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2024 Volume IV: Energy: Past, Present, and Future

Energy: Virginia's Past, Present, and Future Will Blow You Away!

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Introduction

In late June 2024, I endured a heat wave in Richmond, Virginia with temperatures around 102 ºF and a heat index between 105-110 ºF. The heat and humidity made it unbearable to go outside. During the same timeframe, Hurricane Beryl began churning in the Atlantic Ocean and became the first hurricane of the 2024 season. It became the first Category 4 hurricane to form in June. Beryl, fueled by exceptionally warm ocean waters, continued to grow. On July 2, 2024, Hurricane Beryl attained Category 5 strength, making it the earliest a Category 5 hurricane formed on record.[1] As ocean waters warm, the occurrence of this type of phenomenon becomes more likely. This is an example how climate change is affecting the world in which we live. A goal of The Paris Agreement of 2015 is to hold "the increase in the global average temperature to well below 2 ºC above pre-industrial levels," and to pursue efforts, "to limit the temperature increase to 1.5 ºC above pre-industrial levels."[2] In order to achieve these goals, emissions, or carbon dioxide (CO_2),in the atmosphere need to be reduced by 45% by 2030 and reach net zero by 2050. This curriculum unit will examine the past, present, and future of energy in Virginia, and how the state is moving toward these goals.

This cross-curricular unit titled *Energy: Virginia's Past, Present, and Future Will Blow You Away!* will examine how people throughout Virginia history have used natural resources to provide energy. The unit is written for my fourth-grade students who live in a city built upon the falls of the James River in 1723. Throughout history, the Virginia settlers have harnessed energy from natural resources, such as the James River, to drive economic development. With the Second Industrial Revolution, coal became an important natural resource and energy source for Virginia. Coal not only provided a cheap fuel, but also brought about climate change. As we look to the future, we will examine clean energy sources, focusing on wind energy, to help us achieve the 2050 net zero goal.

Demographics

The school where I teach, Mary Munford Elementary, is in the west end of the city of Richmond, Virginia. It is a part of Richmond Public Schools. I teach my fourth-graders mathematics, language arts, science, and history (Virginia Studies). My students mostly come from middle class homes with a lot of parental support, but there are also immigrants, students from low-income homes and a few homeless families. My school also serves low-incidence autistic students. The range of skill level in fourth grade is huge. A few students barely speak English, some perform more than two years below grade-level, and other students perform in the 99th percentile on norm-referenced tests for reading and math. My students' general knowledge also varies greatly. Some students read constantly and have opportunities to travel around the country and to other countries, while others rarely leave Richmond.

Rationale

The world is facing a climate crisis and is in a race against time. Throughout two Industrial Revolutions over two hundred years, we have burned fossil fuels and released massive amounts of carbon dioxide into the Earth's atmosphere. The result is rising temperatures and the threat to life on Earth, possibly within the next hundred years. The carbon dioxide levels in the atmosphere must be reduced by 2050 to moderate a rise in temperatures and the next mass extinction.

I want my students to understand that burning fossil fuels has been harmful to Earth. Burning fossil fuels for energy seemed cheaper at the time, but now humans are really paying for their costly mistake. I also want them to realize that throughout history humans have relied on natural resources for survival. Humans can once again meet their needs and survive if we use nature. Wind, solar, geothermal, hydroelectric, biomass, and ocean waves are sources of energy that are better for the environment than fossil fuels, and if we instead rely on these, we may be able to save our planet.

The curriculum unit will focus on wind energy for several reasons. It is related to science standards that I must teach including weather, oceans, and natural resources. Wind energy is timely and relevant. Dominion Energy, a Richmond-based company, is currently constructing a 2.6-gigawatt off-shore wind project 27 miles from Virginia Beach. My students reside about 90 miles west of Virginia Beach. This project is a major part of the shift to renewable energy and the effort that is underway to reach net zero emissions by 2050. The transformation from fossil fuels to green energy will drive the economy and energy policies and will be a turning point in history.

Background Content

Climate Change

The temperature of the Earth is rising, and scientists expect the temperature to rise 3º Celsius by the end of the century.[3] The rise in temperature is directly related to burning fossil fuels for two hundred years. As fossil fuels burn, they emit carbon dioxide into the atmosphere. The carbon dioxide prevents the sun's radiant heat from escaping in much the same way as heat is trapped in the atmosphere of Venus. The atmosphere on Venus is hot enough to melt lead!

The rise in temperatures is causing many changes to the Earth. Glaciers melt, sea levels rise, and ocean waters warm. The increase in the temperature results in more severe storms, particularly hurricanes and heavy rains. The temperature change alters the habitat zones of plants and animals.

Mass Extinction

There have been five mass extinctions on Earth over the last 450 million years.[4] We can look to the past to learn about the future. During the Pliocene Epoch, temperatures were about 3 ºC higher than pre-industrial levels, which is where the Earth is headed if we do not reach our goals and reduce emissions. During the Pliocene Epoch, the atmosphere had similar levels of atmospheric CO_2 as today, which is why scientists are using modeling from the Pliocene Epoch to better understand the climate change we are facing.[5] Scientists hypothesize that during the Pliocene Epoch, sea-level rise led to the abrupt loss of coastal habitats and changes in the ocean which was the impetus to extinction.[6]

Virginia's History

The Virginia history curriculum examines the varied geography and natural resources throughout the state. There are five geographic regions: Coastal Plain, Piedmont, Blue Ridge Mountains, Valley and Ridge, and Appalachian Plateau. The regions are distinct, so there are diverse plants, animals, rocks and minerals, and other resources.

After an overview of the land and resources, the focus shifts to the people. Virginia's history begins with the Native Peoples and how they used the natural environment to fuel their bodies, provide shelter, and meet their needs. Then, the English settlers arrived at Jamestown in 1607. The colonists struggled to survive, and likely would not have succeeded if it were not for the Native Americans showing them how to farm and teaching them survival skills.

In 1619, Africans arrive against their will. Virginia utilized enslaved Africans and became a thriving agrarian society. In the 1700's, the first Industrial Revolution (1760's-1840's) took place. During this revolution, we see the convergence of energy and communications, when steam power and printing press meet. This combination leads to a more literate society where printed materials are more readily available. During this time, water power and steam power are changed into mechanical energy. In the first half of the 1800's, technological advances, such as the cotton gin and the mechanical reaper, led people to move out of Virginia through the Cumberland Gap as they sought more land and better opportunities. The Cumberland Gap is located at the southwest tip of Virginia where Virginia, Tennessee, and Kentucky meet. It was a gateway to the west traveled by animals, Native American tribes, and settlers.

Beginning in the 19th century and extending through the 20th century, the Industrial Revolution transformed Virginia from an agricultural society to a more industrialized society. The first Industrial Revolution relied on water and steam power which fostered the continued growth of cities such as Alexandria, Fredericksburg, and Richmond along the Fall Line. The Fall Line is a natural boundary separating two geographic regions of Virginia, the Coastal Plain and the Piedmont. The Fall Line is where rivers such as the James, Rappahannock, and Potomac become too rocky and have waterfalls that prevent further travel upstream by boat. Cities developed along the Fall Line since the waterfalls were a source of energy for early industry and goods could be transported downstream.

Then, coal was discovered in Tazewell County in southwest Virginia. People left farming and went to Tazewell County to work in the coal mines. Coal was used to power steam engines which led to the expansion of railroads. Cities developed along the railroad, providing opportunities for businesses, factories, and jobs. This was considered the Second Industrial Revolution. It was the result of the convergence of fossil fuels and the telegraph, radio, and eventually the television and telephone. Virginia also used electricity to run the first streetcar system in the United States. By the early 1900's, the automobile was invented. Along with the need for better roads, automobiles also ushered in a long-lasting dependence on fossil fuels. Throughout the 20th century Virginia became more connected to the rest of the United States. Today, Virginia is a part of the global economy.

Virginia's Energy Through the Years

The curriculum unit will explore Virginia's energy resources. Virginia has a history of being a leader, from the first permanent English colony to the first coal mine and the first electric streetcar.

The first coal mine in America was located just outside of Richmond in Midlothian, Virginia (see Figure 1). The Midlothian Coal Mine began in 1775 and until 1789 it would serve only local demand. In 1789, the wider market included northern cities and, "For many years the bituminous coal deposits of the Richmond basin were the only source from which the mineral could be procured and shipped coastwise."[7] Between 1830-1840, Midlothian mines produced about 40,000 tons of coal. It was sent on the railroad 12 miles to the Manchester wharf and most of it was shipped to Boston, New York, and Philadelphia. Coal was mined in Midlothian until the 1930's.

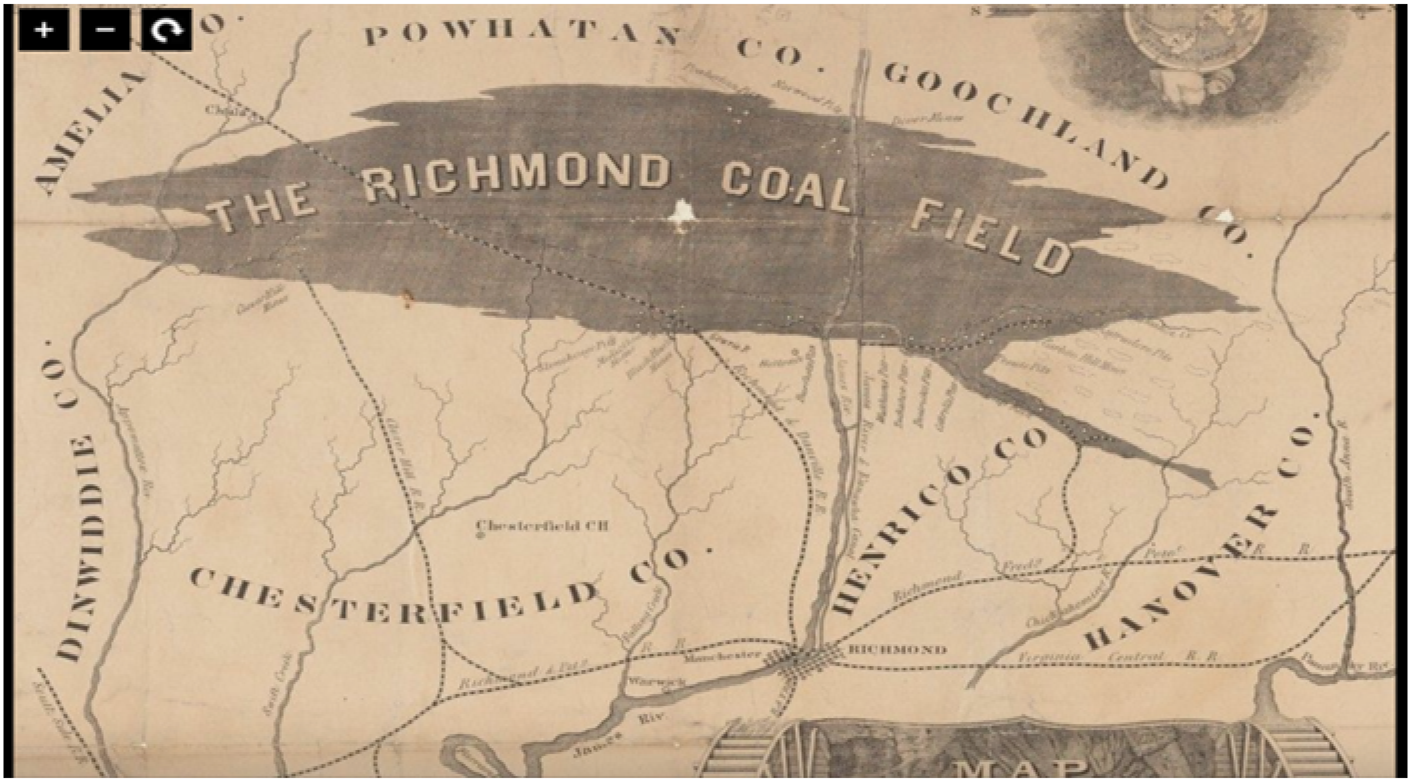

Figure 1: Map of Richmond coal field by Herries De Bow Mining Engineer, Geol, &c; lith of Ritchie & Dunnavant, Richmond, VA. Credit: Beinecke Rare Book and Manuscript Library

Tazewell County in southwest Virginia began mining coal in the 1880's. Railroads traversed the state and connected the mines in Tazewell County to the port in Norfolk. During the late 1800's, Norfolk, which was the terminus of the Chesapeake & Ohio Railroad (C & O), became a major international coal port. The Newport News Ship Building and Dry Dock Company was started by the chief of C & O Railroads. The company was contracted to build naval gunboats for the Norfolk Navy Yard. It completed construction of the *USS Virginia* battleship in 1906.[8] This would be the beginning of the development of the Norfolk/Hampton Roads area into a major shipbuilding area.

In addition to the first coal mine, the first commercial nuclear generator was built at Fort Belvoir in 1957. Virginia has a rich history of leading the way with industry and energy. In 1985, the largest pumped storage hydroelectric station in the world opened in Bath County. This will be discussed more in the hydroelectric section.

Virginia's Present

Virginia seems to be doing well with renewable and clean energy. Since 2010, Virginia has been shifting to cleaner electrical generation. Coal generation was reduced from 35% to 4% and burning cleaner natural gas increased from 23% to 61%. Virginia utilizes a mix of energy resources. The Surry and North Anna nuclear power stations provide 95% of Virginia's clean electricity. The changes resulted in a 20% reduction in carbon dioxide emissions, a 91% decrease in sulfur oxide emissions, and a 58% reduction of nitrogen oxide.[9] The decreases were primarily a result of a shift from coal to natural gas.[10]

As of July 2024, there are about 16 power companies throughout Virginia. Dominion Energy is not only the largest one, but it is also headquartered in Richmond, where my students live. Dominion currently has four nuclear power stations. They are Millstone Power Station, North Anna Power Station, Surry Power Station, and VC Summer Power Station. There are three hydro power pumping stations: Bath County Pumped Storage Station, North Anna Hydro Power Station, and Roanoke Rapids Hydro Power Station. There are about 20 facilities that handle natural gas, oil, and other non-renewable energies. There are close to 40 solar facilities throughout the state and many more under construction or proposed. Currently, there are two off-shore wind turbines, which is the beginning of large off-shore wind project that is discussed in the future section of this curriculum unit.[11]

Virginia's Energy Future

In 2020, the General Assembly, Virginia's legislative body, passed the Virginia Clean Economy Act (VCEA) which set a goal of 100% zero-carbon energy generation by 2050.[12] The shift to renewable energies will bring additional costs to consumers. Dominion and the State Corporation Commission, SCC, costs will increase 53% and 72% over 2020 levels by 2030 and 2050, respectively.[13]

According to the 2022 Virginia's Energy Plan (2022 VEP), Virginia is taking an "all of the above" approach which would include using natural gas, nuclear, and renewables to provide more energy generation and reliable transmission. Virginia needs to invest in emerging technologies such as hydrogen, carbon capture, energy storage, and small modular nuclear reactors (SMRs) to develop enough clean energy for the future. Concerns are expressed in the plan around cost and the ability to provide sufficient reliable energy. The plan explains that periodic evaluation will be necessary and that the plan should be open to adapt to innovation.[14]

Off-shore wind is also a part of the 2022 VEP. Off-shore wind has taken the east coast by storm! Wind prospectors have invested $100 billion over ten years. Dominion Energy, headquartered in Richmond, Virginia, has made the largest investment so far. Dominion is building a 2.6 GW project at the entrance to the Chesapeake Bay in Hampton Roads. The project will build 176 wind turbines, three off-shore substations, undersea cables, and on-shore wind transmission framework that will provide homes and businesses with emission-free wind power.[15] Former governor Ralph Northam proclaimed, "This will be the first deployment of commercial scale turbines in federal waters."[16] There are many naval bases and shipyards in the area. The Port of Virginia could potentially serve as a supply chain hub for large off-shore wind components for the east coast. The location will utilize many of the maritime assets which include: deep water terminals, commercial shipyards, floating drydocks, shipbuilding and repair facilities, as well as additional terminals. The Port of Virginia recently completed a $1.4 billion infrastructure investment. The wider port is now open for two-way traffic permitting ultra-large container vessels. The improvements to the port will make it more efficient by reducing the time ships spend in the berth by 15 percent. Nearby Norfolk Harbor is undergoing a transformation. A $450 million dredging project is scheduled to be complete in the fall 2025. When finished, the Port of Virginia will have the deepest, widest channel on the U.S. East Coast.[17]

Virginia has a long successful history with nuclear energy. Virginia could potentially lead the nation in nuclear energy research and development. Dominion Energy is currently looking into creating the first commercial SMR facility in southwest Virginia. It would be the first one in the U.S.!

Virginia is well positioned to enter the Third Industrial Revolution as described by Jeremy Rifkin in his book, "The Third Industrial Revolution". Rifkin describes the next industrial revolution as the convergence of renewable energy and internet technology with the capability to share electrons across a world-wide grid. Through my research, I am not sure the infrastructure for a power grid that can share electrons is coming to Virginia or the United States soon, but with more innovation, it could in the future. The idea Rifkin proposes in his book is if each building can generate renewable energy and store it, then the excess can be shared through the grid to places in need. Rifkin lays out five pillars that must be developed simultaneously to move us into the Third Industrial Revolution. The five pillars are: 1) Transitioning from carbon-based fossil fuel to renewable energy, 2) Turning every building into a mini-powerplant that collects renewable energy, 3) Installing hydrogen and other storage in every building to store intermittent renewable energy for a continuous supply, 4) Creating a grid using Internet technology to share energy with others, and 5) Changing the transportation fleet to one powered by renewable energies generated by all of the buildings and shared on the electricity grid. Virginia is not systematically developing self-sustaining green buildings, but the renewable projects being undertaken are massive and are moving Virginia toward the goal of net zero energy generation by 2050.

Rifkin's plan shares some ideas proposed in "The 100% Solution" by Solomon Goldstein-Rose. Both books share common pillars which all must be achieved to reach a solution. They also both express the need for industrial countries to help developing nations by sharing energy and resources, as the cost would be prohibitive for many countries throughout the world.

Both Rifkin's plan for economic development and energy systems and Goldstein-Rose's solution could save the world from our own self-destructive behaviors.

Hydroelectric – How It Works

Hydroelectric Stored Power Plants typically have two reservoirs separated by a large drop in elevation. Water is typically pumped up to the upper reservoir for storage. Water is released and flows down due to gravity. The water flows through penstocks, or pipes that deliver water from a source to a turbine. The turbine turns and spins a generator which creates electricity. Hydroelectric power is released during peak demand, as a hot summer day when there is a high demand for air conditioning. Hydroelectric also supplies energy to fill the gaps when solar and wind energy are intermittent. Solar energy is not produced on cloudy or rainy days or at nighttime. If the wind isn't blowing, stored energy would need to be released. On hot, sunny days, an excess of solar energy is produced and used to pump water up to the upper reservoir (see Figure 2). A surplus of wind energy is produced on windy days and is also used to pump water up to the reservoir for times when there is little wind. With the worldwide push to move toward green energy by 2050, hydroelectric storage power stations are becoming more prevalent throughout the world. A limitation of hydroelectric power is that it cannot be utilized everywhere. Hydroelectric is dependent on the geography of the land and natural resources. It requires a change in elevation and a supply of water.

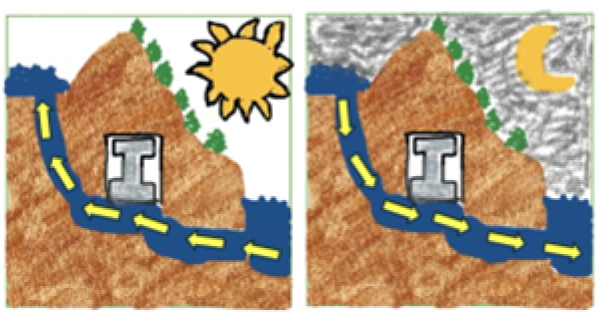

Figure 2: The cartoon shows how excess solar or wind energy is used to pump water uphill during the day and water is released downhill at night to generate electrical power.

Hydroelectricity Pump Storage

Pumped storage hydroelectricity is a technology that began in the 1890's but is serving an important role in the renewable energy era. Pumped storage hydroelectricity is used to store energy from intermittent sources such as wind and solar. Construction on The Bath County Power Station began in 1977. The station first operated in 1985. Originally, it had a capacity of 2,100 megawatts (MW). After undergoing two upgrades in 2004 and 2009, it became the largest pumped hydroelectric storage station in the world, providing 3,003 megawatts. It was often referred to as the largest battery in the world. The station uses two reservoirs separated by 380 meters in elevation. Each reservoir has a dam. The reservoirs are connected by three tunnels, each 28.5 feet in diameter and lined with concrete. The tunnels feed into six turbines. Dominion Energy currently owns and manages the storage station.[18]

Linth Hydropower Plant

Located in Switzerland, the Linth hydropower plant was the largest in the world in 2016.[19] It is similar to the Bath County Power Station in that it utilizes two lakes, Lake Mutt and Lake Limmern, to generate energy, and pumps water uphill to store energy and then lets the water flow down using gravity when solar energy is not available. Germany pays the Swiss to take their excess solar energy during the day. The Swiss use the solar energy to pump water uphill during the day. Then, when Germany does not have enough solar energy at night, the Swiss run the water downhill and sell the energy back to the Germans.[20] This is quite a clever business plan!

Turbines and Generators

There are several different kinds of turbines. Some are designed like a waterwheel turned on its side and others like a boat propeller. The use of a turbine to power a generator is not new. Steam engines use steam to turn a turbine which then turns a shaft in an electric generator. In both cases, the energy of water flowing over a turbine in liquid form or gas form is turned into mechanical energy. The generator then transforms the mechanical energy of rotation into electrical energy by moving electromagnets around a conductor. In a generator (see Figure 3), the rotors turn past the stator. The stator contains wire which is wrapped around the moving magnets. The generator was invented by Michael Faraday in 1831, and the technology still uses his principles.

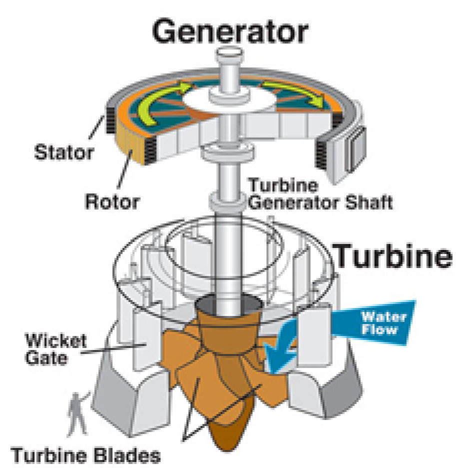

Figure 3: Diagram of a hydroelectric turbine and generator. Credit: U.S. Army Corps of Engineers

Air Currents

Air currents are primarily caused by differences in air temperature and air pressure. The Earth heats unevenly since the air above land heats more quickly than the air above water. Warm air expands and is lighter. The rising air causes a current of warm air. Cool air is heavier and sinks below warm air, thus causing a cool air current. Wind is moving air and air currents are essentially rivers of air that flow in a certain direction. Air pressure also plays a part in moving air currents. Air masses move from areas of high pressure to areas of low pressure. A greater difference in air pressure will cause greater wind speed.[21]

Wind Energy

Wind energy or wind power has been used to power sailboats and fly kites. When wind energy is turned into mechanical energy, it can grind grain, pump water, or power industrial equipment. Wind turbines transform wind energy into electricity. Wind turbines work much like a fan. With a fan, electricity turns the turbine and moves the blades. Wind energy turns the blades which turn a turbine around a rotor. The rotor spins a generator and creates electricity.[22] Many wind turbines use “gear boxes,” to speed up the rotation thus enabling the use of a smaller generator.

Types of Turbines

There are two types of turbines, a horizontal-axis wind turbine (HAWT) and a vertical-axis wind turbine (VAWT). The horizontal axis wind turbines typically have three blades and face the upwind. As the name suggests, the axis of rotation is horizontal. An advantage of a horizontal-axis turbine is that the pitch of the blades can be controlled, which allows for control of rotor speed and power output, thus protecting the turbine when wind speed becomes too high.

With a vertical-axis wind turbine (VAWT), the axis of rotation is vertical. There are several different designs. Vertical-axis turbines do not have to face the wind and work well in areas where wind direction is variable.[23] Vertical-axis turbines are quieter than horizontal-axis turbines, which are advantages when placed in residential or urban areas. VAWTs are not as efficient as HAWTs.

Wind turbines are also categorized based on their application. There are land-based wind, off-shore wind, and distributed wind turbines. Land-based wind is used on land. They are often seen in groups called wind farms. Land-based wind turbines are difficult to move over land for shipping and installation because the length of the blades is limited by our highways. Off-shore wind turbines are massive! They are transported with ships, which makes shipping and installation easier than going over land. Distributed wind turbines are smaller and are used by “customers,” on the consumer side of the grid. The “customer” can be an individual residence, a small farm, or a small industry to name a few. A distributed wind turbine may generate 5 kilowatts – 20 MW of electricity.[24]

How Does Wind Turn the Blades?

The aerodynamic principles for the blades or propellers are like the ones used for airplane wings or helicopter propellers. When the wind blows across the blades, there is a difference in the air pressure on the two sides of the propeller. This creates lift and drag. The lift is stronger causing the rotor to turn.[25]

Fixed-Bottom vs Floating

Off-shore wind energy technology depends on the characteristics of the ocean at a particular location. The depth of the ocean is a key consideration as is the attributes of the seafloor. Like the land of Virginia, the geography of the seafloor is also varied. There are distinct features such as the continental shelf, the continental slope, continental rise, abyssal plain, trench, mid-ocean ridge, and volcanic mountains. The outer continental shelf, about 27 miles from the coast, is the area of the seafloor that is used for Virginia's off-shore wind project.[26]

Floating wind turbines have a substructure that is either floating or a hull. They also use mooring lines to tether the platform to anchors on the ocean floor. Floating structures are used when the water depth is greater than 60 meters (. These floating structures are modeled after similar structures used in the oil and gas industry.[27] By 2023, floating structures will be used in 11-25% of all new off-shore wind energy projects.[28] Fixed-bottom wind turbines have a substructure that is attached to the floor of the ocean. Fixed-bottom structures are used in water depths that are less than 60 meters, or about 200 feet deep.[29]

Cables

Off-shore wind delivers electricity to land through subsea cables which are usually buried below the ocean floor. Array cables link wind turbines together and carry electricity to the off-shore substation, while export cables transmit electricity from off-shore substation to land-based substations.[30]

According to Anthony Kirincich, an oceanographer at Woods Hole Oceanographic Institute (WHOI), "Most people focus on the spinning blades of turbines to ensure that an offshore wind energy project will be successful, but the subsea cables that bring that power to land are equally as important."[31] The cables need to be monitored for damage from ships, anchors, trawlers, and nets. Inspections are important to avoid disruptions in the power grid. In the past, ships that tow equipment have been used for the inspections, but the use of ships for monitoring subsea cables is expensive and time-consuming. As off-shore wind turbines are increasing along the east coast, there will be a demand for cheaper ways to monitor the underwater cables. One option is to use autonomous underwater vehicles (AUV's), which have long been used in oceanographic research.[32] Temperature sensing and vibration sensing are two ways that subsea cables are inspected. The depth of the cable is also checked to make sure it is not moving too far up or down from its original burial location.[33]

Effect on Ecosystems

Off-shore wind projects have both positive and negative effects on ecosystems. During construction and installation, marine species move out of the area. With the construction of the structures, the sediment gets disturbed which disrupts the benthic community. Animals that live on the sea floor are called benthos and are mostly invertebrates. Some examples of organisms that live in a benthic community are anemones, sea stars, crabs, sea urchins, bivalves, and coral. Rocks and other materials are used for support and to decrease erosion around the base. The rocky structures form artificial reefs which create habitats and diversify homogenous seabeds. The artificial reefs attract a wide variety of species, increase biodiversity, and enhance the richness of ecosystems. The artificial reefs provide a variety of food and offer protection against currents and predators. Bottom trawling is prohibited around off-shore wind structures, thus protecting the benthos community and fish. Ship traffic also avoids the area around wind turbines. A benefit of off-shore wind stations is that they provide resting areas for birds. However, a negative impact of the off-shore turbines is bird strikes, which not only affect birds who live near the turbines, but also migratory birds.

Strategies

Hands-on activities and demonstrations

The students will engage in many hands-on activities throughout this lesson. Students are more interested and excited when they are actively involved. Students also remember information better when they are doing and involve more senses into the learning experience.

Guest Speakers

It is always nice to engage with experts in the field. For this unit, I currently have two guest speakers in mind. First, I would like to have someone from Dominion Energy come speak to my class about the off-shore wind project. I also would like to invite a parent of a rising fifth grader who works in the area of energy, oil, and gas law. His work also includes environmental law.

Design Thinking and Modeling

Students will be introduced to Design Thinking through a workshop model. The steps of the design process will be modeled and explored. The students will apply the Design Thinking process through several projects. The class will design sail cars to harness wind power. Later in the unit, they will design a wind turbine with a marine ecosystem at the base. The students will use Bird Brain robotics and Scratch coding for this project. Some of the activities will use an abbreviated version of Design Thinking. Other activities will require students to go through the entire process.

Collaborative Groups

Students will work in collaborative groups. This will allow them to help each other and talk through their ideas, iterations, and modifications. I regularly use collaborative groups and discourse. Students understand what they are learning better when they discuss and explain content.

Reading and Research

The students will read non-fiction articles about fossil fuels, climate change, wind and wind energy to build background knowledge. They will conduct repeated readings and annotate as they read.

Activities

Day 1 The students will watch a phenomena video of a cold front. They will make observations. Then the class will create currents in a tub of water using warm water and cold water to model how currents (wind or water) work.

Day 2 Explore the power of wind with sail cars.

Day 3 Read, annotate, and conduct research on wind energy.

Day 4 Read, annotate, and conduct research on wind energy.

Day 5 Present information about wind energy. During presentation have students engage through discussion at certain points.

Day 6 Use Kid Wind Firefly mini turbines to experiment with different blades

Day 7 Use Kid Wind Firefly mini turbines to experiment with different blades

Day 8 Begin with images of hydroelectric pumped power (see *Figure 2*) and share an image of the duck curve. Present information about hydroelectric stored power plants. During presentation have students engage in discussion at certain points.

Day 9 Discuss pros and cons to the marine ecosystem.

Day 10 Guest speakers from Dominion Energy and energy lawyer

Day 11 Culminating project

Day 12 Culminating project

Day 13 Culminating project

Day 14 Culminating project

Day 15 Culminating project

Activity 1

The activity for Day 1 will begin by watching a short, time-lapsed video of a cold front. Students will make record notices and wonders. Then, the class will work in collaborative groups to explore currents. Fill a shoebox-sized, plastic tub with about 2 inches of cold water. Get two 3 fl. ounce paper cups. Poke a push pin through each one about ½ inch from the bottom. Leave the push pins in the cup. Add about 1 inch of hot water (from a faucet, so students cannot burn themselves) to one cup and about 1 inch of cold water to the other cup. Add red food coloring to the hot one and blue food coloring to the cold one. Place them in corners that are diagonally across from each other in the plastic tub. Students should pull out the push pins and record observations. After about ten minutes, or when water is no longer streaming out from the cups, students can either write or discuss a reflection/connection between the tub activity and the video of the cold front. This tub activity can be conducted a second time with hot water (not too hot that it could burn the children) in the tub instead of cold water. This activity models how changes in temperature cause currents. It also models how warm water or air rises and cold water or air sinks. The currents are not as strong when the water is closer to the same temperature.

Activity 2

For the Day 2 activity, students will build a sail car. Directions can be found with a quick Google search of

KidWind or Instructables and sail car. The designs and the materials can be changed. I used a plastic foam core board for the base, wooden beads for the wheels, a straw and skewers for the axle, a dowel for the mast, and the students can choose either cellophane (acetate) squares, card stock, or foam for the sails. This can be done as an engineering design challenge. Provide materials and parameters and the students can race their cars either outside on a windy day or inside with a box fan. Sail cars lend themselves to many scientific investigations. It is recommended that only one variable is changed at a time. The shape of the sail or the material of the sail can be changed. If time is a restriction, the teacher can construct the base of the car, and the students can add the mast and the sail.

Activity 3

The Day 6 and Day 7 activity will use a class set of KidWind Fireflies. These are mini turbines that transform wind energy into electricity. Students can explore and conduct experiments using the blades provided or make their own blades. If Fireflies are not available, students can experiment with pinwheels that use different designs. There is a Science Buddies video that shows step by step how to make different types of pinwheels.

Activity 4

Day 8 begins with this short activity. Students will examine the pictures in *Figure 2* which show water being pumped uphill for storage during the day and being released downhill at night. Ask the students why might solar or wind energy get stored during the day? Answers may include there may be a surplus of solar and wind energy during the day or there may be less people using energy during the daytime. Then find an image of the “Duck Curve.” I love the one with a yellow duck for fourth graders. Ask the students what they notice and what they wonder. Ask the students why the “belly” sags? Possible answers include there is more energy than needed or there is less demand. Why would the “belly” be from about 9AM-1PM? Answers may include the sun is shining and moving directly overhead and people are at work and not at home, so less electricity is being used in homes. There is more energy than is needed. Why would stored energy be released in the evening? Possible answers are that there is more demand or solar energy is not collected at night so stored energy is used. Why is there a sharp rise from the belly to the head of the duck? A possible explanation is that there is more demand when everyone is home at night. People are cooking, watching T.V., heating or cooling their house more, and using lights at night when it is dark. There is less energy available since solar is not being generated at night after the sun has set.

Activity 5

The culminating project (Days 11-15) will take about 5 days. The students will have to create a wind turbine. Ideally the wind would generate electricity, but with fourth graders, I’d be happy if the blades turn. I am planning to use Scratch coding and Bird Brain robotics kits, but the wind turbine can be created with everyday craft items. I also want the students to create an artificial reef at the base of the turbine. Students will not only have fun with this, but it will reinforce ocean ecosystems and show a benefit of the wind turbines beneath the ocean. I will ask my students to make at least one creature move in the ecosystem. Students will present their projects to the class.

Annotated Bibliography

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Author links open overlay panel Stephen C.L. Watson a b, a, b, c, d, Highlights Consolidates global evidence of ecosystem services (ES) impacts of this sector. Negative impacts on biodiversity and ES are slightly prevalent Positive ES effects on fisheries, and Abstract Understanding the global impact of offshore wind farms (OWF) on biodiversity and ecosystem services (ES) is crucial in developing sustainable energy transition pathways. This study takes a holistic approach. “The Global Impact of Offshore Wind Farms on Ecosystem Services.” Ocean & Coastal Management, January 18, 2024. https://www.sciencedirect.com/science/article/pii/S0964569124000085. This article was useful for information about ecological impacts of off-shore wind energy.

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https://www.hydroreview.com/world-regions/europe/switzerland-s-1-000-mw-linthal-pumped-storage-plant-connected-to-grid/#gref. Accessed July 15, 2024. This website provided information about a specific hydropower station in Switzerland. The content was useful, but it is limited to that subject.

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Lewis, Scott. “The 10 Largest Pumped-Storage Hydropower Plants in the World.” Engineering News Record RSS, November 11, 2021. Accessed July 14, 2024. https://www.enr.com/articles/44302-the-10-largest-pumped-storage-hydropower-plants-in-the-world. This website has great pictures of the largest hydropower plants in the world. It may be a challenge to view the site as the "free articles" are limited.

“A New Way of ‘Seeing’ Offshore Wind Power Cables.” Woods Hole Oceanographic Institution, July 25, 2019. Accessed July 13, 2024. https://www.whoi.edu/news-insights/content/a-new-way-of-seeing-offshore-wind-power-cables/. This website shows how scientist check the underwater cables of wind turbines using underwater vehicles.

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“Virginia Is All in for Offshore Wind!” YouTube, December 1, 2020. Accessed July 16, 2024. https://www.youtube.com/watch?v=KUtHZvF94gw&t=2s. This is a short video that visually speaks about the wind project that is planned for the coast of Virginia. It explains the resources of the area and why the location is amenable for wind energy.

List of Materials

Activity 1: Clear plastic tubs, 3 fl. ounce paper cups, push pins, food coloring (red and blue), cold water, hot water, time-elapsed video of cold front

Activity 2: Plastic foam core board cut into 5” x 2 ½” pieces, X-Acto knife or utility blade, plastic straws, round wooden beads, wooden skewers, button (to attach mast to), ¼ inch diameter dowels for masts, hot glue gun(s), glue sticks, acetate sheets (5” x 6”), foam sheets (cut into 5” x 6” pieces), card stock (cut into 5” x 6” pieces), scissors, rulers, and box fan (if sailed inside).

Activity 3: KidWind Firefly kits; pinwheel activity supplies: scissors, pencils or dowels, ruler, Scotch® tape, glue stick, construction paper (8½” x 11”), and thumb tacks.

Activity 4: Copies of *Figure 2* (in this curriculum unit) for each group, image of “Duck Curve” to display.

Activity 5: Possible list of materials to construct wind turbine with ecosystem below: cardboard, shoeboxes, plastic foam core board, hot glue gun, glue sticks, egg cartons, cardboard circles or other round material for a hub, dowels or wooden skewers, straws, popsicle sticks, construction paper, 1.5v motors (optional), AA or C batteries (optional), electrical wires (optional), and electrical tape(optional)

Appendix Implementing District Standards

The standards discussed below are Virginia Standards of Learning. I focused on the science standards as this is a science unit. I will also briefly mention the main Virginia Studies standards that are addressed. Virginia Studies standard 2 (VS2) focuses on the geography of Virginia which relates to the natural resources and energy that is conducive to each region. VS9 relates to the second industrial revolution and the changes from an agrarian society to an industrial society in the twentieth century and beyond. VS10 relates to the geography and economics. It describes how improvements in communication, transportation, and technology led to Virginia's role in the global economy. This standard directly relates to the way Jeremy Rifkin described the industrial revolutions.

The science standards that are addressed are 4.1 which speaks to scientific and engineering practices which are embedded in the sail car, Firefly wind turbines, and wind turbine activities.

4.1 The student will demonstrate an understanding of scientific and engineering practices by

e) developing and using models

- develop and/or use models to explain natural phenomena
- identify limitations of models

Standard 4.7 relates to the characteristics of the ocean floor, the location for off-shore wind turbines, the need for adding rocks and materials to the base of turbines to avoid erosion, and the impacts on ocean ecosystems.

4.7 The student will investigate and understand that the ocean environment has characteristics. Key characteristics include a) geology of the ocean floor; b) physical properties and movement of ocean water; and c) interaction of organisms in the ocean.

Standard 4.8 relates to the natural resources throughout Virginia. It connects to the history with coal as well as the favorable locations for various renewable energy sources.

4.8 The student will investigate and understand that Virginia has important natural resources. Key resources include a) watersheds and water; b) plants and animals; c) minerals, rocks, and ores; and d) forests, soil, and land.

The unit also addresses some fifth-grade standards. In Virginia, students are tested in fifth grade on science content from fourth and fifth grade science. By including these standards, the curriculum unit will be more useful throughout the district and the state. The unit shows how energy is transformed when it describes how turbines work in wind energy and hydroelectric pumped power. The curriculum unit addresses renewable and non-renewable energy as well as improvements in technologies.

5.2 The student will investigate and understand that energy can take many forms. Key ideas include a) energy is the ability to do work or to cause change; b) there are many different forms of energy; c) energy can be transformed; and d) energy is conserved.

5.9 The student will investigate and understand that the conservation of energy resources is important. Key ideas include a) some sources of energy are considered renewable, and others are not; b) individuals and communities have means of conserving both energy and matter; c) advances in technology improve the ability to transfer and transform energy.

Notes

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