Energy: Discovering Alternatives to Fossil Fuel Usage

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Introduction

My school is a 6-12 science-based magnet school with a focus on biotechnology and allied health sciences. It is located in Wilmington, DE and offers six pathways for high school students: Biotechnology, Biomedical Science, Computer Science, Nursing, Veterinary Science, and Physical Therapy. Middle School students are offered electives in Bioscience, Forensics, Science Olympiad, Coding, Anatomy, Technology, Business, and Guidance. My school is composed of 1,195 students with varying backgrounds: 13.4% African American, 0.3% American Indian, 4.9% Asian, 16.0% Latino/ Hispanic, 64.4% Caucasian, and 0.9% Multi-Racial. The school houses 528 middle students and 667 high school students.

The biotechnology pathway is unique in that it falls under Technology Education Standards as opposed to Agricultural Education Standards. Technology Education Standards are used along with Next Generation Science Standards (NGSS). This allows for student involvement in the Technology Student Association, or TSA. Students are able to compete in various technology competitions ranging from interviews and debate to building robots and creating video games. There is a specific biotechnology event in which students are given a topic and must create a portfolio and trifold on the subject. The topic for this year is vaccines and all of my students will be participating with the best project going on to compete at the state competition in Harrington, Delaware.

I am a biotechnology and chemistry teacher my school. My students are primarily sophomores and are in their second year of the biotechnology pathway. The biotechnology pathway is a 4-course pathway. The first year focuses on an introduction to biotechnology with a focus on genetics and plants. The second year focuses on microbiology and protein structure. The third year focuses on a biotechnology fair in which the students conduct their own research and experiments towards a self-developed hypothesis. The final year of the biotechnology pathway is optional as students are only required to complete three years of pathway classes. The fourth year focuses on grant writing and a research project. I also teach chemistry at both the Honors and College Preparatory levels. These students are generally in their sophomore year as well, but this unit will focus on my biotechnology students.

Biotechnology I and II are content heavy with labs aligned with the content. When students enter Biotechnology III, the main goal of the curriculum is to have students complete a research project in which they test a hypothesis through a protocol they create. It is understood that they have received most of the content and skills necessary to create their own research project. Many of my former students were coming to me to ask me questions concerning energy and how to create biofuels. I realized that most of their focus on renewable energy centered on biofuels and failed to address other options. They were also missing background knowledge on energy and were unable to pinpoint a definition of energy when asked. They could of course tell me that energy is the ability to do work, every student memorizes that basic definition in middle school, but they could not tell me how to measure it nor a more precise definition of work. When I saw this topic offered I thought it would be the perfect opportunity to form a unit on Energy and better yet, to expand their understanding of renewable energy sources.

Essential Questions/ Standards

- What is energy?
- How do we consume energy?
- What is the carbon cycle and how does it impact with climate change?
- What has caused global warming?
- What renewable resources are available to counteract climate change?

Content

What is energy and why do we need it?

Humans have always used energy. Energy has been key to performing daily tasks since the beginning of our existence. Humans are energy consuming machines. Consuming food provides humans with the energy necessary to exist. Energy has been utilized for centuries as a way to light and heat our homes. Humans have harnessed it to provide transportation. Energy has provided convenience and comfort, but has also helped us to industrialize and advance our technology. In simple terms, energy is the ability to do work. But what is work? What does energy look like? What is the difference between, work, power and energy?

> "Energy is the key to accomplishing, or having the capacity for doing, all of the activities that form the basis of modern society. While work is causing an object to move into or out of some position, especially when it moves against resistance. Power measures how quickly we can do work or consume energy." [1]

Energy can be thought of in terms of money. Energy would be your currency and the amount of currency you have would be the amount work that you would be able to accomplish. Having more money would allow you to do more work. Power is how slowly or quickly you perform the work or how quickly or slowly you spend your money.

Human Energy Consumption

Humans obtain energy through consuming food. Human energy is derived from glucose within food. The glucose is converted into ATP or adenosine triphosphate via cellular respiration. ATP provides humans with the energy necessary to exist. It provides energy for muscle contraction and transmission of electrical signals in the nervous system. The human body stores additional ATP and glucose as glycogen for later use. The amount of ATP consumed by a human on a daily basis varies. It varies based upon body weight, metabolism, and activity.

While the human body obtains energy from energy carrying molecules known as ATP, our energy usage is measured in joules. A joule is the amount of work required to produce one watt of power for one second. One calorie is also equal to 4.18 joules. If a human were to consume the FDA's recommended 2,000 calories per day that would equal 8,360 joules or 8.36 kilojoules.

Reading an Electric Bill

While humans obtain their energy from food sources, their homes measure electricity consumption in kilowatt hours (kWh). A kilowatt hour is the usage of 1000 watts in one hour. A 100-watt light bulb can burn for 10 hours totaling 1,000 kilowatt hours. An electricity bill is based upon how many kilowatt hours are used in a month. The average American household consumes 1,000 kilowatt hours per month and 901 kWh per year. An electric company breaks your bill down into several charges. These charges vary from company to company and can even vary from area to area for the same company.

Delmarva, an energy company servicing parts of Delaware, Maryland and Virginia, bill the following charges to their consumers: customer, distribution, low income, green energy fund, energy supply, renewable compliance and utility facility relocation. A customer charge covers billing costs, account maintenance, and meter readings. This is a fixed cost that does not change with increased energy consumption.[2] The customer charge accounts for about 10.5% of one's bill. A distribution charge refers to the transfer of energy from a substation to your home and can account for 19% of one's bill.[2] The Green Energy Fund in Delaware requires that customers are charged $0.000356 per kilowatt-hour in order to fund environmental incentive programs for conservation and energy efficiency.[3] The Green Energy Fund accounts for approximately 0.22% of one's bill. The state low income charge is accrued under Delaware law, in which $0.000095 per kilowatt-hour is collected from customers and forwarded to the Delaware Department of Health and Social Services to be used to fund low-income fuel assistance and weatherization programs within the service territory.[3] The state low income charge can account for up to 0.06% of one's bill. The Renewable Compliance Charge is required under Delaware law known as the "Renewable Energy Portfolio Standards Act" (or "REPSA"). This law states that Delmarva must increase the percentage of electric supply generated from renewable energy sources each year until the year 2025, when a minimum of 25% renewable energy must be achieved.[3] Accordingly, RESPA contributes around 6.2% of one's bill. Energy supply charges correlate to the actual amount of energy consumed by the household and account for 64% of one's bill. The utility facility relocation charge is a rate to recover for costs incurred to relocate gas utility facilities and is 0.02% of the electric bill.

The Carbon Cycle

The carbon cycle has helped to stabilize the existence of humans by balancing atmospheric conditions in a manner that has allowed for life to flourish on earth. Carbon dioxide, along with water vapor, nitrous oxide, and methane, is one of the four major greenhouse gases present in our atmosphere. These gases are quite valuable in that they trap heat allowing for the more comfortable temperatures we experience on earth. If these gases were present in our atmosphere, average temperatures on earth would be much colder and life would be much different. Unfortunately, we have developed an energy infrastructure that is overwhelmingly based on the combustion of fossil fuels, which is coupled to the release of significant amounts of carbon dioxide into the atmosphere causing elevated levels which in turn has resulted in rising average global temperatures. These methods began during the Industrial Revolution in the eighteenth century and started to increase significantly in the mid nineteenth century.

The carbon cycle is a delicate balance that prevents too much carbon from being released into our atmosphere. Carbon is released through various avenues via plants, animals, rocks, and water, which are the more natural methods. Plants take in carbon dioxide and release oxygen via photosynthesis. Humans enjoy a symbiotic relationship with plants and utilize the oxygen they release. Plants utilize the carbon in the carbon dioxide by converting it into compounds that make up the plant. Humans and animals also consume the carbon present in plants by eating them. Plants that are not consumed are left to decompose allowing the carbon to be absorbed into the ground or released into the air. The carbon that is absorbed into the ground by buried plant tissue can be converted to coal.

Humans have learned how to harness the energy found in coal, oil and natural gas. It's through our combustion of these fossil fuels that an exponential increase of emission of greenhouse gases into the atmosphere has occurred. These extra gases, which have been emitted since the beginning of the Industrial Revolution, have caused a rise in our planet's temperatures, leading to the melting of glaciers and ice caps:

> "Everywhere on Earth ice is changing. The famed snows of Kilimanjaro have melted more than 80 percent since 1912. Glaciers in the Garhwali Himalaya in India are retreating so fast that researchers believe that most central and eastern Himalayan glaciers could virtually disappear by 2035." [4]

The melting of glaciers and ice caps has resulted in flooding and the loss of land mass:

> "When temperatures rise and ice melts, more water flows to the seas from glaciers and ice caps, and ocean water warms and expands in volume. This combination of effects has played the major role in raising average global sea level between four and eight inches (10 and 20 centimeters) in the past hundred years, according to the Intergovernmental Panel on Climate Change (IPCC)." [4]
>
> In southern Louisiana coasts are literally sinking by about three feet (a meter) a century, a process called subsidence. A sinking coastline and a rising ocean combine to yield powerful effects. [4]

It can also have an effect on crop yields. Warmer temperatures can shorten the life of crops and the length of their cycle. This would affect their development producing less for our consumption:

> "Higher CO_2 levels can affect crop yields. Some laboratory experiments suggest that elevated CO_2 levels can increase plant growth. However, other factors, such as changing temperatures, ozone, and water and nutrient constraints, may counteract these potential increases in yield. For example, if temperature exceeds a crop's optimal level, if sufficient water and nutrients are not available, yield increases may be reduced or reversed. Elevated CO_2 has been associated with reduced protein and nitrogen content in alfalfa and soybean plants, resulting in a loss of quality. Reduced grain and forage quality can reduce the ability of pasture and rangeland to support grazing livestock." [5]

The extra carbon compounds that have been emitted into our atmosphere will take thousands of years to break down or be reabsorbed. Unfortunately, there are no developed methods for mitigating these compounds. In order to stop the rise and maintain our current temperatures, new alternatives need to be offered to the fossil fuels that we are burning.

Types of Renewable Energy Sources

Biofuels

Biofuels harvest energy stored in plants from photosynthesis. Plants utilized for biofuel production are sugar crops (such as sugar cane or sugar beet), starch (like corn or maize), palm, soybean, and algae. Ethanol and biodiesel are two of the most common biofuels. Ethanol is made from fermenting starches from plants. Ethanol is used as a supplement with gasoline for transportation. Biodiesel is derived from plant oils and can also used to fuel engines for transportation as well.

Currently, many biofuels require more energy to produce than they actually generate upon combustion, due to the harvesting processes and protocols needed to make the actual fuel to be consumed. Some issues lie with producing the resources for biofuels. Land use for biofuel production would drive reallocation of land used for food production. Seasonal changes can also hinder biofuel production. Certain crops can only be produced at certain times of the year. Mass production would have to occur during these times and crops have to be stored during the off season.

Algae is being investigated as the latest biofuel source. It can be converted into electricity, grows quickly, and does not need farm land to grow. It also provides more fuel than your standard corn based biofuel. Depending on the strain, algae might yield 2,000 gallons of fuel per acre every year. Compare this to corn, which produces only 250 gallons per acre.6 Like other biofuels algae converts sunlight into energy. It produces 50% oil and 50% biomass. The oil can be converted into fuel products. This oil is extracted by breaking down the cell structure of the algae and processing it at a biorefinery. More research is still need as to which strains of algae will prove most efficient and what the optimal conditions are for growth of each strain.

Wind

Wind energy is generated from wind turbines, which utilize energy from wind. The wind turns a turbine that spins a shaft which is connected to a generator that produces electricity. Wind turbines provide power and today's turbines can provide up to 1.3 million kWh per year.[6] This is with a 500 kW capacity wind turbine which operates at an efficiency of 30%. The system life of a wind turbine tends to be around 30 years. The average American household uses 901 kWh per year, meaning one wind turbine could power 1,202 homes.

Problems lie with wind availability and its intermittent nature. If one lives in an area that does not generate much wind, the turbines could be useless. Land mass is another concern with wind power. The most efficient modern turbines are large, reaching a height of more than 300 feet and require around 12 square acres of land. An entire farm of around 20 wind turbines requires 247 square acres or 0.4 square miles of land.

Solar

Solar energy absorbs energy from the sun onto photovoltaic cells, which produce direct current. Solar panels are made of solar cells composed of silicon, the second most abundant element in earth's crust. The flow of electrons within a solar cell, which is made of two different types of silicon which produce the current necessary for electricity. The flow of electrons is recyclable and continuous allowing solar cells to be maintained for at least three decades.

Some of the concerns that lie with solar energy are the initial costs for set up and the probability of infrequent sunny days. An inverter must be used to convert the current from direct to alternating in order to power homes. These inverters can prove to be quite expensive and often cost significantly more than the solar cells themselves. Solar energy is unevenly distributed throughout our planet. Areas that are known for persistent cloudy days like Seattle, WA would not benefit as significantly from solar energy, unless solar energy can be stored for later use. Storage would require the usage of batteries or emerging technologies which take up more land mass. More efficient ways are needed to store solar energy.

Geothermal

Geothermal energy is energy provided from heat within the earth. Heat from the earth's crust warms water that has trickled into underground reservoirs. When the water is hot enough it breaks through the earth's surface as steam, which usually happens where the earth's plates shift. Geothermal energy within the earth can be accessed by drilling wells into the earth. The steam can be pumped from the earth to turn a turbine to produce electricity.

Geothermal energy is a clean energy source with minimal effects on the environment compared to fossil fuels. Potential environmental energy problems caused by geothermal energy include water shortages, air pollution, waste effluent disposal, subsidence, and noise. [6] These effects are still considered minimal in contrast with the effects of fossil fuels.

Geothermal energy can even help with recycling wastewater, while providing electricity. Wastewater is injected into the ground to generate more geothermal energy. This is performed in Santa Rosa, Ca:

> "Every day the Santa Rosa Geysers Recharge Project pumps some 12 million gallons of treated wastewater through a pipeline to a mountain-top 40 miles from the city and then injects it down into an aquifer a mile and a half underground. There hot rocks boil the water into steam, which is piped to the surface to drive electricity-generating turbines."[7]

Overall, geothermal energy is an effective replacement for fossil fuels in areas where it is accessible. It works well in areas where tectonic plates are most likely to shift and geysers are present such as California or Nevada. It has the potential to provide 10% of America's energy needs. Unfortunately, it falls short in areas where drilling would have to run deeper into the earth.

Hydroelectric

Hydroelectric power is generated by falling water. The simplest hydroelectric generators involve a waterwheel being spun by moving water, which in turn spins a turbine that generates electricity. More complex hydroelectric power involves dams in which a large structure is built to raise the water level of a large body of water. Raising the water level creates the drop needed for falling water to spin a turbine, which in turn generates electricity. Hydroelectric power can generate up to

Problems lie with the location limitations of hydroelectric plants and their effects on aquatic life. They need to be stationed near large bodies of water. The United States hydroelectric potential has almost been reached and only supplies 11% of the county's energy needs:[6]

> "Unfortunately practical considerations of dam construction and, more recently environmental concerns limit the exploitation of the energy of the world's rivers and to streams to about 16%. By the 1990s the majority of the large acceptable sites had already been developed including essentially all those in the USA."[8]

Nuclear Energy

Nuclear energy produces energy from fission reactions as heat. Nuclear fission in power plants involves splitting uranium or plutonium atoms into smaller elements and excess neutrons. The nuclear reactor contains three major components: fuel elements, a moderator, and control rods. Fuel elements are metal rods that contain fissionable material such as uranium-235 or uranium-238. The moderator houses the fuel elements and immerses them in water. The water slows the fission process allowing the new neutrons produced from the fission reaction to continue in a chain reaction with the fuel elements. The new neutrons will bombard the fuel elements continuously breaking down the uranium in a chain reaction. Control rods composed of boron or cadmium are placed in the moderator to slow fission reactions by absorbing extra neutrons. The placement of the control rods depends upon the rate of reaction needed. Once the water within in the moderator achieves a high temperature it can be used to produce steam. The water is pumped through a heat exchanger producing steam, which turns a turbine. The turbine is then able to generate electricity.

Currently an average sized nuclear power plant has the ability to produce around 800 megawatts of power. Issues tend to lie with the cost of building nuclear power plants and public safety concerns:

> "Conventional nuclear power plants have high first costs. In the Energy Information Administration's latest estimate of overnight capital costs for generating technologies, nuclear power came in at $5,339 per kilowatt. By contrast, the comparable costs were $978 per kilowatt for natural gas–fired combined-cycle plants and $2,844 per kilowatt for advanced pulverized coal.
>
> Conventional nuclear power plants also typically come in large packages of 800 megawatts or more, creating a significant capital risk factor that utility planners must consider."[9]

Nuclear plant safety has been a major concern with instances like Chernobyl, Three Mile Island, and Fukushima. These meltdowns left thousands of people without homes. Some have still not returned and will not be able to in their lifetime. The meltdowns at Three Mile Island and Chernobyl were both caused by human negligence:

> "We now know that properly designed process controls could have prevented the meltdown at Chernobyl. The causes of this accident were similar to those at 3 Mile Island seven years earlier. Both of these accidents occurred at night, after a shift change of operators who were poorly trained, uninformed and were operating the plants under manual control while their safety controls were bypassed."[10]

The Fukushima meltdown was the result of a tsunami caused by a 9.0 earthquake off the coast of Japan. This event in particular demonstrated that more planning and consideration needed to be taken when building nuclear power plants. As a result, many governments pulled funding for nuclear power plants and the reputation has continued to be viewed negatively:

> "The Fukushima accident has also had a significant effect on the nuclear policies of many countries. Many governments have changed or redirected their investments in nuclear energy, and the construction of various nuclear power plants has been suspended. The Japanese government announced a comprehensive review of its energy policy and halted its plans to build additional nuclear reactors. Germany shut down all 17 of its operational nuclear power reactors, and Switzerland agreed to phase out its 5 aging power reactors as they reached the end of their lifecycles over the next 25 years. Italy decided to exclude nuclear energy from its future energy mix."[11]

In order for nuclear energy to be successful strict codes need to be enforced with every possible risk scenario assessed. The environment surrounding a potential plant should be researched for weather patterns and geological concerns. Is there a fault line nearby? Is the area frequented by hurricanes or tornadoes? In turn, highly qualified scientists and engineers should be involved in their construction and day-to-day activity of the plant.

Strategies

Lecture and Discussion

The unit will open with a warm-up question asking the students what energy is. I will be expecting answers that go a little deeper than “the ability to do work.” Once we have discussed their views and definitions of energy, the unit will open with direct instruction, concerning what energy is and why we consume it. Students will be encouraged to ask questions and offer their own input.

Activity

Since students tend to have difficulty understanding the concept of energy, as it is not something that they can physically see, we will head to the library and perform an energy audit of the lighting being used. Through this activity the students will be able to calculate how much their school pays per kilowatt-hour, how much energy is consumed by the lighting in the library on a daily, monthly and yearly basis and the amount of carbon dioxide emitted as a result of this energy. The results of this activity will help the students to be able to read an electric bill and to calculate the amount of carbon dioxide their homes emit each month.

The library was chosen as it is the one room in the school frequented by students all day long. One can assume that the lights will remain on in the library consistently throughout the day. Consulting with the custodian and librarian provides the hours of the school library, the type of lights and the wattage of the lights used. The lights remain on for 45 hours a week for 36 weeks when school is in session and for 30 hours a week for 6 weeks when school is not in session. Once the custodian has informed you of the types of lights, a simple walk around the library counting the different types and multiplying them by the wattage will provide you with the total wattage of the library. Our school library contains the following lights:

Lighting	**# of lights**	**watts**	**wattage**
Spotlight incandescent light bulbs with 75 watts	8	X 75 watts	600

Exit signs with incandescent light bulbs	1	X 40 watts	40
Fluorescent light tubes (T8)	60	X 34 watts	2040
LED Fluorescent tubes	102	X 16 watts	1632
Single fluorescent light bulbs	20	X 22 watts	440
		Total wattage	4752

Fortunately, most of the lights in our library are energy efficient as they are fluorescent or fluorescent LED. It would still be beneficial to replace the 8 spotlight incandescent bulbs with compact fluorescent lights and changing the exit sign from an incandescent to a LED. This would reduce daily wattage use by 518 watts.

Lighting	**# of lights**	**watts**	**wattage**
Spotlight incandescent light bulbs with replaced by compact fluorescent lights	8	X 15 watts	120
Exit signs with incandescent light bulbs replaced by LED exit sign	1	X 2 watts	2
Fluorescent light tubes (T8)	60	X 34 watts	2040
LED Fluorescent tubes	102	X 16 watts	1632
Single fluorescent light bulbs	20	X 22 watts	440
		Total wattage	4234

Since electric bills are based on the kilowatt-hour, you must divide the wattage by 1000 and multiply by the total hours of usage. Our school library is used 1,710 hours per year, which comes to 8125.92 kWh used per year. By multiplying the total amount of kWh used per year by a factor of 2 to account for 2 lbs. per kWh of carbon dioxide emitted results in the amount of carbon dioxide emitted by our library.[9] Our library emits a total of 16,251.84 lbs. of CO_2 in one year. Our savings of 518 watts with energy efficient lighting would mean a decrease in kWh consumption by 885.78 kWh per year. This would in turn mean a decrease in CO_2 gas emission by 1,771.56 lbs. in one year.

A cost analysis can also be performed to see how much money can be saved by switching to more energy efficient lights. By contacting the district office at your school you can obtain the total monthly energy bill in dollars and the total kilowatt-hours used per month. Dividing these two numbers will give you the total cost per kilowatt-hour. Subtracting the amount of kilowatt-hours used with the current lights from the kilowatt-hours used from the energy efficient lights and multiplying by the cost per kilowatt-hour will provide you with total money saved. The Calculating Energy Usage activity in Appendix 2 provides more details on this activity.

Project

Groups of 2-3 students will be assigned one of the following renewable energy sources at random: geothermal, solar, wind, hydroelectric, biofuels, and nuclear. They will research one of the different methods of clean energy and become an expert on the topic. They will use reliable sources and search engines such as the University of Delaware library. They will be taught how to differentiate between reliable (scholarly journals) and non-reliable resources (Wikipedia) and shown the access available to them through the University of Delaware library. My students will then present their findings on their clean energy source to the entire class via a Google slides presentation. Each presentation is to include a description of the energy source, how the energy source is used, current research on the energy source, and their opinion of the energy source. They will also be graded on neatness, creativity, and professional presentation skills. The presentation will be shared with each student in the class in order to allow them to review it for reference. Once we have studied the different types of clean energy we will then hold a class discussion and actively discuss how the energy crisis can be solved.

Laboratory Activities

The unit will commence with two laboratory activities, one highlighting a multiple energy sources and the other focusing on biofuels. In the first laboratory activity, students in groups of 2-3 will explore 8 stations over two class periods in 15 minute increments. Each station will contain an activity pertaining to one of eight different energy sources or energy source mediums: coal, solar, wind, battery, natural gas, geothermal, water, and hydrogen. Students are then to evaluate advantages and disadvantages of each through answering critical thinking questions after the completion of each station.

Coal is gasified via a test tube and Bunsen burner and observed. Solar energy is harnessed via photovoltaic cells and measured with a galvanometer. Wind energy is channeled through a turbine with dowel rods and blades made of paper. A DC motor is attached to the turbine and the electric current is measured with a galvanometer. Wind is generated in the lab with a fan. The speed and direction of the fan is varied in order to produce a variety of results. In the battery station, 9-volt and D-cell batteries are compared by measuring electric current with a galvanometer. Natural gas is burned by making a soap solution. Tubing connected to a gas valve is placed in the soap solution. Bubbles accumulated from the mixture are removed placed beside a lit candle. Students are then to observe the results. Geothermal energy is harnessed through hot water and pinwheel by steam. The steam generated turns the pinwheel utilizing the energy. Water energy is produced through hydropower by constructing a waterwheel. Hydrogen fuel is produced with a sodium sulfate solution, an electrode stand, 2 small test tubes, and a 9 volt battery. The test tubes are filled with the sodium sulfate solution and the electrode stand is immersed in the solution as well. The test tubes are slid into the electrode stand filled with the solution. The 9-volt battery is attached to the electrode stand producing hydrogen gas in one of the test tubes. A toothpick lit with a match and placed in the mouth of the test tube with the gas present. Observations are made. A toothpick that had just been lit and blown out is inserted into the tube with less gas and observed as well. This laboratory activity is available as a kit through Carolina® as Carolina Ecokits™ Energy Sources[12].

Students will explore a laboratory activity in groups of 2-3 on biofuels in which they use an enzyme (amylase) to break down a starch. Demonstration will be given in which starch is placed n 4 tubes. Two tubes will be at 35 ^{o}C and the other two tubes will be at 80 ^{o}C. Pancreatin will be add to one 35 ^{o}C tube and to one 80 ^{o}C. Iodine-potassium iodide is added to each tube to indicate if the starch has broken down. If the tube stays dark brown or purplish then starch is still present. If the tube stays clear or yellowish then the starch has been broken down. The tube expected to have the clear to yellowish color is the tube with starch and pancreatin at 35 ^{o}C. Now that the students have seen what conditions are necessary to break down the starch, they are then to design their own reaction chamber that will allow them produce ethanol by fermenting yeast and measure the carbon dioxide gas produced. The following materials will be provided:

- 25 mL of yeast suspension in a cup
- Sugar packets, 2
- 15 mL centrifuge tubes, 2
- 10 cc syringes, 2
- End caps for syringes, 2
- Balloons, 2
- Plastic medicine cups, 2
- Wooden stirrers, 2
- Plastic bags, 2
- Tap water
- Permanent marker
- Transparent adhesive tape
- Timer
- Thermometer

They must first design a prototype or plan for how they will solve the design problem. The plan will be recorded in their laboratory notebooks and approved by the teacher.

Once they have received approval they can then move on to actual building of their design, making modifications as necessary. The students will then present their findings to the class and explain the apparatus constructed. They will make comparisons between their initial design and the finished product. They will reflect on design challenges and how they could improve their design. This laboratory activity is available as a kit through Carolina® as Carolina STEM Challenge® Biofuels[13].

Appendix 1

Next Generation Science Standards	
Discipline	Standard
Physical Science	HS-PS3-D2 The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis
	HS-PS3-D3 Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy
	HS-PS3-D4 Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation
Engineering, Technology, and Applications of Science	HS-ETS1-B1 When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural and environmental impacts
Science and Engineering Practices	4.2 Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
	7.2 Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
	8.1 Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

	8.3 Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
Life Science	HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Appendix 2

Name: __________________________________ Date: ________ Period: _______

Library Lighting Analysis

Introduction

Lights are easily turned on with the flip of a switch, but how much electricity is used? How much does it cost? How efficient are the lights used? How much carbon dioxide is emitted as a result of the lights? In this activity, you will explore the lighting in the library at your school. The library was chosen because it is the room that is most consistently used throughout a school. The lights remain on all day long in a school library and even a few hours after the school day ends. The consistency will make it easiest to calculate electricity usage of the lights. By exploring the lighting in your library, gathering data, and performing the calculations below you will be able to calculate how much electricity is used, how much it costs, how efficient the lights are, and how much carbon dioxide is emitted by the lights.

Part 1: Calculating the amount of electricity used, the cost, and the amount of CO_2 emitted for the current library lights

1) Calculate the area of the library.

(length x width)

2) Calculate the usage of the lights in the library during a year

Hours per week that the lights are on when school is in session= _________

Weeks school is in session = _________

Hours per week lights are on when school is not in session= __________

Weeks during year when school is not in session = _________

(Hours per week that the lights are on when school is in session x Weeks school is in session) + (Hours per week lights are on when school is not in session x Weeks during year when school is not in session)

3) Calculate the average cost your school pays per kilo-watt hour

(Total monthly energy bill in $ / Total kilowatt-hours from monthly bill)

4) Calculate the number of watts used in the library

Lighting (ask custodian for details)	**# of lights**	**watts**	**wattage**
		X	
		X	
		X	
		X	
		X	
		Total wattage	

5) Calculate the amount of kilowatt-hours consumed by the lights in the library.

(Total wattage X total hours lights in library are used in a year) / 1000

6) Determine the annual cost of operating the library lights.

(Kilowatt-hours consumed by library lights x cost per kilowatt-hour)

7) The amount of carbon dioxide greenhouse gas generated during electricity production ranges from 1.4 lbs. to 2.8 lbs. per kilowatt-hour, depending on whether or not the electricity is produced from coal, nuclear power, or hydropower. Multiply the total kilowatt-hours consumed by the library in a year by a factor of 2 lbs. per kilowatt-hour to account for greenhouse gases generated.

(Total kilowatt-hours consumed by library lights x 2) = amount of carbon dioxide gas in lbs. generated in one year

8) Calculate the overall lighting index for the library. The lighting index is the Watts consumed per square foot.

(Total wattage / Area of library)

Part 2: Calculating the amount of electricity used, the cost, and the amount of CO_2 emitted for the current library lights

9) The non-efficient lighting used at our school are the incandescent light bulbs and exit sign. Calculate the amount of wattage used by the more efficient replacement bulbs available and the more efficient bulbs already in place if there are any.

Replacement Lighting & Energy Efficient Lighting Already in Place (consult custodian)	**# of lights**	**watts**	**wattage**
		X	
		X	
		X	
		X	
		X	
		Total wattage	

10) Calculate the amount of kilowatt-hours consumed the new lights in the library.

(Total wattage above X total hours lights in library are used in a year) / 1000

11) Calculate the current annual cost of operating the new lights in the library.

(Kilowatt-hours consumed by new library lights x cost per kilowatt-hour)

12) Multiply the total kilowatt-hours consumed by the library in a year by a factor of 2 to account for greenhouse gases generated.

(Total kilowatt-hours consumed by library lights x 2)

13) Calculate the overall lighting index for the library. The lighting index is the Watts consumed per square foot.

(Total wattage / Area of library)

14) Calculate the energy savings between the current lights in the library and the new lights recommended.

(Kilowatt hours consumed current by library lights – kilowatt hours consumed by new library lights)

15) Calculate the energy cost savings between the current lights and the new lights.

(Annual cost of operating the current library lights- Annual cost of operating the new library lights.)

16) Calculate the greenhouse gas emissions prevented by replacing the library lights.

(Lbs. of CO_2 emitted currently – lbs. of CO_2 emitted from new lights)

17) Report your computed data in the chart below

	Energy	**Cost**	**Greenhouse Gas**
Current Lights in the Library			
Replacing Energy Saving Lights with Current Lights			

18) Using the data generated, do you feel that it is worth it for school library to switch to all energy efficient lights? Why or why not? What other information would you need to make a more accurate decision?

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Appendix 3

Name(s): ____

Renewable Energy Sources Presentation Rubric

Renewable Energy Source: ______________________________

	10 points	**8 points**	**5 points**	**2 points**	**0 points**	**Points Earned**
Description of Energy Source	Description is detailed and illustrated in slides	Description lacks detail or illustration	Description is provided but lacks detail and illustration	Description is incorrect	No description provided	
How energy source is used	Detailed explanation given of how energy source is used along with pictures and/ or diagrams to illustrate	Explanation given of how energy source is used along with pictures and/ or diagrams to illustrate lacks detail	Explanation given of how energy source is used along with pictures and/ or diagrams to illustrate lacks detail and is unclear	Energy source usage provided is incorrect and/ or minimal in description	No information provided on how energy source is used	
Current research involving energy source	Current research is detailed, and contains an explanation	Current research provided lacks detail and explanation	Current research provided is detailed but incorrect	Current research provided is incorrect and/ or minimal	No current research provided	
Opinion of energy source	A detailed, reasonable clear, opinion was provided	Opinion lacked detail but was clear and reasonable	Opinion was provided but explanation was unclear	Opinion was provided but not explained	No opinion of energy source provided	
Neatness, Creativity, Presentation	All group members presented. Presentation is neat with pictures illustrating concepts and no spelling or grammatical errors are present. Presentation was professional and well-rehearsed.	One of the following occurred: Not all group members presented, Pictures did not relate to the presentation or where not present, spelling or grammatical errors are present, or Presentation was unprofessional and not practiced.	Two of the following occurred: Not all group members presented, Pictures did not relate to the presentation or where not present, spelling or grammatical errors are present or Presentation was unprofessional and not practiced.	Three or more of the following occurred: Not all group members presented, Pictures did not relate to the presentation or where not present, spelling or grammatical errors are present or Presentation was unprofessional and not practiced.	All of the following occurred: Not all group members presented, Pictures did not relate to the presentation or where not present, spelling or grammatical errors are present or Presentation was unprofessional and not practiced.	

Total Points Earned: _____________/50

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