Making the Switch to Alternative Energy Sources in the United States

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This curriculum unit is recommended for:
AP Environmental Science
Earth & Environmental Science

Keywords: Climate change, alternative energy, atmosphere, climate and weather, ocean acidification, pollution, land use, energy usage and consumption, biodiversity and food webs

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: Anthropogenic climate change is a large, overarching topic that can be daunting to teach in one unit. This curriculum unit divides the major topics of climate change into smaller, more manageable modules that can be used separately for different grade levels and abilities or as a holistic approach to the topic. The original design of the unit was to repeatedly weave the information about greenhouse gases, climate change and alternative energy through the many and varied units of AP Environmental Science. The goal is to have a culminating capstone activity that would require students to synthesize the knowledge from all the different units and evaluate the feasibility of switching different geographic regions to fossil fuel free power generation. This curriculum unit includes background knowledge on greenhouse gases and climate change, pollution, the atmosphere, weather and climate, as well as ocean acidification. Also discussed are mining and resource management, land use and conservation, and renewable energy sources. This unit also includes strategies for engaging students in hands-on science activities. The intent of this unit is that each module can be used individually or as part of the whole, so that educators of different science courses and grade levels can tailor the content to utilize as much or as little as they need for their own classroom enrichment.

I plan to teach this unit during the coming year to 50 students in AP Environmental Science.

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Introduction

Cato Middle College High School (CMCHS) is a Cooperative Innovative High School that is under the umbrella of the CMS/NC Career and College Promise. In this program students are provided the opportunity to earn college credit while completing their high school diploma requirements. The school has a cap of 200 students, serves 11th and 12th grade students from Mecklenburg County and is housed on the Cato Campus of Central Piedmont Community College (CPCC). Students take their remaining high school courses required for graduation while taking college transfer classes at Central Piedmont Community College at no cost for coursework or textbooks. The student body consists of students coming from over 20 high schools in Mecklenburg County and reflects the diverse community that it serves. For the 2012-2013 school year the student population was composed of 45.9% African-American, 36.1% White, 7.7% Asian, 6.7% Multi-Racial and 3.6% American Indian students. The student body is unequally distributed in terms of sex, with 64.4% of the attendees being female to only 35.6% male. Students must apply for admission to CMCHS. To be eligible, students must have an un-weighted GPA of 2.5 or above, a good discipline and attendance record at their home school, and must pass the CPCC Accuplacer Exams. CMCHS had a 100% graduation rate for the years 2011, 2012 and 2013, and students graduate with an average of 30 college credit hours. The school is set up on a block schedule, semester system that follows the CPCC calendar. There are three, 90-minute CMS classes per day. I am the sole science teacher at CMCHS. My course load includes Honors Chemistry, Honors Physics, AP Physics B, and AP Environmental Science. The ability levels in the classes can vary widely, due to the students coming from so many different high schools and backgrounds. I ensure that activities are differentiated to reach all learners while maintaining rigor appropriate to Honors and AP level classes.

My classes follow different standards depending on whether they are Honors or AP. The Honors level classes follow the NC Standard Course of Study Essential Standards 2009, from the NC Department of Public Instruction. AP level classes follow the Course Descriptions as published by College Board. My classroom is outfitted with a smart lectern, which houses a computer attached to an LCD projector mounted to the ceiling, as well as white boards and individual desks and chairs that can be moved around the room. I try to incorporate lab based activities as much as possible to enhance learning and differentiate instruction. I include lab activities that will challenge students' firmly held scientific misconceptions, as my mainly anecdotal beliefs show that they will hold tightly to their misconceptions, often even in the face of contradictory evidence. Labs and activities are the best way to attempt to overcome this, since simply lecturing to the students will do nothing to dig out these entrenched ideas. My lessons are a mix of lecture, activities and group work nearly every day. Every new unit, I assign my students to new groups of 3-4 students whose desks are attached to each other but separate from the other groups. These groupings can be done randomly, but are most often mixed ability groups that combine high and low academic achieving students to allow for peer tutoring when possible. Several times a week, the groups prepare white boards that demonstrate their work, either solving problems or answering open-ended questions. The groups present their white boards to the class and facilitate whole class discussions on their assignment. Unit tests are given at the end of each unit, with quizzes and checks of white boards allowing me to keep track of student progress throughout each unit.

Rationale

It is my belief that anthropogenic global climate change is the most significant environmental danger facing the world today. The main cause of climate change is carbon emissions into the atmosphere with the worst culprit for CO_2 emissions being the combustion of fossil fuels. Methane (CH_4) in the atmosphere is also a significant factor, due to its greater ability to trap heat, however, methane is released in much smaller quantities and from sources that are harder to pinpoint, regulate and mitigate. Automobile exhaust is also a significant factor in carbon emissions, however, that is another issue that is difficult to regulate and contain. Therefore, I will be focusing on the issue of fossil fuel combustion for power generation. The use of fossil fuel for power generation results in environmental issues related to obtaining the fossil fuels, such as mining coal and hydraulic fracturing for natural gas, as well as the issue of carbon emissions from the combustion of the fossil fuels. Historically, fossil fuels have conferred on civilization a great energy boon when the fossil fuel was easily obtainable. But at what cost to our atmosphere, air and water quality, and land?

Alternative energy sources have the ability to decrease our reliance on fossil fuels for power, which would have the benefit of significantly decreasing carbon emissions. However, not all alternative energy sources are viable alternatives. Most would need to be used in conjunction with multiple sources due to limitations on each type. Specific alternative energy sources may be preferable in certain regions depending on factors such as climate and topography. My objective in this unit will be to increase student awareness of the dangers of using fossil fuels for power generation, from the obtaining of said fuels to the burning and release of carbon into the atmosphere. After students realize the need to lessen reliance on fossil fuels, I intend to introduce them to alternative energy sources that can be used for power generation, while being realistic about each type's benefits and drawbacks. I then intend to have students complete a project that synthesizes their knowledge about fossil fuels and alternative energy sources. This project is described in greater detail in the Classroom Activities section.

Objectives

It is not completely appropriate to call this a curriculum “unit” as that term is often thought to denote an individual thing that is regarded as single and complete on its own. However, there is an alternate definition which allows that a “unit” can also form an individual component of a larger or more complex whole. The second of those two definitions is how I plan to structure my curriculum unit for The Nature of Energy.

This unit is being written specifically to enhance multiple topics for an AP Environmental Science class, however, it is meant to be accessible to a variety of grade levels. With modification, parts of the unit could be used for all secondary levels and perhaps even in advanced elementary grade levels. I have chosen 5 main topics, with several sub-topics, from the AP Environmental Science Topic Outline, as published by the College Board, through which I plan to weave the foundation knowledge students will need to complete a capstone project near the end of the course. This capstone project will synthesize student learning on alternative energy and require them to create an alternative energy plan recommendation for a specified region of the United States.

The 5 topics I have chosen cover the majority of the AP Environmental Science material tested (65-90% by College Board approximations). However, the individual goals could easily be considered modular units that could be pulled out and modified for any age range that is studying the environmental topic under consideration. I am presenting the units in the order in which they are listed in the College Board’s Topic Outline; however one would be free to use them in a modular fashion wherever appropriate.

Module 1: Earth’s Systems and Resources

This unit comprises 10-15% of the AP Environmental Science content and covers such topics as the atmosphere, global water resources and soil and soil dynamics. For my purposes, I plan to begin my interlacing of alternative energy into the study of the atmosphere. Without a solid understanding of the composition, complexity and importance of Earth’s atmosphere students will be unable to grasp the significance of fossil fuel consumption. Here is where I will address the atmosphere’s role in weather and climate patterns and atmospheric circulation to prepare students for a later understanding of global climate change. Another important foundational concept to develop here is the importance atmosphere-ocean interactions.

Module 2: Land and Water Use

This unit also covers 10-15% of the curriculum and includes a wide variety of topics from agriculture and land use, forestry, urban development, wilderness preservation and mining. In this unit I plan to develop activities that will force students to weigh the needs of a growing population vs. the importance of wilderness areas. Students will also need to evaluate the risks associated with allowing drilling and mining on public lands and determine who suffers most, and who is responsible, when accidents occur.

Module 3: Energy Resources and Consumption

This unit contains an estimated 10-15% of the course content and covers such concepts as forms of energy and the units of energy, fossil fuel resources and use, and various types of alternative energy sources. I plan on developing specific activities to continue to prepare my students for their capstone project at the end of the course. Two specific sub-topics I plan on developing activities for are energy consumption and renewable energy, specifically solar energy.

Module 4: Pollution

Pollution is by far the largest portion of the Environmental Science curriculum; the topics cover 25-30% of the material. This is due to it being a very broad topic, covering not only the types of pollution, but the impacts on the environment and human health, and the economic impacts as well. For the purposes of this curriculum unit, I will be focusing on air and water pollution caused by fossil fuel obtainment, refinement, and consumption.

Module 5: Global Change

This final topic in the AP Environmental Science Topic Outline, Global Change comprises 10-15% of the curriculum. This unit covers such concepts as ozone depletion, global climate change, and the loss of biodiversity. I will be developing activities related to global climate change as a function of fossil fuel use for power generation. As this will be nearing the end of the course, students should begin making connections with ideas from previous units that will allow for richer discussion and more in-depth activities that will prepare them for their capstone project.

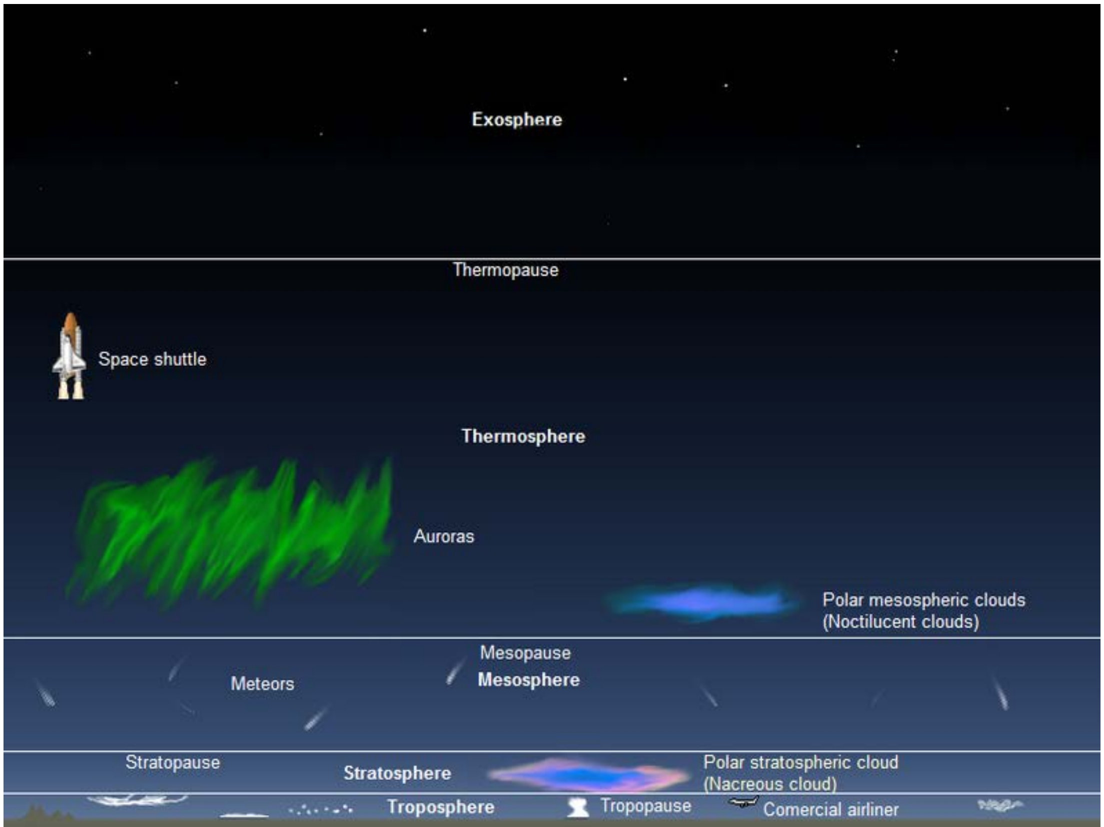
Scientific Content: Overview for Teachers

Earth’s Systems and Resources

The AP Environmental Science course is an incredibly rich and diverse subject. Students cover a lot of material in a one semester course, so it is important for the instructor to be well informed in their content knowledge. This section of the course covers such a range of topics as geologic time scales, plate tectonics, seasons, the atmosphere, weather, climate, water resources, the rock cycle, and soil. In the Classroom Activities section below, the activities I am focusing on deal mainly with the effects of excess CO_2 in the atmosphere and the ocean-atmosphere interactions, as well as the effects of ocean acidification on marine life.

Earth's atmosphere is a thin, gaseous envelope that covers the planet becoming less dense as it extends upward due to the decreasing influence of gravity and the increasing space in which the particles interact. The predominant gases that make up the atmosphere are oxygen (21%) and nitrogen (78%). These percentages fluctuate by season and planetary location. The remaining 1% of gases is composed of a mixture of argon, carbon dioxide, neon, and helium with trace amounts of water vapor and various pollutants.[1] The carbon dioxide in the atmosphere is responsible for The Greenhouse Effect, which is a phenomenon in which some of the heat that is absorbed by the planet is retained near the surface, creating a homeostasis effect that makes life possible on Earth. However, excess CO_2 and other so called greenhouse gases such as methane in the atmosphere have been linked to an increase in mean surface temperatures near Earth's surface. The excess CO_2 is attributed to human activities such as power generation and transportation, while ecological issues such as deforestation have led to a loss of CO_2 sinks that previously helped regulate the balance of CO_2 in the atmosphere. This lack of a balancing, or regulating, mechanism has led to an alarming increase in greenhouse gases in the atmosphere that has been correlated to global climate change.[2]

The atmosphere is usually described as being divided into five layers. The troposphere is the layer that is closest to Earth's surface and extends to a height of approximately 7 km at the poles and 17 km at the equator. It is in this layer that all weather and most clouds occur. Temperature decreases with altitude in this layer. The second layer up is the stratosphere, which extends upwards from the troposphere to about 50 km. The ozone layer is found in the stratosphere, where it works to filter out harmful ultraviolet radiation from the sun. Due to the absorption of the UV radiation from the sun, temperature increases with altitude in this layer. The third highest layer, the mesosphere, extends from the stratosphere to an altitude of approximately 80-85 km. Temperature again decreases with altitude in this layer due to the decreased density of atmospheric gases. The mesosphere is the coldest of all atmospheric layers. Water vapor found in this layer freezes into ice clouds that can be seen occasionally after sunset. The fourth layer of the atmosphere is the thermosphere, which extends from the mesosphere to approximately 640 km above Earth's surface. Temperature increases with altitude in this layer because the particles of gas present absorb enormous amounts of energy from the sun; however, this layer would "feel" cold because the concentration of particles is so low that there would be insufficient numbers to transfer the thermal energy they contain. The final layer of the atmosphere is the exosphere, which extends from the thermosphere to approximately 10,000 km. It is here where Earth's atmosphere is actually merging into space and where most satellites orbit.[3] A diagram of the layers of the atmosphere is shown below.



Layers of the Atmosphere[4]

The atmosphere is constantly interacting with the ocean. Water from the ocean evaporates into the atmosphere and gases from the atmosphere dissolve into the ocean. The ocean has always acted as a natural CO_2 sink for the atmosphere, however, due to the rising levels of this gas, the ocean has been absorbing excessive amounts. This has led to pH changes in the ocean, a process called ocean acidification. Ocean acidification has the effect of removing calcium carbonate from seawater, which is causing significant problems among various forms of marine life. All marine organisms which rely on calcium carbonate to form calcareous skeletons and shells are being affected. Some single-celled plankton, which form the basis of the marine food chain, also construct calcareous shells and could be affected. Corals and organisms with shells are becoming thinner and more brittle; while conversely, lobsters and other crustaceans are developing thicker shells. Both of these processes have the effect of disrupting the food chain and altering the life cycles of these organisms.[5]

Land and Water Use

This is an extremely large unit in AP Environmental Science, which covers the following range of topics: agriculture, pest control, forestry, rangelands, urban land development, transportation infrastructure, public and federal lands, land conservation, mining and global economics. My activities for this module focus on mining and public land use as well as balancing the needs of a growing population versus resource consumption and public lands.

Mining is a 'necessary evil' in today's economy. The growing population is always in need of more material goods which must be manufactured. If they are manufactured from raw materials instead of recycled, those resources must be obtained from somewhere. This is where mining enters the picture. Mines are used to obtain minerals and fossil fuels and come in two varieties, surface mines and underground mines. One of the biggest environmental concerns that accompany mining is the waste generated through the process. The bulk of waste generated comes from the rock and soil that is removed, called overburden, to access the desired material. Some of this material is waste that must be removed, while some of it may be used in other applications, such as low grade ore or landscaping rock and topsoil.[6] The waste material is often used to backfill cut areas or fill in naturally occurring low areas. This can have a devastating effect on local geography, animal habitats, and watersheds. If the material is not backfilled, it is often allowed to accumulate in large piles near the mining location. In all of these scenarios, the waste material can cause environmental problems where the exposed minerals and heavy metals in the waste leach into the soil and make their way into the groundwater or enter surface waters through runoff. The desired material/ore is usually a very small fraction of the material removed and purifying it is another environmental concern. This process is called beneficiation and there are many different ways to accomplish it, depending on the material that is being mined.[7] Environmentally concerning chemicals are used to refine the ore and also must be disposed of.

There are other environmental concerns related to mining besides waste removal. Strip mining is a type of surface mining that "strips" off the top layer of soil to get at the desired material. The removed material is often not replaced or landscaped after mining operations move on; this leaves an area with soil erosion issues that is also considered an eyesore. Another public welfare issue that accompanies mining is the process known as mountain top removal. In this technique, dynamite is used to remove large quantities of material from the tops of mountains, significantly changing the ecosystem, geology and watershed patterns of the region. The images below show the devastating effects of both of these procedures.

Strip Mining[8]

Mountain Top Removal[9]

Energy Resources and Consumption

This unit in AP Environmental Science focuses on energy concepts and forms, energy consumption, present global energy use and future energy needs, fossil fuel resources, alternative energy sources and energy conservation. The activities in my module and my capstone activity concentrate on global and domestic energy usage, renewable energy sources and replacing fossil fuels.

Fossil fuels are notoriously harmful to the environment and to wildlife and ecosystems. Researchers have been searching for viable alternatives for decades; however, no alternative energy source is establishing itself as a clear winner in the race to replace fossil fuels. Each type of renewable energy has benefits and drawbacks, which leads one to think that a blended approach is going to be the best solution to converting from fossil fuel based to renewable power generation. The problems with fossil fuels are myriad and well documented. They have been linked to increased levels of CO_2 in the atmosphere, leading to global climate change, as well as particulate pollution that affects air quality to the point of being a health issue in some locales. It seems obvious that a switch to alternative energy sources is needed, but there have been many roadblocks to making this happen. First and foremost, the fossil fuel industries, from coal to oil, are immensely profitable and have powerful lobbies working on their behalf to maintain the status quo. With a dearth of political will to convert to renewable energy sources, funding for research and development as well as subsidies of renewables lags behind the fossil fuel industry.

However, great advances have been made in developing renewable energy sources. Some alternatives are nearly able to compete with fossil fuels and some alternatives are not there yet, but represent a bright and growing future. Established alternatives include solar, wind, hydroelectric, geothermal, and nuclear power. Solar power works by harnessing the power of the sun and is generally utilized in one of two ways. Solar energy can be collected with photovoltaic cells that directly convert solar energy to electricity that can be immediately transferred to the grid and used by consumers. The drawbacks to this include the fact that the cells are expensive and made of environmentally troubling materials, as well as their inability to generate electricity when the sun is not shining. Another type of solar power is a thermal solar collector. This method collects heat by concentrating sunlight and storing it in a thermally efficient material. In this manner, the heat can be slowly recaptured from the material, even when the sun is not shining. An excellent resource for further information is the U.S. Energy Information Administration's website "Energy Kids". The links for each are included here for convenience. (Solar - http://www.eia.gov/kids/energy.cfm?page=solar_home-basics).[10]

Wind power represents another possible renewable resource. Wind turbines are placed in geographic areas that experience steady winds. The rotating turbines are connected to a generator that converts the mechanical energy to electricity, which is then transferred to the electrical grid. Again, a downside of this is that if the wind is not blowing, the turbines are not generating electricity and a backup method would be required. (Wind - http://www.eia.gov/kids/energy.cfm?page=wind_home-basics).[11] Hydroelectric power is generated through the energy of falling water, usually by means of a dam. The process here is the same idea as all electricity generation, where the water flowing past turns a turbine connected to a generator. (Hydropower - http://www.eia.gov/kids/energy.cfm?page=hydropower_home-basics).[12]

Geothermal energy can work in two ways. One that most people are familiar with is to capture the heat released from the earth in geologic hot spots. This heat can be used directly to heat houses and water, or in a power plant to generate electricity that goes out into the grid. Another form of geothermal energy utilizes the constant temperatures under the earth's surface. A closed system of liquid filled tubing connects from below the surface of the earth to a heat pump on a consumer's house. In the winter, the air coming from below the surface would be significantly warmer than the ambient temperature and would need to be heated less than air drawn from the outside. The reverse happens in the summer. (Geothermal - http://www.eia.gov/kids/energy.cfm?page=geothermal_home-basics).[13]

Finally, nuclear power is an underappreciated energy source that has been around for decades, but has waxed and waned in popularity. It is often seen as dangerous, but it is actually quite safe, reliable, and non-polluting. In a nuclear power plant, rather than burning coal to heat the water to steam to turn the turbine, the water is heated by the fission and radioactive decay of fissile material. The main concern for environmentalists is the radioactive waste in the spent fuel rods. One main benefit is that there is no polluting waste released from the plant itself; the sole emission is water vapor and some residual heat. (Nuclear - http://www.eia.gov/kids/energy.cfm?page=nuclear_home-basics).[14]

Pollution

This unit in AP Environmental Science focuses on all types of pollution, including air pollution, water pollution, noise pollution, solid waste management and pollution's impacts on health. Pollution comes in many different forms, including air, water, and soil pollution, and pollution is released from many different sources. Pollution can be a chemical substance, an energy source (such as heat or light), or a naturally occurring substance. Pollution is often a by-product of a manufacturing process, industrial operation, or farming. Pollution can be divided into two main categories, point and non-point sources. A point source of pollution comes from one location and can usually be traced back to its source. Common examples of point source pollution would be smokestacks and liquid effluent, or wastewater, which drains into a water source. Non-point sources of pollution come from large areas and cannot be traced back to one specific source. Some common examples of non-point sources of pollution would be runoff from highways or farming operations and exhaust from automotive tailpipes.

Global Change

This unit in AP Environmental Science focuses on Earth's systems and how minor changes can cause major perturbations in the system as a whole. Topics range from stratospheric ozone to global climate change to loss of biodiversity. The activity I developed for this module deals with climate change and biodiversity issues. Climate change issues and content were addressed above in the section on Earth's Systems and Resources. Biodiversity refers to the variation that exists between organisms from the species level to ecosystems. Biodiversity addresses organism habitats (where they live), ecological niches (the role the organism plays), and genetic diversity within species and populations. Biodiversity in organisms is extremely important. It promotes species hardiness by providing such protections as resistance to disease and adaptability to a changing environment. Every organism plays a role in its ecosystem, called its niche. Some niche overlap occurs between species, this is good for the ecosystem, as the loss of a certain organism will not devastate the entire system. Many modern conveniences, from medicine to cosmetics, have been formulated from resources from the natural world. Biodiversity enriches modern life and uncatalogued species could represent untapped potential for further advances. Biodiversity also serves the purpose of providing recreational opportunities and solace and inspiration.[15]

Teaching Strategies

It is sometimes a struggle to find teaching strategies that work in the science classroom. Most of the published, or well known, strategies are more suitable for liberal arts style classes such as English or Social Studies. However, there is certainly a wide range of strategies that are not only suitable for the science classroom, but enhance learning to a great degree. The majority of the strategies I outline below come from a book I was given as a new teacher almost ten years ago, “Why Didn’t I Learn This in College?”[16] I still consult this book when I am looking for new ideas to refresh my teaching. Some of the strategies I have had the most success with, or am the most excited about using, are below.

Consensus Conclusions

In this strategy, students create individually a list of the five most important facts, equations, concepts, etc. that they have learned in a unit of study. The students then move into groups where they share their lists with each other, clarifying their rationales for their choices through discussion. Each group is then required to come to a consensus on their five most important facts as a group. At this point, it can go one of two ways. The students can be placed into new, larger groups which will require more discussion and consensus building. Otherwise, each group then presents their list of five along with the rationale for their selections, leading to whole class discussions. As an additional alternative, the selections can be posted in the room for later examination and discussion.

Line-Ups

This activity serves to force students to take a stand on a subject and defend their position. There are many ways it can be done, from sequencing and ranking tasks, to chronological steps. I plan on using it to make students think about their level of support for varying topics such as nuclear power or legislating controls on reproduction. It would work as follows – a statement would be read to the class, such as “The United States should immediately convert all power generation plants to nuclear power stations.” The students are then directed to decide on their support of that position on the scale of 1 to 10, where 1 means Completely Disagree and 10 means Completely Agree. They then line themselves up in numerical order. Find the middle of the line and then fold it on itself, so that students are facing other students, with 10s facing 1s. Have them discuss their rationale for the position they hold.

Walking Tour/Graffiti Mashup

In this activity, posters or charts that represent content material are created, either by the students or by the instructor, leaving plenty of blank space for writing, and then placed around the classroom. Examples for science could include a process (Nitrogen Cycle) or a problem to solve (Ideal Gas Laws). Students are divided into tour groups which are initially assigned to a certain poster or chart as a starting point. Students are given a set amount of time to react to the prompt on the poster and will then write their thoughts and reactions, or work out a problem, or do whatever may be required on the poster before moving on to the next one. At the next poster, the students need to evaluate the previous group’s work, and either correct it, or continue it as appropriate. Continue until every group has rotated through all the charts at least once.

Case Studies

At the high school level, students tend to learn better from examples than from derivations or logical reasoning. Case studies can be used very effectively in science when teachers want students to explore how what they have learned applies to real world situations. This has the major advantage of allowing students to transition their learning from theory to application and improves their skills in problem solving, analysis and decision making. Case studies come in a variety of formats, from the simple ("What would you do in this situation?") to more detailed descriptions of a problem with accompanying data to analyze. The most common method for presenting a case study requires students to generate an answer to an open-ended question or develop a solution to a problem with more than one potential solution. Most case studies share certain characteristics, such as a stakeholder who is struggling with a problem that needs solved, a description of the problem, and supporting data, pictures, charts, etc.

Service Learning

This strategy is a teaching and learning strategy that combines useful, meaningful community service with teaching and reflection to augment the learning experience. With this type of experience, students are able to use what they learn in the classroom to solve real life problems; this allows them to gain practical knowledge, and possibly more importantly develop citizenship skills and community relationships. This allows teachable moments that simultaneously address community concerns and needs. Many people are not familiar with this concept, so I am presenting an example. If students were to participate in a trash pickup along the roadway by their school, that would be a valuable service. However, the students taking it further and analyzing the composition of the waste they collected (perhaps using laboratory techniques or forensic science), determining the sources of the pollution, and sharing those results with the community would be service learning.

Concept Sketches

This strategy is not to be confused with the similarly sounding concept maps, which are varying types of graphic organizers. Concept sketches are student-generated drawings with detailed, content-based annotations. This strategy allows visual and kinesthetic learners to interact with the material in a more hands-on way and reinforces the material for other learners.

Classroom Activities

My plan is to weave the information for this curriculum unit throughout several units in my AP Environmental Science (APES) class over the course of the semester long class. I will introduce the topic of fossil fuel issues initially in the unit on the atmosphere. It will fit in well with understanding the Greenhouse Effect, which is natural and necessary for life on Earth, and show how excess carbon is triggering problems with this phenomenon. Fossil fuel issues will be brought up again when we cover the unit on pollution. Issues surrounding coal play a large part in polluting surface waters around mines, and groundwater can be contaminated by heavy metals and other toxins that leach out of mine tailings. Finally, I will return to the topic for an in-depth treatment in the unit on energy resources and consumption. Specific activities for each module are presented below, with ideas for further explorations as well.

Module 1: Earth's Systems and Resources

For this module, I modified an activity, used with permission from Channel Islands Sanctuary (http://www.cisanctuary.org/ocean-acidification/hands_on_activities.php)[17], which focuses on the atmosphere's role in regulating climate and how ocean-atmosphere interactions are affecting weather, climate and marine life. Students need to understand that the excess CO_2 in the atmosphere is not only affecting surface temperatures, but that it is also affecting the temperature and pH of the ocean. Students will make simulated ocean samples using a flask with distilled water and a commercial salinization kit to most closely mimic actual seawater. Students will then add a pH indicator to their ocean water to measure the pH change. I believe the visual change in color will help reinforce the idea that the composition of the ocean water is changing more than just using a pH probe. Bromothymol Blue is a weak acid-base indicator that appears yellow for pH below 6.0 (acid), blue in solutions with a pH greater than 7.6 (base) and green in between the two, at neutral pH values. Since the average pH at the surface of the ocean is 8.2, the student samples should be blue at the outset. Students will then take a straw, and being careful not to insert the straw into the water, they will breathe out through the straw into the air above the water's surface. The CO_2 from their breath will be absorbed by and slowly acidify the water, turning it green. Students will then respond to critical thinking questions regarding this activity.

There are several modifications that could be made to this activity depending on age level and need. For example, students could make an indicator from red cabbage juice to use in place of Bromothymol Blue as a pH indicator. Alternatively, a chemical reaction such as baking soda in vinegar, or a small sample of dry ice, could be used as the source of CO_2. Students could use an open container floating on the surface of the ocean sample, and place vinegar and baking soda, or dry ice, into the container. Since CO_2 is denser than air, as it evolves from the container it will sink onto the surface of the water and acidify it, causing the desired color change in the indicator. Another extension to this activity is to show how ocean acidification affects marine life. This can be done easily by soaking bivalve shells or coral in a weak acid and showing how they become softer and break easily after exposure to a more acidic surrounding. As a math correlation and reinforcement activity, students could graph the mean global temperature over the last several hundred years versus the increase in CO_2 in the atmosphere.

Module 2: Land and Water Use

In this module, I want to emphasize student thinking and discussion about balancing the needs of a growing population with preserving habitats and wilderness areas as well as the possible effects of drilling, mining and other such activities. For this activity, students will be recreating the devastating ecological effects of a significant rainfall event, such as a 500 year storm. Students, in small groups, will create a model that has natural terrain, a slight slope, and a “river” running through their model, ending in a small pool at the bottom. Be sure to account for a water outlet location, such as a small channel that leads to a bucket. One possible method of construction would be to take a flat plastic container, such as used for under-bed storage, and build this landscape structure out of papier-mâché. The model could then be sprayed with a commercial silicon sealant to make it reasonably water-tight for the duration of the project.

Students will then be told that a mining operation has been established near their habitat and they will be instructed to create a clay containment pond for mining waste. Have students fill the containment pond with some type of measurable solution, such as highly saline water or an acid like vinegar. Inform students that a significant rainfall event has been forecast for their area (a return to the weather and climate unit). As the students are pouring small amounts of distilled water into their river channel, the instructor will walk by and pour a large amount of distilled water near the headlands of their stream. Be sure that there is adequate water in the flood to overflow the banks of the containment pond. Once the water has settled back to normal levels, have the students measure the salinity or pH in their small natural pool at the bottom of the stream. Students will then discuss the effects of having drilling and mining operations on public lands that are a resource for everyone. In terms of modifying this for other grade levels, this could be easily done as a class project where different students contribute different parts of the model, as opposed to being done in small groups. Younger students could do this using colored water in the containment pond so that they could see the color change in the natural pool after the rain event. As an additional or alternate activity, students could hold a debate arguing for and against drilling and mining on public lands.

Module 3: Energy Resources and Consumption

In this module, students need to understand the scale of the units used when discussing power generation and resource consumption. The first activity students will complete will be one using dimensional analysis, or unit conversion. Students will be told the output of a power plant, in megawatt-hours. Using a series of conversion factors, they will change the units of megawatt-hours to “people” based on average resource consumption. Students will complete this calculation twice, once for people in developed countries, and once for people in developing countries. Students will then discuss why there is such a large discrepancy in the numbers of people a similarly sized power plant could serve. Additional activities students could complete include calculating their own personal carbon footprint (a sample carbon footprint calculator website can be found at http://www.epa.gov/climatechange/ghgemissions/ind-calculator.html)[18] and researching average power usage by United States households. The United States Energy Information Administration compiles detailed reports for selected years, including information on fuel usage, appliances, heating, and more. These reports can be accessed at their website (http://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3).[19]

In the second activity, students will be exposed to an alternate form of energy generation that will really pique their interest. Depending on cost and availability of supplies, students will make, or help make, a solar-powered charging station for their cell phones. The following description is brief, however, more in-depth directions can be found on numerous sites on the internet. The supplies needed are: 1-3 solar-powered garden lights, a soldering gun and solder, a voltage meter, a diode, and a spare charging cable for their phone. Students will be instructed to remove the solar panels from the garden lights and cut the wires going to the rechargeable battery. Test the panel in bright light with a voltage meter. If the solar panel is not measuring at least 5 volts, then the students will need to remove and cut the wires to another panel and solder it in series with the first panel. Test again. Students will continue adding panels until 5 volts are measured on the voltage meter. Students will then solder the diode to the positive wire of their solar panel system to prevent any current from going back into the panels. Next, students will cut and strip the spare charging cable for their phone, and wire and solder it to the solar panel system. At this point, the piece is essentially done, but can be made sturdier and longer lasting by hot gluing to a piece of cardboard or plywood. (A different, but similar, activity with an excellent write up can be found at Make Magazine, http://makezine.com/projects/solar-usb-charger/).[20] Alternatively, if cost or student age is a factor, another good activity for showing solar power is to make a solar oven, which is an excellent entry point to understanding solar power. (NASA has an excellent example on how to do this at http://www.nasa.gov/offices/education/programs/national/summer/education_resources/engineering_grades7-9/E_solar-oven.html).[21]

Module 4: Pollution

In this unit, an instructor could easily refer back to the ocean acidification activity and the water containment activity as forms of pollution. Additionally, I plan on relating pollution to fossil fuel consumption through the following activity. Students will use common household or classroom materials to create a funnel to capture automobile exhaust emissions inside flexible tubing. The exhaust filled tubing will be set up in a distillation apparatus, where the emission filled tubing will be used as a condensing coil. Students can then test the water that comes out of the condensing coil for particulates, pH, and a variety of other factors. At this point, students will be given a refresher on the water cycle, specifically the part where evaporation is the step where the water is purified. The reminder to students will be important so that as they run their distillation apparatus they see that the only place pollution is added to the water is from the automobile exhaust inside the tubing. Students will then be asked to relate the particulates in the exhaust to particulates in the atmosphere. Variations could occur within lab groups by having some students test newer cars vs. older cars, or capturing the emissions when the car is first started vs. after the car has been running for a few minutes, etc. Please see Appendix Two for a detailed write-up of this activity.

Module 5: Global Change

The activity I developed for this module is a game that will address the effects of both climate change and loss of biodiversity on a food web. This game will be best played outside, especially on a lawn or other grassy area. Students will be assigned to one of three groups, primary consumers (mice), secondary consumers (hawks), or decomposers (fungi). Green poker chips, used to simulate the energy in primary producers such as algae and plants will be spread throughout the grassy area. The mice will have a set amount of time (vary for different age levels) to run through the grass and “eat” by retrieving green chips. At the end of the allotted time period, the mice will reveal to the instructor how many chips they found. Mice who did not find enough chips (starvation level to be set by the teacher) will be assumed to have starved to death. These mice must surrender their chips to the instructor and be removed from this round. Mice that retrieve a number of chips above the starvation threshold live to reproduce themselves. Make note of how many students will rejoin the game later as the offspring of these successful mice. Do not allow any hawks or fungi to see how many chips the successful mice have, although they can watch the mice hunting for chips in the field. At this point, the SCs enter the game. They are each allowed to choose mice to “hunt” and the mice must surrender their green chips to the hawks. Hawks who do not hunt successfully, that is, gain enough chips to survive, must surrender their chips to the instructor. The rest of the hawks also live and reproduce themselves. At this point, collect the chips from the successful hawks and add them to the chips from the starved animals. Trade the green chips, one for one, with red chips. These red chips will represent the carcasses that the fungi can consume to return the energy back to the ecosystem. Have the mice and hawks scatter the red chips in the field and then allow the fungi to hunt for the red chips. After time is up, the same rules apply. Those fungi who found enough chips survive and reproduce, while the others “starve”. All found red chips are converted back to green chips and scattered in the field again. Red chips that were not recovered by the fungi stay in the field as well.

After a round or two to establish the rules and how energy is flowing through the ecosystem, inform the students that climate change has increased the temperature where they live. It is now too hot for the fungi to thrive and many of them will die off. Remove several fungi from the game. Each round, the instructor advises the students that it is getting hotter and hotter, and remove more fungi. The students should quickly pick up on the imbalance in the game, when the red chips are not being retrieved from the field and turned back into green chips. Have the students discuss what the effects would be from removing each of the other links in the food web.

Capstone Activity

During the unit on energy resources and consumption, I plan to have students learn in detail about the current systems of power generation in the United States and around the world. We will then look at problems related to the current methods of power generation. Finally, we will cover alternative energy sources along with a careful study of the benefits and drawbacks of each one. The students will have already seen a lot of this information in previous units, as mentioned above. The capstone activity for this curriculum unit will culminate in a student project that examines and reinforces all aspects of the different modules and activities.

The student project will be a challenge between different student groups. I will assign each student group a region of the United States. The students will begin by researching the population, geography, and current methods of power generation in their assigned region, along with associated costs. Students may also want to research alternative energy usage in other countries to determine what might be applicable to different regions of the United States. The students will then develop an alternative energy power generation plan specific to their region that completely eliminates fossil fuel usage. In order to replace fossil fuels they must use at least three alternative energy sources that are efficient and make sense for their particular region. Students must then calculate costs associated with their new systems and establish cost per amount of power produced in terms of "people" as calculated in the Module 3 dimensional analysis activity. The student group with the lowest cost per person will be determined to be the winners.

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[1] (Raven, Hassenzahl and Berg 2012)
[2] (Fabian 2006)
[3] (NASA n.d.)
[4] (http://commons.wikimedia.org/wiki/File:Layers_of_the_atmosphere.PNG)
[5] (GRID-Arendal n.d.)
[6] (U.S. EPA n.d.)
[7] (U.S. EPA n.d.)
[8] (http://commons.wikimedia.org/wiki/File:Strip_mining.jpg)
[9] (http://lcweb2.loc.gov/afc/afccmns/lec039/lec03907v.jpg)
[10] (U.S. Energy Information Administration n.d.)

[11] (U.S. Energy Information Administration n.d.)
[12] (U.S. Energy Information Administration n.d.)
[13] (U.S. Energy Information Administration n.d.)
[14] (U.S. Energy Information Administration n.d.)
[15] (Raven, Hassenzahl and Berg 2012)
[16] (Rutherford 2002)
[17] (Channel Islands Sanctuary n.d.)
[18] (U.S. Environmental Protection Agency n.d.)
[19] (U.S. Energy Information Administration 2009)
[20] (Hobley 2012)
[21] (NASA n.d.)

Appendix One

Implementing Common Core Standards
& Essential Standards

Mary S. Fabian

CCSS.ELA-Literacy.RST.11-12.3 *Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.*

Students will create a USB solar charger from a complex list of technical directions. Students will also be responsible for creating a landscape model to perform water pollution measurements during significant rain event simulations.

CCSS.ELA-Literacy.RST.11-12.7 *Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.*

CCSS.ELA-Literacy.RST.11-12.9 *Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.*

Students will complete a capstone activity in which they will need to integrate material from many different units from the semester. They will evaluate current regions of the United States for their fossil fuel and alternative energy usage and then synthesize this information into a recommendation for switching their assigned region to power generation from alternative fuel sources only.

NC Essential Standard EEn.2.5 *Understand the structure of and processes within our atmosphere.*

Students will be completing a significant number of activities related to this standard, including studying atmospheric composition, weather and climate, and ocean-atmosphere interactions. Students will also be investigating the effects of increased atmospheric disturbances leading to ocean acidification.

NC Essential Standard EEn.2.8 *Evaluate human behaviors in terms of how likely they are to ensure the ability to live sustainably on Earth.*

Students will be studying anthropogenic climate change and its relation to increased fossil fuel consumption. Students will research and recommend alternative energy sources for different regions of the country.

Appendix Two

Procedure for Module 4: Pollution

Auto Exhaust Collection
Materials Needed
Manila File Folder
Tape
Oven mitts
Flexible tubing, 1” outer diameter
2 stoppers for capping the tubing

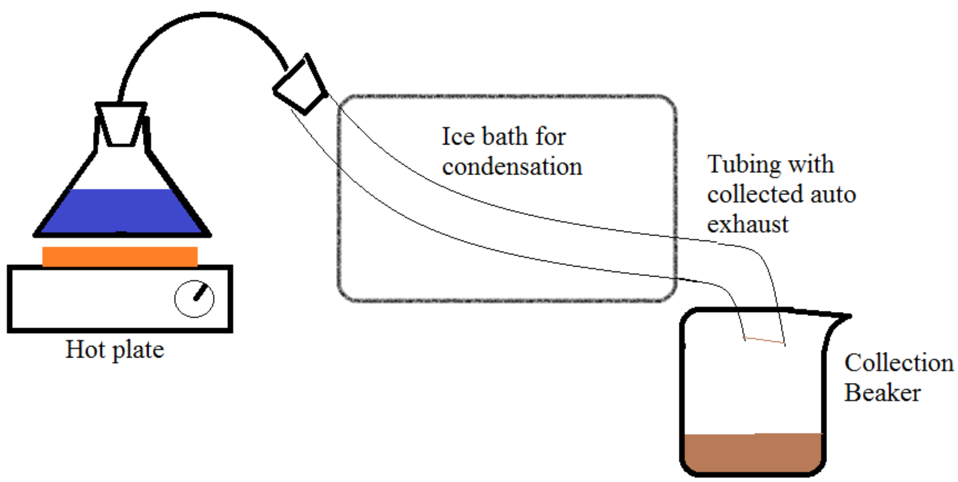
Procedure

1. Roll up the file folder to make a cone shape, with one end small enough to roughly fit inside the tubing and the other end large enough to surround an automobile exhaust tailpipe.
2. Secure the cone shape with duct tape. Seal the edges of the folder to make it as airtight as possible.
3. Insert narrow end of cone tightly into one end of the tubing, ensuring both ends are open.
4. Turn on the car to be tested.
5. Using oven mitts carefully hold the wide end of the cone over the tailpipe, funneling the exhaust through the tubing.
6. After the exhaust has run through the tubing for 1-2 minutes, use a stopper to plug the open end of the tubing. Allow the tubing to fill for another minute or so, then quickly remove the cone and insert the second stopper, trapping the exhaust inside the tubing.

Distillation and Condensation
Materials Needed
Tube of exhaust from Auto Exhaust Collection
Erlenmeyer flask
(2) 1-hole rubber stoppers (1 to fit flask and 1 to fit tubing)
Glass tubing to fit inside stoppers
Flexible tubing to fit over glass tubing
Ice with container
Hot plate
Collection beaker

Procedure

1. Fill Erlenmeyer flask with water.
2. Carefully lubricate and insert glass tubing into both stoppers and attach flexible tubing between them.
3. Stopper flask with 1-hole stopper.
4. Stopper auto exhaust collection tube with other 1-hole stopper.
5. Pass the auto exhaust tubing through the container full of ice, coiling as much as possible. Ensure the entire tube is covered with ice, except the outlet portion (do not remove outlet portion stopper).
6. Position the outlet portion of the auto exhaust tubing over the collection beaker.
7. Place flask on hot plate and turn on.
8. Allow the water to boil and travel through the condensation tube. Once the water starts to build up inside the tubing, remove the stopper from the outlet portion and collect the water for testing.



Suggested Water Quality Tests

pH to test for acidification from CO_2 (or use indicator solution)
Turbidity tests
Dissolved oxygen
Presence of heavy metals

Teacher and Student Resources and Bibliography

Alley, Richard B. *Earth, The Operator's Manual.* New York: W.H. Norton & Company, Inc., 2011.

> This book is a companion novel to the PBS Documentary that explores the ideas presented in much greater depth. This book would be excellent for a teacher who wishes to increase their personal content knowledge before tackling this subject with their students.

Channel Islands Sanctuary. *Understanding Ocean Acidification.* http://www.cisanctuary.org/ocean-acidification/hands_on_activities.php (accessed October 24, 2013).

> This website is an excellent resource for understanding ocean acidification. It contains a link to workshops for educators, as well as a page of classroom ready hands-on activities. There is also a useful links page that lists a large variety of excellent resources by topics relating to ocean acidification.

Fabian, Mary S. *Architecture of Methanotroph Biofilms in Landfill Cover Soil.* Charlotte, 2006.

> A master's thesis on methanotrophic bacteria in landfill soil emphasizing their impact on climate change. It contains extensive background on the history of climate change research and carbon's role in atmospheric change.

GRID-Arendal. *Ocean Acidification.* http://www.grida.no/publications/rr/in-dead-water/page/1247.aspx (accessed October 25, 2013).

> Specific information about the changes being caused by ocean acidification. This resource would be suitable for teacher use or higher level student research.

Hobley, Steve. *Solar USB Charger.* April 2012. http://makezine.com/projects/solar-usb-charger/ (accessed November 18, 2013).

> This is the website for the popular Make: magazine. This is a great resource to start with when looking for resources on making gadgets and gizmos that are more technical. Very useful for hands-on science projects and activities.

Kruger, Paul. *Energy Resources; The Quest for Sustainable Energy*. Hoboken, New Jersey: John Wiley & Sons, Inc., 2006.

A content heavy introduction to alternative and renewable energy sources aimed toward engineering students. A focus is placed on balanced discussion.

McCaffrey, Paul. *U.S. National Debate Topic 2008-2009: Alternative Energy*. New York: H.W. Wilson Company, 2008.

This book features essays on both sides of the alternative energy debate. It includes arguments from leading researchers in the climate change fields, such as Bill McKibben and Charles Petit.

Melnyk, Markian M.W., and Robert M. Andersen. *Offshore Power; Building Renewable Energy Projects in U.S. Waters.* Tulsa, Oklahoma: PennWell Corporation, 2009.

This book features practical advice on using marine environments for renewable energy locations. Discussions include permitting, licensing, economic considerations and potential environmental impacts.

Mott-Smith, Morton. *The Concept of Energy Simply Explained.* New York: Dover Publications, Inc., 1964.

A highly recommended classic for anyone seeking a deeper conceptual understanding of energy from a chemistry or physics perspective.

NASA. *Building a Solar Oven.* http://www.nasa.gov/offices/education/programs/national/summer/education_resources/engineering_grades7-9/E_solar-oven.html (accessed November 18, 2013).

The NASA website is full of great resources for teachers and students alike. An excellent location for finding research and project ideas, science lesson plans, diagrams, explanations and more.

—. *The Layers of Earth's Atmosphere.* airs.jpl.nasa.gov/maps/satellite_feed/atmosphere_layers/ (accessed November 1, 2013).

This website is suitable for use as an introduction to the layers of the atmosphere and would be appropriate for all age levels. There are also links to quite a few other NASA weather and climate resources.

Raven, Peter H., David M. Hassenzahl, and Linda M. Berg. *Environment, 8th Edition.* Jefferson City: Wiley, 2012.

This is an introductory college level textbook Environmental Science classes. The writing is accessible and clear. This book would be recommended for teachers who wish to supplement their personal content knowledge or advanced students who need enrichment or higher level differentiated content.

Rutherford, Paula. *Why Didn't I Learn This in College?* Alexandria, Virgina: Just ASK Publications, 2002.

This book contains a myriad of content-enriching strategies and activities for classroom teachers. There is enough variety that classroom teachers of every age and content area would find something of use in this book.

Simon, Christopher A. *Alternative Energy: Political, Economic, and Social Feasibility.* New York: Rowman & Littlefield Publishers, Inc., 2007.

This book would be an excellent resource for students participating in a classroom debate. It includes the political, economic and social feasibility of the various kinds of alternative energy.

Switch; Discover the Future of Energy. Directed by Harry Lynch. Performed by Scott Tinker. 2012.

This video highlights the progress of countries that generate a significant portion of their electricity from alternative energy sources and contrasts that with the use of fossil fuels. The message is slightly biased towards eliminating fossil fuel usage and completely switching to alternative energy sources.

U.S. Energy Information Administration. *EIA Energy Kids - Geothermal.* http://www.eia.gov/kids/energy.cfm?page=geothermal_home-basics (accessed November 17, 2013).

—. *EIA Energy Kids - Hydropower.* http://www.eia.gov/kids/energy.cfm?page=hydropower_home-basics (accessed November 17, 2013).

—. *EIA Energy Kids - Solar.* http://www.eia.gov/kids/energy.cfm?page=solar_home-basics (accessed November 17, 2013).

—. *EIA Energy Kids - Uranium (Nuclear).* http://www.eia.gov/kids/energy.cfm?page=nuclear_home-basics (accessed November 17, 2013).

—. *EIA Energy Kids - Wind.* http://www.eia.gov/kids/energy.cfm?page=wind_home-basics (accessed November 17, 2013).

—. *Energy Kids.* http://www.eia.gov/kids/ (accessed October 28, 2013).

Energy Kids is a great starting place to learn more about energy sources and the basics of energy. Even though the website says "kids" it is definitely appropriate for all ages and could easily be used to enhance teacher or student content knowledge.

—. *Residential Energy Consumption Survey.* 2009. http://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3 (accessed November 18, 2013).

This website offers data about domestic energy usage for specific years.

U.S. Environmental Protection Agency. *Household Carbon Footprint Calculator.* http://www.epa.gov/climatechange/ghgemissions/ind-calculator.html (accessed November 18, 2013).

This is the EPA website for calculating personal carbon footprints. It takes into account household size, age of residence, individual commutes and much more.

U.S. EPA. *Mining Waste.* http://www.epa.gov/osw/nonhaz/industrial/special/mining/ (accessed October 31, 2013).

This website is useful for a very brief introduction to the terms used in mining that a teacher or student might encounter, such as overburden, leaching and tailing. it includes many links to other EPA information about mining.

—. *Mining Wastes.* http://www.epa.gov/radiation/tenorm/mining.html (accessed October 31, 2013).

This website is similar to the above mentioned EPA website, except that it also explains how ore is extracted from rocks and the environmental hazards that entails.