *Trees and mist in the green forest of Stanislaus National Forest from Yosemite National Park, in California. 2011. (iStock)*

Activity 1 - **2573** - *Aña Maria Guch, President of "Women for Development in Action," shows how her association of women makes aloe shampoo with bicimáquinas. From the interview: "First we cut the aloe, then we take off the skin and we put it in the bicilucuadora blender and we pedal!" April 2011. Guatemela. (Matteo de Mayda)*

Activity 1 - **2574** - *Bicidesgranadora (Mill/Corn Thresher). This bicycle machine is adapted to fit a hand-powered grinding mill or a corn thresher. The mill function has the capacity to mill pounds per minute of any type of grain. The most common use is for milling yellow maize, soya beans, and coffee. The thresher is used post-harvest and easily degrains 12 to 15 quintals (1 quintal = 100lbs.) per day and requires only one person to operate the machine. April 2011. Guatemela. (Matteo de Mayda)*



Activity 1 - **2575** - *An eruption was captured by NASA's Solar Dynamics Observatory in the 304 Angstrom wavelength, which is typically colored in red. April 16, 2012. (NASA/SDO/AIA)*

Activity 1 - **2581** - *Geothermal power station. 2007. Iceland. (iStock)*

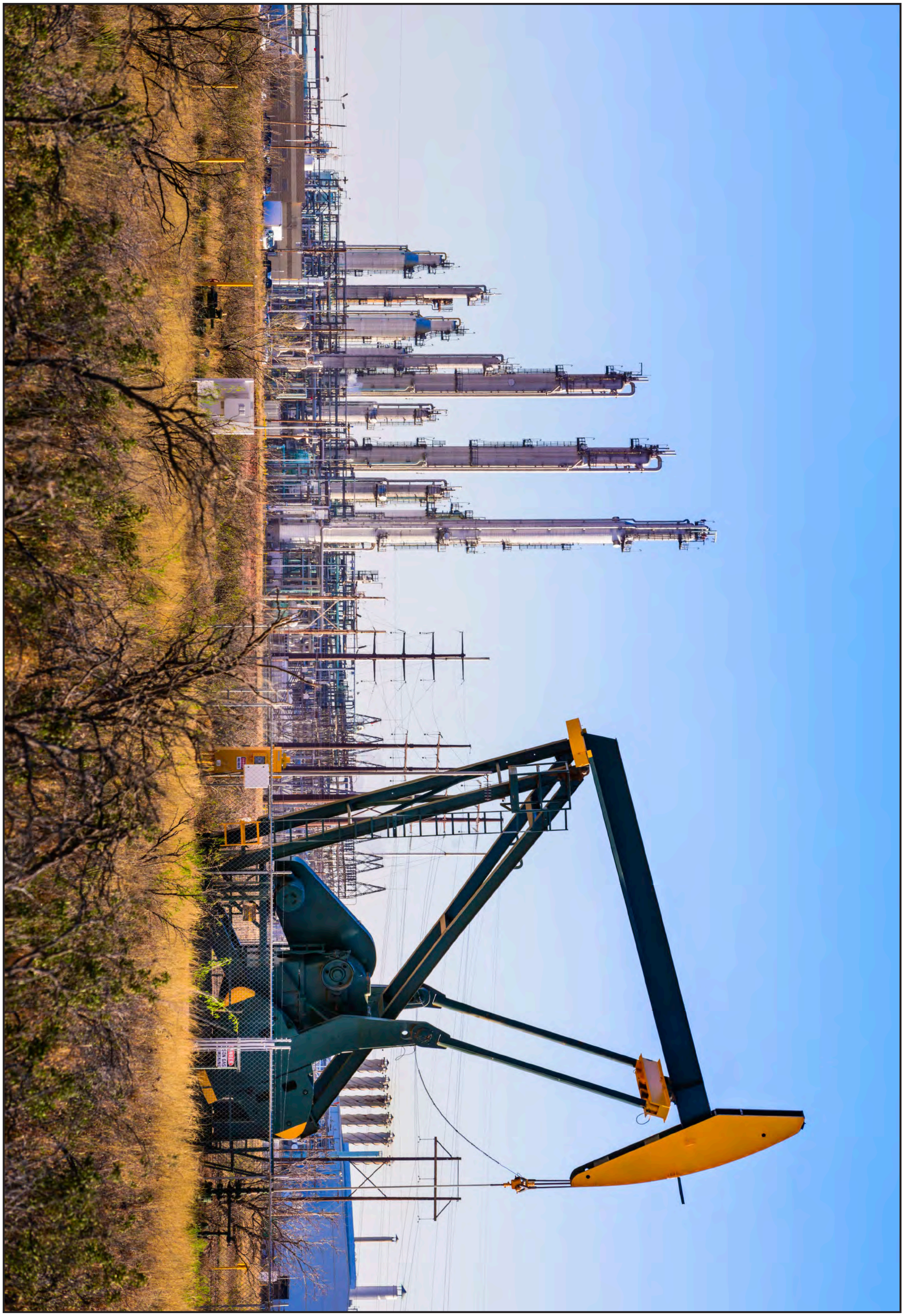
Activity 1 - **2592** - *Wind up/hand crank flashlight. (Shutterstock)*

Activity 1 - **2596** - *Surfer on blue ocean wave in the tube getting barreled. 2013. (iStock)*

Activity 2 - **2528** - *Old mill wheel. 2014. Heiligenblut, Austria. (iStock)*

Activity 2 - **2544** - *Onshore wind farm. Date unknown. Westereems, Netherlands. (RWE Innogy UK)*

Activity 2 - **2548** - *The Milgro Nurseries greenhouse near New Castle, Utah, is one of the approximately 40 greenhouses nationwide that benefit from the direct use of geothermal energy. The Newcastle geothermal resource is located at the southeastern margin of the Escalate Valley, in the transition zone between the Basin and Range and Colorado Plateau physiographic provinces. October 22, 2002. New Castle, Utah. (Robert Blackett / NREL 13995)*



Activity 2 - **2576** - *A pumpjack (oil derrick) and oil refinery. 2014. Seminole, West Texas. (iStock)*

Activity 2 - **2578** - *Power station and electricity pylon at dawn. 2008. (iStock)*

Activity 2 - **2582** - *Power lines. 2010. San Francisco, California. (iStock)*

Activity 2 - **2587** - *Fuel pump. 2013. (iStock)*

Activity 2 - **2589** - *Water electric power dam. 2014. (iStock)*

Activity 2 - **2591** - *Light bulb. Circa 2009. (iStock)*

Activity 2 - **2593** - *High-tension wire and wind-energy converters. 2013. (iStock)*

Activity 2 - **2595** - *Geothermal power station in a lava field in Grindavík, Iceland. People are bathing nearby in the Blue Lagoon geothermal hot spring. 2007. Grindavík, Iceland. (iStock)*

Activity 2 - **2597** - *Steam engine, photo taken on Pittsburgh's north side. August 12, 2012. Pittsburgh, Pennsylvania. (Matt Robinson Photography)*

Activity 2 - **2598** - *Alamosa Solar Generating Project is the largest high concentrating solar photovoltaic power generation system in the world. Alamosa Solar consists of over 500 dual-axis, pedestal mounted tracker assemblies, each producing 60 kW. Each tracker assembly is 70 ft. wide by 50 ft. high and contains 7,560 Fresnel lenses that concentrate sunlight by a multiple of 500 onto multi-junction cells. The photovoltaic assemblies were provided by Amonix Alamosa Solar and is located on 225 acres in the San Luis Valley near Alamosa, Colorado. May 5, 2014. (Dennis Schroeder/NREL 31439)*

Activity 3 - **2500** - *Aerial view of a techs working on the ALSTOM ECO 100, 3MW horizontal-axis upwind turbine at NREL's National Wind Technology Center (NWTC). August 7, 2012. National Wind Technology Center, Colorado. (Dennis Schroeder/NREL 21869)*

Activity 3 - **2506** - *Aerial view of the National Wind Technology Center at National Renewable Energy Laboratory. July 25, 2013. National Wind Technology Center, Colorado.* *(Dennis Schroeder/NREL 19059)*

Activity 3 - **2543** - *Onshore wind farm. Date unknown. Suwalki, Poland. (RWE Innogy UK)*

Activity 3 - **2554** - *Power County wind farm. March 7, 2012. Power County, Idaho. (Department of Energy)*

Activity 3 - **2555** - *Workers use a giant crane for lifting the blade assembly as work continues on the 2 MW Gamesa wind turbine being installed at NREL's National Wind Technology Center (NWTC). September 22, 2011. National Wind Technology Center, Colorado. (Dennis Schroeder/NREL 20869)*

Activity 3 - **2564** - *Vertical-axis wind turbines on hill. Date unknown. Altamont Pass, California. (Shutterstock)*

Activity 3 - **2594** - *World's largest vertical axis wind turbine and largest wind farm. Wind is becoming a more significant part of Quebec's energy supply. July 2009. Cap Chat, Quebec. (Shutterstock)*

Activity 3 - **2599** - *Damien Cuello uses the more than 110-foot high view from a 900kW wind turbine to get a better visual inspection of the other 900kW turbine and four other 225kW turbines at 45th Operations Group Detachment 2, Ascension Auxiliary Airfield, South Atlantic Ocean. The power house operator/mechanical associate is tethered and stands on the drive-line to get parallel views of the other generator housings. Cuello is a Computer Sciences Raytheon contract associate in charge of maintenance for the 6-wind turbine facility. June 24, 2009. Ascension Island. (Lance Cheung/U.S. Air Force)*

Oregon Public Broadcasting