Curriculum Units by Fellows of the National Initiative
2016 Volume IV: Energy Sciences

The Future of Energy

Curriculum Unit 16.04.08, published September 2016
by Jacqueline Rastrullo

Overview

According to Richard Smalley, energy is the number one problem that faces humanity in the next 50 years. In the event a natural disaster and long-term energy loss, what will you do? This project-based unit, "The Future of Energy", is about world energy production, consumption, and its environmental impact. The unit begins with energy history, starting with the carbon cycle and the formation of fossil fuels and seeks to explore the human environmental impact of current usage and dependence on conventional energy. This unit will also teach students how to research alternative energies, including nuclear, geothermal, wind, and solar in order to apply this deeper knowledge gained to engage in a Socratic Seminar about the topic. The unit concludes with the students innovating a contraption to cook food and make potable water in the event of a power outage. The unit will take place over five weeks in a sixth grade math and science classroom. It can be adapted for upper elementary through high school aged students.

Rationale

Over the hundreds of years of history of the Hayward-Rogers Creek Fault, there have been about twelve large earthquakes (above a magnitude 6.3), with an interval of approximately 138 years. The last large earthquake occurred in 1868, which means the fault is "overdue" for the next big one. Over the years since the last large earthquake, the fault has occasionally ruptured, releasing energy on this transform, or strike-slip boundary. Scientists predict there is a one in three chance the fault will produce a large earthquake in the next 30 years. My school lies within miles of this and other fault zones, as do many schools in California. The artist known as plate tectonics has painted the beautiful topography of the west coast of the United States. The landscapes are constantly changing; and as inhabitants of this region, we need to be prepared for what this could mean. Across the country, natural disasters can include earthquakes, floods, hurricanes, tornadoes, etc. and can happen anywhere in world. Energy security has become a top priority for world leaders and the task of ensuring the continued availability at a low cost has influenced geopolitics. The world is on a quest for energy independence, to an attempt to curtail the geopolitical implications of not being energy dependent. Cold War politics has been put aside for energy. The ability to extract this energy in the amounts needed to fill the demand has made for a higher standard of living for many people in the world. As a population, we enjoy travel, our televisions, cars, and smartphones, all things that require an energy source. It is only when these natural disasters strike do we come to realize our reliance and consumption of energy.

The population today is reliant on energy to power the technologies that run the applications we rely on day in and day out. Where does this energy come from? How would the loss of energy impact our daily lives? I want my students to start thinking about the environmental impact of this rate of consumption, research viable clean renewables for different regions in the world. It will culminate with an enrichment project where the students use their gained knowledge to engineer a contraption that will cook food and create potable water in the event of a natural disaster.

An interesting side note is California teacher pensions are invested in energy futures (namely coal and oil), with the thought that the energy crisis will increase prices and yield a positive return. In this unit, teachers and students will learn why this is a bad idea and it is time we move in a different direction. The direction we need to move is toward clean renewables.

Demographics

Students participating in this unit are sixth grade consumers-of-energy in a diverse and large urban middle school, which houses the district's Newcomer Program, English learners who have been in the country for less than a year. The school setting is a departmentalized sixth through eighth grade; however, the sixth grade is cored for English/history and math/science; my students meet for a 90-minute block period, five days a week. The district is considered a corridor district, serving students in cities to the north and south that are underperforming. However, nearby is a large public university and a booming technology industry; this dichotomy creates a gap between our most and least privileged students. Currently, the district just finished its first year of the rollout, which began with sixth grade, of the new science standards with 2018 being the first year of full implementation of the Next Generation Science Standards (NGSS).

When I have taught this unit in the past, we used the old California State Standards solely focused on Earth science in my state. Students did a modified research project on alternative energies, not all "clean energy". The previous way I taught this unit was much more simplistic; for example, I only gave them two options for solar energy: solar thermal and photovoltaics, when there are at least five subcategories. Additionally, I disaggregated solar energy from biomass and biofuels, which is really more a type of solar energy than a category of its own. After this seminar, while I will still mention how nuclear energy is carbon neutral, I would like my students to focus more on clean energy and take a stand on a viable solution for the future. I would like my students to take the knowledge gained and be innovators of clean energy.

Although this unit is designed for sixth graders in a math and science core class, it is adaptable across many grade levels and some Common Core Standards for English. It is recommended that the teacher implement more scaffolding strategies if done with younger students. For example, provide a list of credible and curated sources (see Teacher Resources). Students can also work in pairs or small groups to do the research or teachers could provide a graphic organizer for the note taking or a guided worksheet. For older students, this unit could be adapted to include a persuasive writing piece on the alternative energy researched. With older students, there is also room for a service-learning component. Some possibilities include: research ways to become involved with organizations such as Greenpeace, the Sierra Club, or EcoWatch, writing to government officials about the topic of clean energy, or volunteering with a local organization. This unit can also be done in collaboration with an English Language Arts class.

In order to meet the content standards, this unit will bridge together grade level NGSS units on energy, climate change, and human impact as well as Common Core State Standards (CCSS) for speaking and listening.

Content Background

History of Energy

How are fossil fuels created? It all begins with the sun and photosynthesis in green plants. Plants convert carbon dioxide in our atmosphere to create much of our energy and the air we breathe. Carbon dioxide, a greenhouse gas, helps sustain life on our planet because of its ability to trap heat in the atmosphere. Along with plants and animals, fossil fuels were formed through the process of photosynthesis, time, and pressure during the Carboniferous Age, about 300 million years ago during the late Paleozoic Era. During this time carbon dioxide was more abundant than oxygen on Earth, the period when coal was deposited into the lithosphere.

Currently the reverse is happening, “the carbon dioxide which was extracted from the atmosphere by millennia of photosynthesis in the carboniferous age and locked into oil and coal reserves, is being returned, in a dramatically short time, by Man’s profligate use of fossil fuels.” David Walker is referring to the Industrial Revolution and invention of the steam engine and how this development in technology launched the era of energy dependence and the need to for new energy sources. Coal was abundant enough but the population and technology boom determined more resources were needed.

About a century after the start of the Industrial Revolution, Yale chemist Benjamin Silliman Jr. was commissioned to test the viability of harvesting oil in Pennsylvania in 1855. At the time, there was a different kind of energy crisis: whales were being decimated for their oil and scientists were forced to find a new source for lighting lamps at night. The report led to the first drilling for oil, which commenced at Titusville, Pennsylvania in 1859. These two events (the Industrial Revolution and the beginning of the drilling for oil) have led to a steep spike in carbon dioxide levels in the atmosphere. Since then, the population has increased exponentially. People are also eating more animal products which contributes to higher methane levels, another greenhouse gas, in the atmosphere. The demand for energy to turn on our electronics, heat our homes, and power our cars has led to more mining of coal and drilling for oil and natural gas, all of which are burned. Burning fossil fuels releases carbon dioxide into the atmosphere. The reason this is an issue is because some solar radiation is reflected back into space, the atmosphere absorbs some, and some reaches the Earth’s surface. The solar radiation that reaches the surface radiates heat as infrared. Carbon dioxide, along with methane (CH_4) and water vapor are greenhouse gases that absorb the Earth’s heat, thus trapping it in the atmosphere, leading to climate change.

Present Energy Use

Conventional Energy

Why are we burning fossil fuels for energy? Our lifestyles are dependent on it. Historically money was spent on building highways instead of creating mass transit systems. People want bigger homes. Urban city centers are already over developed thus creating suburban sprawl. People love two major energy exhausters: gadgets and gas-guzzling cars. The average global consumption rate is about 13 terawatts; with population and economic growth this is predicted to double by the year 2100.[1] A substantial amount of the world's energy comes from conventional sources, fossil fuels: coal, oil, and natural gas. According to the US Energy Information Administration, our energy comes from about 35 percent oil, 25 percent natural gas, 18 percent coal, and 10 percent renewable.[2] Between 1850 and 1950, the supply of energy from these fossil fuels increased from 50 percent to 93 percent.[3] Drilling into the wells where the fossil fuels are trapped accesses the oil and natural gas conventionally. However, some of this conventional energy is not attained in a conventional way. Much of the oil and natural gas has not yet accumulated in reservoirs and instead "broadly disseminated throughout host rocks—typically siltstones, mudstones, tight sands, or shales with low permeability."[4] This can be accessed through hydraulic fracturing, or fracking, a process by which liquids are injected into the rocks at high pressure, releasing the trapped fossil fuels. Fracking allows for access to a large supply of oil and natural gas, so much so that because of it, the United States has become energy independent.[5] There is an abundance of fossil fuels on the planet; some of it is just harder to get to.

Since the millennium, coal has had the biggest increase in energy output globally, twice the amount of oil and three times that from natural gas. Coal is extracted by mining and burned in coal plants in order to create steam to turn turbines and generate electricity. In the United States, "between 1975 and 1990 the output of coal-generated electricity literally doubled."[6] Most places in the world, the use of coal use is still growing because of its reliability as a secure energy source; this is not the case in Europe and the United States. Because coal produces more than twice the amount of carbon dioxide than natural gas, there has been much political and regulatory opposition to coal; therefore, the use of coal has declined in United States. Coal, widely known as one of the major contributors to air and water pollution, is considered the dirtiest of the fossil fuels also because of the ways it is extracted form the earth, mining and mountain top removal, which requires the physical removal of the tops of mountains in order to access the coal.

Another non-renewable energy source is natural gas, made mostly of methane (CH_4). In the United States, natural gas is derived from shale, and other sedimentary rocks, that store large amounts of natural gas within the rock layers. In order to extract this resource from the sedimentary rock, horizontal drilling or fracturing of the rock is needed. It is a type of gas that is primarily used as a fuel for heating. Liquid Natural Gas (LNG) is another type that is liquefied for transportation. Natural gas is also used in some areas to generate electricity. Oil, like coal and natural gas, is also a non-renewable resource that is extracted from the earth, refined, and used as fuel for heating and transportation.

Over the years, there has been an ebb and flow of research and development in the area of renewable energy. Scientists had previously thought that the world would run out of fossil fuels and the theory of "peak oil" frightened governments and people. But new discoveries and advances in technology continue to allow for the extraction and ease of transport of fossil fuels across thousands of miles.[7] Currently, fossil fuels cost so little to power the globe and more and more resources are being discovered everyday. However, loss of production is possible in the event of a natural disaster such as an earthquake. We need other energy options to continue to maintain our technology-dependent ways of living.

Environmental Impact

The present energy use has impacts on climate, water, and seismicity. With the population increase, more energy is produced to keep up with the rising consumption demand. The burning of fossil fuels by humans is the largest contributor of carbon dioxide into the atmosphere, creating and contributing to global warming. Large scale burning of forests has also contributed to the increased levels of carbon dioxide. As more and more of the world becomes industrialized, more carbon dioxide is emitted into the atmosphere. The more carbon dioxide emitted into the atmosphere, the more heat that is absorbed and unable to leave the atmosphere, trapping it like in a greenhouse. Even a slight rise in temperature has severe implications for the planet. A temperature rise can melt glaciers and cause sea level to rise. The melting of sea ice has implications for Arctic ecosystems and human populations that live along the coast. Low lying coastal cities in places such as Florida will be under water. Photosynthesis cannot keep up with the increase in carbon dioxide emissions that contribute to global warming. The study of human impact on climate is not new. In 1938 Guy Stewart Callendar made the connection that increased carbon dioxide emissions had an impact on climate change, which was later proved by Charles Keeling's work.[8] At the same time the world's population began to grow exponentially; both the world's population and gross domestic product (GDP) has tripled in the last seventy years.[9]

Water and seismicity concerns stem from the unconventional extraction of fossil fuels. Hydraulic fracturing uses local fresh water, a precious resource in drought-stricken areas. The water that is injected to release the trapped oil and gas contains inorganic chemicals that contaminate aquifers when not disposed of properly.[10] Tens of thousands of hydraulic fracturing wells have been built since 1950. Earthquakes as large as 5.7 in magnitude are occurring in places such as Oklahoma, Ohio, and Texas, which are not along plate boundaries.[11]

With 80 percent of the world's energy dependent on fossil fuels, reducing our carbon footprint is imperative. One way to reduce carbon dioxide emissions is to put a price on it either through a tax or carbon capture and sequestration. Taxing carbon dioxide emissions is not a popular solution and estimates are that carbon capture and sequestration would raise the price of coal-fired electricity by 80 percent, which does not sound like such a bad thing.[12] However, since climate change is not an immediate phenomenon, the cost of renewable energy needs to compete with conventional energy sources. Currently, it is so economical to continue with the status quo, some fossil fuels are simply wasted as a bi-product of drilling for others.

Future Energy Use (not to be confused with "Energy Futures")

Renewables such as hydroelectricity, geothermal, wind, solar, and nuclear are providing alterative solutions, which are renewable and emit less carbon dioxide into the atmosphere. There is still a sizable amount of work to be done to shift the population's thinking to influence how the energy crisis affects international policy, or geopolicy, around research and development. Not all renewables work well in all areas, and some are more efficient than others. There is nothing like hitting the reset button to get the creativity flowing about this complicated matter. The future is renewables. But which one is best? Which is more efficient? Which has the least environmental impact?

Hydroelectricity

Currently, at about a quarter, the largest piece of the renewable portion of the pie comes from hydropower. All hydroelectric power needs is elevation and rainfall[13] , and "that's why 'dam' is no longer a bad word."[14] To calculate the gravitational power a dam could generate, one would multiply the rainfall, density of the water, strength of the gravity and the elevation. Dams work by creating a blockage to the flowing water and releasing the water through turbines to generate electricity.

Hydropower can also be generated by the ocean tides. Tidal energy, which is sometimes referred to as lunar energy, is produced by the moon's gravitational force. The Earth and moon rotate around the sun together about once every 365 days; while the moon is rotating around the Earth about once every 28 days, the Earth spins a full 360 degrees once every 24 hours. The imbalances of the rotation and spinning create variance in tides. New moons and full moons occur like clockwork every two weeks when the moon and sun are in alignment. The new moon and full moon cause big "spring tides" (not to be confused with the season). Neap tides are half the size and occur at the half-moons. This cycle produces tidal crests and troughs, which can be used to spin a turbine and generate electricity.[15]

In 2014, hydropower constituted over a quarter of renewable energy in the United States; however, in many places around the world, the construction of more dams is "either circumscribed or blocked altogether by environmental opposition".[16] By their nature, dams or turbines in water interfere with ecosystems in rivers and wetlands.

Geothermal

Geothermal energy works as a renewable clean energy because it has to do with plate tectonics and the heat that is available underneath the Earth's surface. It uses water injected into the hot rocks deep in the lithosphere, or Earth's crust, where it is heated and brought back to the surface as steam. This steam moves turbines and generates electricity.

This alternative energy source has a lot of potential in certain areas, namely plate boundaries where magma is upwelling, as the plates are continuously moving, creating a constant source of access to the heat under the crust. Divergent boundaries, where the plates are moving apart, are ideal because the geologic activity is more gradual when compared to convergent boundaries, which produce volcanoes and have the potential for stronger earthquakes. The biggest disadvantage is unfortunately, there are only two places in the world where divergent boundaries are located on land: Iceland and eastern Africa making it not very viable as a major resource globally.

Wind

Perhaps the most well-developed of the renewables is wind power. Wind power has been around since the first sailboats. On land, windmills date back at least a thousand years to grind grain and for irrigation in Persia.[17] Traditional windmills capture wind, kinetic energy, and transform it to mechanical energy by turning a turbine and generating energy that can be fed into the power grid. Currently, China and Denmark are leading in wind installation. In the United States there is also a lot potential; wind power is still the fastest growing renewable. From 2006 to today, the use of wind as a renewable has increased from 0.5 percent to 6.6 percent.[18]

The potential for wind energy is much greater than that of other alternative energies except for solar. It has a higher capacity. In fact if 100-meter tall turbines were installed on land and on the coast, it could generate enough energy to power the entire planet (times five!).[19] Wind can produce up to 2,000 watts per square meter versus solar power, which can produce up to 200 watts per square meter.[20] Additionally, new research simulations show that offshore wind turbines could reduce the speeds of hurricanes by 5-10 meters per second and reduce the impact of a storm surge by 70 percent.[21]

A disadvantage to wind power is that it is not always a consistent at places where we are able to put windmills; wind is much more consistent at elevations above 10,000 meters. Another problem is transporting the electricity from where it is produced. Most people do not live in areas that are near areas ideal for wind power. Also, similar to hydroelectric power, wind farms can interfere with ecosystems. One major concern is the amount of bird deaths related to wind mills.

Solar

Another sustainable energy alternative with huge potential is solar energy. According to rough calculations, "The power of raw sunshine at midday on a cloudless day is 1000 W per square metre. That's 1000 W per m^2 of area oriented towards the sun, not per m^2 of land area."[22] Unlike wind power, the sun is a consistent, viable source of energy in many places in the world. Solar energy can be divided into five types: biomass, photovoltaics, artificial photosynthesis, heat engines, and solar thermal.

Biomass, or natural photosynthesis, comes from everything directly or indirectly from photosynthesis. Half of the world's population uses biomass (wood or other recently produced organic material such as animal waste) for heating and cooking purposes. According to the US Energy Information Administration, biomass as a renewable can be categorized into three types: biomass waste, biofuels, and wood. Approximately half of renewable energy in 2014 is from biomass. Out of those three types, 5 percent comes from biomass waste, 22 percent from biofuels, and 23 percent from wood, which along with hydroelectric is considered a traditional renewable. Since *Homo habilis* discovered the practical uses of fire millions of years ago, humans have burned wood for heating and cooking purposes. In some developing subtropical regions, the waste from the sugar cane used to make alcohol can be used as fuel used for transportation. For example the climate in Brazil provides the ideal growing environment for sugar cane, which is abundant there. In other parts of the world, treatment of sewage can provide methane as fuel for lighting. In temperate places like California and Israel, sewage is treated with algae to produce energy. The algal ponds photosynthesize and the end product can be used as animal feed, and another important byproduct for drought stricken regions such as California: clean water. Some advantages of using biomass waste is its transportability, biomass is relatively light similar to oil and coal and the "up-cycling" of sewage, which is hard to dispose of. A disadvantage is that burning releases an unpleasant odor and poisonous gases such as such as hydrogen sulfide. Biofuels include biodiesel, bioethanol, and cellulosic ethanol. Although biomass is a carbon neutral source of energy, the yield is only slightly positive. Currently, the US produces about 16.2 billion liters of ethanol per year, with government mandates of 2.8 percent as a fuel additive.[23] Ethanol produces less energy as a fuel additive than octane, so at only a one percent efficiency rate of photosynthesis, it may not be ethical to burn corn-derived bioethanol simply because it is carbon neutral. This is especially true because food shortage is one of the major problems that humanity for the next 50 years.[24]

The second type of solar energy is the photovoltaic. These include the solar panels on residential and commercial spaces. Photovoltaics utilize solar energy by converting light into electrical energy. There are four types of photovoltaic solar cells: single crystal silicon photovoltaic, organic photovoltaic, dye-sensitized solar cells, and perovskite solar cells.[25]

Artificial photosynthesis, or the process of creating solar fuel by using light to store energy in chemical bonds, is a third type of solar energy that is still in its research and development phase. This technology works by splitting water to get hydrogen and oxygen gases which converts solar energy to chemical energy. This process absorbs visible light, uses the energy from the excited state, and utilizes the energy from the separation of charge separation create electricity or split the water into hydrogen and oxygen.[26] The two types of artificial photosynthesis are molecular assembly and semi-conductor based. In molecular assembly, carotenoid, porphyrin, and fullerene are used to synthesize molecules to increase the separation charge separation that happens during natural photosynthesis.[27] Semi-conductor based artificial photosynthesis utilizes either silicon or titanium dioxide and a dye sensitized solar cell. The advantage of this technology is that it is inexpensive to make and the materials are pretty readily available; a downside is it does not last very long because of instability of component parts.

The fourth type of solar energy is based on heat using a heat engine such as the Stirling Engine or molten salt power plants.[28] The Stirling Engine uses light concentrated from an array onto a point from the sun to heat air within a piston, which increases the pressure in the engine; when the air expands the piston moves, rotating a crankshaft with the force of air. Molten salt is a way to harness solar energy for use at night. The advantage of heat engines is that they collect the whole solar wavelength spectrum and are 60-70 percent efficient. A downside to heat engines is the potential cost of the producing and maintaining engines, although one might argue coal power plants could be replaced by Stirling Engine powered plants because they are similarly complex. Additionally, the mirror arrays will require a lot of maintenance due to dust and other debris.

Lastly, solar thermal energy, which is used in the heat engine but could have its own category, is a passive way to trap energy from the sun, and perhaps the easiest and most readily available to the average energy consumer. This works when different objects absorb the sunlight and can be used to heat water, homes, or even cook food. For successful solar thermal energy production you need dark material, such as black paint, to absorb the light, a container or water, to heat up, and a way to concentrate the reflection of the sunlight to that location. Simply filling up plastic two-liter bottles with water, painting them black, and leaving them in a sun-facing window sill can passively heat up a small space. In countries such as Cyprus, hot water is attained from water-heating ducts on the roofs of homes. Many swimming pools are also heated using this method.

Nuclear

Another type of renewable energy source, and probably the most controversial, is nuclear energy. It is widely used in places like France and Japan, but extremely controversial in other places in the world. Although "the only large-scale, well established, broadly deployable source of electric generation currently available that is carbon free",[29] nuclear energy is the most controversial resource because of the radioactive waste it produces. Nuclear power can be divided into two types: fission and fusion. Fission uses uranium (a heavy element) as fuel. The fission process creates a reaction with uranium that causes it to lose mass. The loss of mass is turned into energy and creates helium as a byproduct. Fusion uses lighter elements such as hydrogen as fuel.[30]

The biggest upside to nuclear energy is that it is very efficient. Nuclear energy also produces a relatively small amount of waste when compared to coal; however, producing nuclear power creates waste that is not easily disposed of. There have been plans for storage of the radioactive waste at a site in Yucca Mountain, New Mexico; however, because the possibility of no leakage could not be promised, the site was shut down before nuclear waste was ever stored there because it stays radioactive for a very long time. Additionally, natural disasters such as the one in Japan that shut down the Fukushima power plant are both unpredictable and inevitable. Even more of a contemporaneous concern is that power plants could become targets for terrorist organizations looking to produce nuclear weapons. Even if there were a way to safely dispose of the waste and safely shut down a reactor in the event of an emergency, world uranium supplies would be depleted.[31]

Local Solution

If geothermal energy is abundant in Iceland, wind power in the Gulf of Mexico can slow down hurricanes, and solar power is has a lot of potential in deserts, should the solution be based on local viability and efficiency? Many rural areas are already “off the grid”, using local resources. Who will determine where the world gets the energy it consumes going forward?

Teaching Strategies

This unit incorporates learning about conventional energy sources: including the different ways in which it is produced, which sources were predominantly used historically, environmental effects, and research about alternative renewable energies. As part of the unit, students will research local energy resources. This unit can be adapted to fit any region, just frame it with a local natural disaster (or a zombie apocalypse if your students are into that).

Pictorial Input Chart[32]

Before students learn about energy sources, we will review photosynthesis (covered in the previous unit) as it relates to the carbon cycle by doing a lecture style direct instruction through the use of a Pictorial Input Chart telling the story of the carbon cycle.

Cornell Note Taking and Research

Cornell Note[33] taking is a common note taking strategy that can be used in any lecture, video, discussion, or reading. Students take notes on the right side of the page and write questions on the left side, highlighting content vocabulary and underlining any important information. Students then write a summary of the notes by succinctly answering the questions from the left side.

Outside the Classroom

The greenhouse effect will be illustrated through a visit to our school’s greenhouse. The sixth grade students will also take a field trip the Lawrence Hall of Science. On this field trip they will hear from a group of college students taking a class called “Communicating Climate Change”. The topics range from rising sea levels to the carbon cycle to ocean acidification. Once students have an understanding of the basics of how energy is generated and the different environmental impacts, they will research different alternative renewable energies and create a poster that describes how it works and the advantages and disadvantages.

Concept Mapping

Concept mapping,[34] or a word web, is a type of graphic organizer and way for students to conceptualize and retain the information learned in this unit. The concept map can be used as a formative assessment of the research progress as well as a tool used in an academic discussion. Key vocabulary words from the unit such as: energy, renewable, non-renewable, oil, natural gas, coal, nuclear energy, carbon, carbon dioxide, wind energy, geothermal energy, hydro power, solar, thermal, etc. are provided for the students along with “mortar” words used to connect one concept to another.

Socratic Seminar

A Socratic Seminar is a structured way for students to discuss a concept they have been learning about in class. Students should be sitting in a circle with the annotated reading, notes, and concept map from the lesson above in front of them for the duration of the discussion.

Engineering Project

Students will work collaboratively to build, using only items commonly found in their homes, a contraption that will cook food and make potable water. They will plan and build a prototype, test, and redesign based on their initial research and results.

Classroom Activities

Part 1

Lesson 1: Carbon Cycle

Introduce the carbon cycle using a Pictorial Input Chart. Prepare for the lesson by projecting the image on a document camera and trace on chart paper using a pencil for each class. Trace the image in marker as you tell the story of the carbon cycle as it relates to fossil fuels and the greenhouse effect.

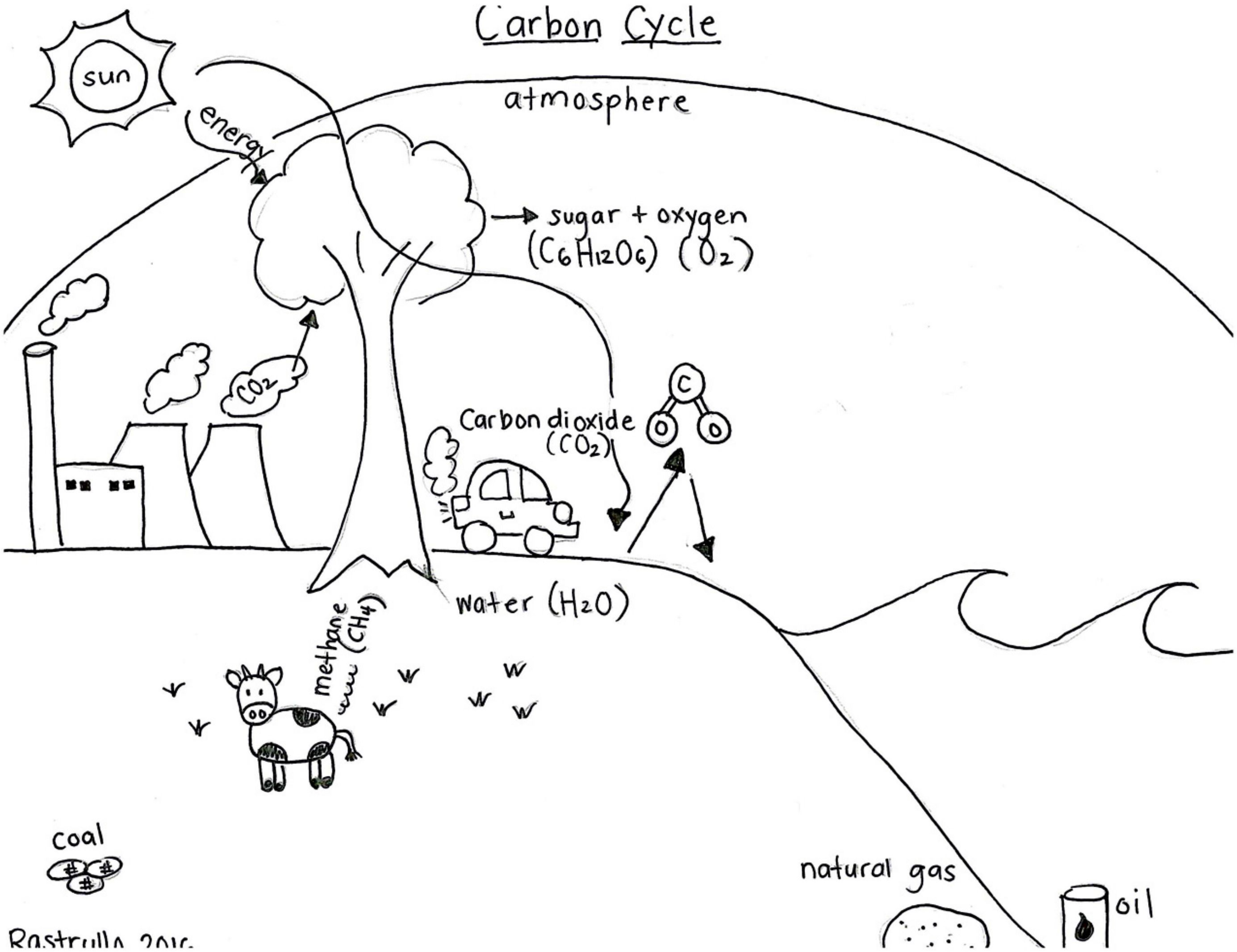

Figure 1: Illustration of carbon cycle for use as in Pictorial Input Chart lecture.

Lesson 2: A Day Without Energy

Students will think about their own energy consumption and what activities they do daily that require energy. Then, we will take a closer look at the most common energy sources: coal, oil, and natural gas and do activities that relate to the environmental impact of obtaining these sources. With the backdrop of an earthquake or natural disaster as the setting, students brainstorm all the things they do in a 24-hour period that require energy and all the things they would not be able to do or have to do differently. Connect this to the carbon cycle. Page 70 in *Sustainable Energy – without the hot air* by David MacKay lists many gadgets and their power consumption.[35]

Lesson 3: Conventional Energy

Introduce the three types of conventional energy sources: coal, oil, and natural gas, with specifics for your area. Students take Cornell Notes on how each type works and the advantages and disadvantages of each. I would include a small copy of the Pictorial Input Chart from lesson one and leave the vocabulary words (coal, oil, natural gas) blank to fill in more information about the process of extracting these fossil fuels, and how they are used for energy.

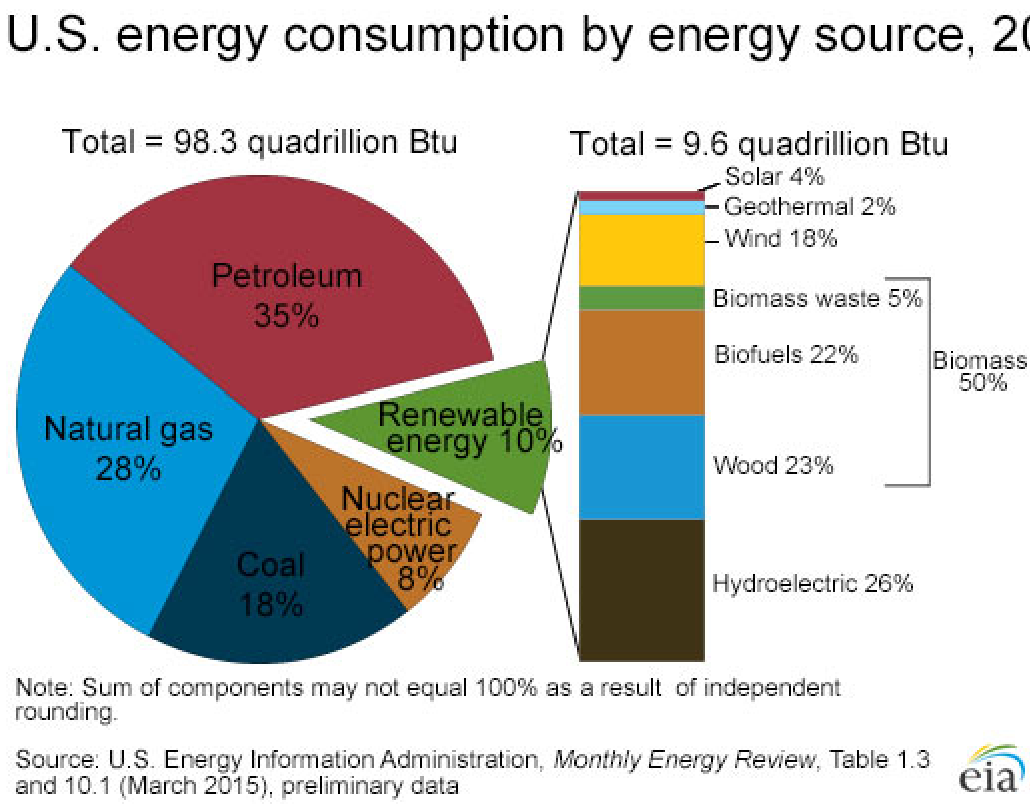

Figure 2: US energy consumption in 2014. Source: U.S. Energy Information Administration (March 2015).

Lesson 4: Conventional Energy's Environmental Impact

To illustrate the environmental impact of mining for coal and drilling for oil, use a cookie mining activity. For this activity, I use Chips A'hoy with chocolate chips and M&Ms. For each student, provide a cookie, one-centimeter graph paper, and a small paper clip. The cookie represents the land, chocolate chips represent coal, and the candy represents oil. Use the graph paper to measure the surface area of the cookie before and after mining for the fossil fuels and the paper clip as the "drill". Use this a framework for a discussion about the environmental impacts of continued use of conventional energy. Show the video "Carbon-Free Energy".[36]

Lesson 5: Visit a Garden Greenhouse to Model the Greenhouse Effect

Take a trip to a local plant nursery with a greenhouse and discuss how the physical greenhouse relates to global climate change. Have students refer to the notes from lesson 3. Provide sentence frames for the discussion. In the carbon dioxide trapping game, the glass in the greenhouse represents the atmosphere and a group of students represent carbon dioxide while another group of students represent heat energy trying to escape. A full write-up of this lesson can be found on Edible School Yard Berkeley's website.

Lesson 6: Field Trip to Lawrence Hall of Science

Students take a field trip to Lawrence Hall of Science to view demonstrations about climate change. The University of California at Berkeley offers an undergraduate science class titled "Communicating Climate Change" for which their final project is to create model demonstrations to show how increases in carbon dioxide affect the oceans, temperature, and animals. I suggest contacting your local community college or university to see if your students could attend their final presentations on this topic or if they can come to your school to do the demonstrations.

Part 2

Lesson 7: Alternative Energy/Renewables Overview

Review the terms potential, kinetic, turbine, generator, (especially if this was not covered in a previous unit). Have students do a think-pair-share about possible cleaner energy alternatives. Chart their ideas and eventually group them into categories: geothermal, hydroelectric, wind, and solar. Provide a concept map that includes energy, non-renewable, renewable, clean energy, oil, natural gas, coal, nuclear, solar, biofuels, biomass, photovoltaics, ethanol, solar thermal, hydropower, wind, and geothermal.

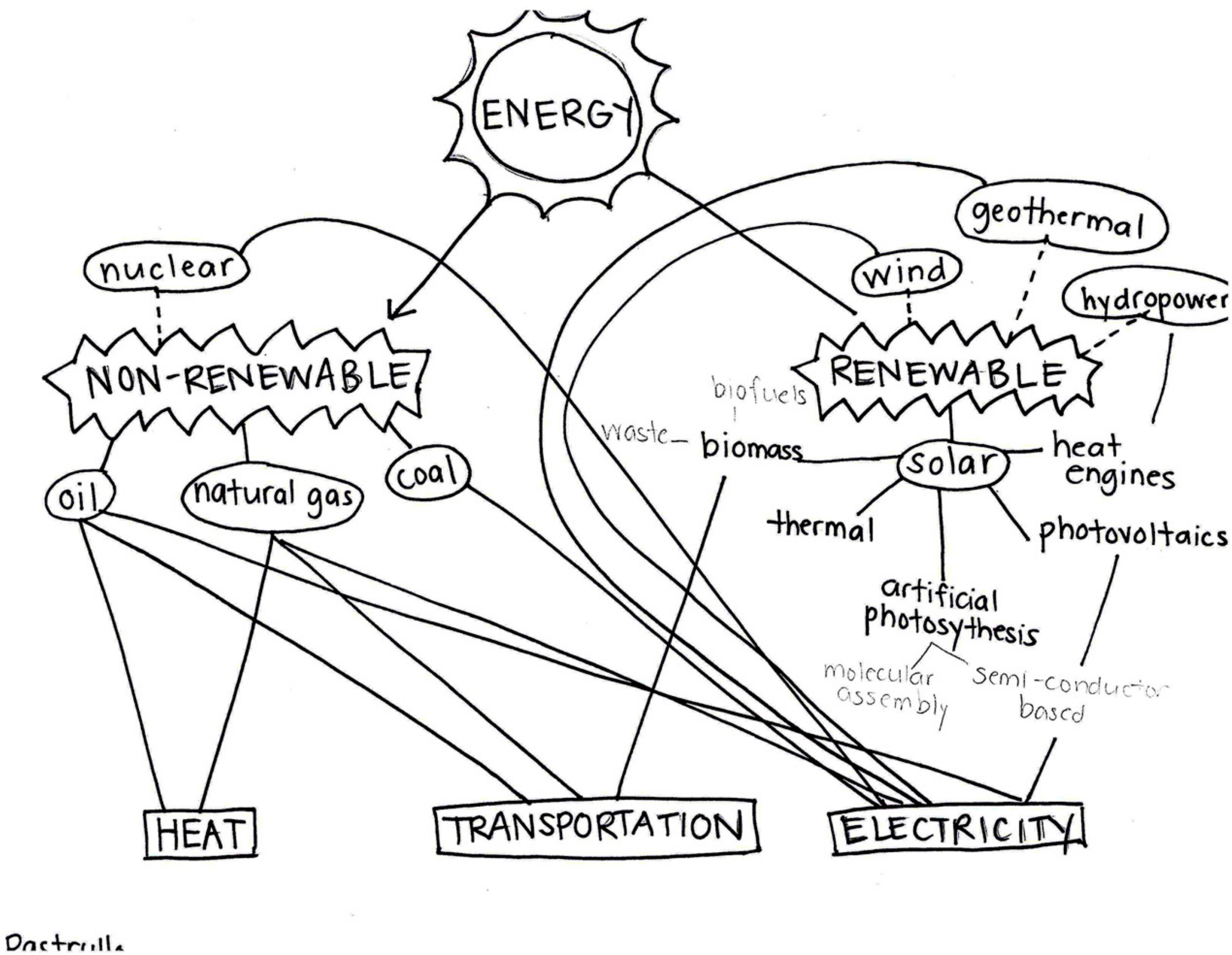

Figure 3: Concept map of energy sources and uses

Lesson 8-12: Research a Clean Renewable

Using Critical Reading strategy, students read, annotate, and take Cornell Notes on a specific renewable energy. Depending on the levels and personalities of your students, you may want to let them choose or pre-select the topic for them so you are able to scaffold the Critical Reading and Cornell Note taking.

Lesson 13: Concept Map Compare and Contrast of Two Renewables

Group students researching different topics with each other in pairs. Have them write their two topics in the middle of a large chart paper next to each other. Provide key content vocabulary that can be used with both topics (environmental impact, efficiency rate, etc.) and connecting mortar phrases.

Lesson 14: Socratic Seminar/Paidiea Seminar

Based on the research and concept maps, students make a claim about which renewable energy should be pursued further in a Paideia Seminar. For this, students' desks need to be arranged so they are facing each other and use their notes and concept maps for this discussion. Follow the protocols detailed in Chowning's research study, "Socratic Seminars in Science Class".[37]

Lesson 15-25? Engineer a Solar Oven and Potable Water

The final part of the unit can includes planning, building a prototype, testing, redesigning a solar oven. The book *Catch the Wind, Harness the Sun*[38] has many ideas students can try if they get stuck.

Teacher Resources

Ausubel, David P. The Acquisition and Retention of Knowledge: A Cognitive View. Electronic.

This book describes the use of concept maps as a comprehension tool in the classroom.

Caduto, Michael J. *Catch the Wind Harness the Sun: 22 Super-Charged Science Projects for Kids*. Storey Publishing: North Adams,MA, 2011.

This book includes materials and step-by-step instructions for classroom experiments that illustrate wind and solar energy.

Chowning, Jeanne Ting. "Socratic Seminars in Science Class: Providing a Structured Format to Promote Dialogue and Understanding." The Science Teacher, October 1, 2009.

This article details the procedures and protocols for setting up a Paideia Seminar in science classrooms.

"Carbon-Free Energy - Flocabulary." Carbon-Free Energy - Flocabulary. Accessed July 18, 2016. https://www.flocabulary.com/unit/carbon-free-energy/video/.

This is a music video that discusses the environmental impact of conventional energy.

"The Energenius Program". Pacific Gas and Electric Home Page. Accessed July 11, 2016. http://www.pge.com/en/safety/educationalresources/energenius/index.page.

This website lists access to student friendly texts on the topic of energy.

"G6-4 Greenhouse Lab (ESYB)." The Edible Schoolyard Project. Accessed August 16, 2016. https://edibleschoolyard.org/resource/g6-4-greenhouse-lab-esyb.

This is Edible Schoolyard Berkeley's webpage detailing the greenhouse lesson described above.

"National Renewable Energy Laboratory (NREL) Home Page." National Renewable Energy Laboratory (NREL) Home Page. Accessed April 30, 2016. http://www.nrel.gov/.

"Renewable". US Energy Information Administration Home Page. Accessed July 12, 2016. https://www.eia.gov/kids/energy.cfm?page=renewable_home-basics.

This website lists student friendly texts on the topic of energy.

Appendix: Implementing District Standards

Next Generation Science Standards (NGSS)

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3–5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century**.**

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

California Common Core State Standards (CCSS)

RST.6–8.1 Cite specific textual evidence to support analysis of science and technical texts.

WHST.6–8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Endnotes

1. Nathan Lewis, Basic Research Needs for Solar Utilization, report, United States Department of Energy, Office of Science (2005), 7.
2. U.S. Energy Information Administration (2015).
3. Daniel Yergin. *The Quest: Energy, Security, and the Remaking of the Modern World.* New York: Penguin, 2012,
4. George M. Hornberger and John C. Ayers, "Hydraulic Fracturing," Environmental Science, September 29, 2014.
5. George M. Hornberger and John C. Ayers, "Hydraulic Fracturing," Environmental Science, September 29, 2014.
6. IBID, 403.
7. Daniel Yergin. *The Quest: Energy, Security, and the Remaking of the Modern World.* New York: Penguin, 2012,
8. IBID, 403.
9. IBID, 403.
10. George M. Hornberger and John C. Ayers, "Hydraulic Fracturing," Environmental Science, September 29, 2014.
11. George M. Hornberger and John C. Ayers, "Hydraulic Fracturing," Environmental Science, September 29, 2014.
12. IBID, 404.
13. David Allen Walker. *Energy, Plants, and Man.* Oxygraphics, 1992, 55.
14. "Carbon-Free Energy - Flocabulary," Carbon-Free Energy - Flocabulary, , accessed July 14, 2016, https://www.flocabulary.com/unit/carbon-free-energy/video/.
15. David J. C. MacKay. *Sustainable Energy--without the Hot Air*. Cambridge, England: UIT, 2009, 81.
16. Daniel Yergin. *The Quest: Energy, Security, and the Remaking of the Modern World.* New York: Penguin, 2012, 721.
17. Daniel Yergin. *The Quest: Energy, Security, and the Remaking of the Modern World.* New York: Penguin, 2012, 597.
18. Daniel M. Kammen “The Rise of Renewable Energy”. Scientific American. September 2006, 84-93.
19. IBID, 84-93.
20. IBID, 84-93.
21. Christina L. Archer, "Why Wind Energy?" lecture, At the Podium, Rutgers University.
22. David J. C. MacKay. *Sustainable Energy--without the Hot Air*. Cambridge, England: UIT, 2009, 38.
23. Scientific American, 2006.
24. "Top Ten Problems of Humanity for Next 50 Years", Professor R. E. Smalley, Energy & NanoTechnology Conference, Rice University, May 3, 2003.
25. Gary Brudvig. "Energy Sciences." Personal Communication, Yale National Initiative, Yale University, New Haven, July 11, 2016.
26. Gary Brudvig. "Energy Sciences." Personal Communication, Yale National Initiative, Yale University, New Haven, July 14, 2016.
27. Gary Brudvig. "Energy Sciences." Personal Communication, Yale National Initiative, Yale University, New Haven, July 15, 2016.
28. Gary Brudvig. "Energy Sciences." Personal Communication, Yale National Initiative, Yale University, New Haven, July 15, 2016.
29. Daniel Yergin. *The Quest: Energy, Security, and the Remaking of the Modern World.* New York: Penguin, 2012, 407
30. David J. C. MacKay. *Sustainable Energy--without the Hot Air*. Cambridge, England: UIT, 2009, 161.
31. David J. C. MacKay. *Sustainable Energy--without the Hot Air*. Cambridge, England: UIT, 2009, 2.
32. Project GLAD
33. Developed by Walter Pauk, Director of Reading and Studies Center, Cornell University
34. David P. Ausubel, The Acquisition and Retention of Knowledge: A Cognitive View, Electronic.
35. David J. C. MacKay. *Sustainable Energy--without the Hot Air*. Cambridge, England: UIT, 2009, 70.
36. "Carbon-Free Energy - Flocabulary." Carbon-Free Energy - Flocabulary. Accessed July 18, 2016.

https://www.flocabulary.com/unit/carbon-free-energy/video/.
37. Jeanne Ting Chowning. "Socratic Seminars in Science Class: Providing a Structured Format to Promote Dialogue and Understanding." The Science Teacher, October 1, 2009.
38. Michael J. Caduto. *Catch the Wind Harness the Sun: 22 Super-Charged Science Projects for Kids.* Storey Publishing: North Adams ,MA, 2011.

Bibliography

Archer, Christina L. "Why Wind Energy?" Lecture, At the Podium, Rutgers University, https://www.youtube.com/watch?v=0RIxPWXcw3Q (accessed July 16, 2016).

Biello, David. "How to Use Solar Energy at Night." Scientific American, February 18, 2009. http://www.scientificamerican.com/article/how-to-use-solar-energy-at-night/. (accessed July 15, 2016).

Brudvig, Gary. "Energy Sciences." Personal Communication, Yale National Initiative: Summer Intensive, Yale University, New Haven, July 11-22, 2016.

Hornberger, George M., and John C. Ayers. "Hydraulic Fracturing." Environmental Science, September 29, 2014.

Lewis, Nathan. “Basic Research Needs for Solar Utilization”. Report. United States Department of Energy, Office of Science. 2005.

MacKay, David J. C. *Sustainable Energy--without the Hot Air*. Cambridge, England: UIT, 2009.

Kammen, Daniel M. “The Rise of Renewable Energy”. Scientific American. September 2006.

"Stanford Engineers Develop State-by-state Plan to Convert U.S. to Clean, Renewable Energy," Stanford News. http://news.stanford.edu/2015/06/08/50states-renewable-energy-060815/. (accessed July 18, 2016).

Starkman, Dean. "CalPERS, CalSTRS Took Big Losses on Energy Investments." Los Angeles Times, August 13, 2015. http://www.latimes.com/business/la-fi-calpers-calstrs-energy-losses-20150813-story.html. (accessed July 12, 2016).

Walker, David Allen. *Energy, Plants, and Man.* Oxygraphics, 1992.

Yergin, Daniel. *The Quest: Energy, Security, and the Remaking of the Modern World.* New York: Penguin, 2012.