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The Future of Renewable Energy and Solar Electric Innovations

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Introduction and Rationale

This unit is designed for middle school students and is intended to get students interested in thinking about the future of renewable energy and creative ways we can collect solar power and use it in our everyday lives. Humans use a lot of energy and most of that energy is created using fossil fuels. It is predicted that the number one problem humanity will face in the next 50 years is an energy crisis. This problem will require advancements in renewable energy technologies and a shift to green energy production. Scientists and engineers are already innovating ways of producing green energy and storing energy produced from renewable sources. To reduce greenhouse gas emissions in the atmosphere, we will need to electrify equipment that currently uses fossil fuels, such as transportation, heating, and powering homes. The term renewable energy generally refers to electricity generated from renewable energy sources, such as wind and solar power, geothermal, hydropower, and various forms of biomass from plants (biofuels). These energy sources are considered renewable sources because they are continuously replenished on the Earth.[1] The future of energy is going to depend on successful implementation of green power or renewable energy resources and technologies, because they provide the greatest environmental and cost benefits. Energy production is shifting away from conventional power or combustion of fossil fuels (coal, natural gas, and oil) to more sustainable options that are more cost effective and have less impact on the environment. Fossil Fuels have environmental costs from mining, drilling, or extraction, and they emit greenhouse gases and pollution during combustion.[2] Switching from conventional power to green power or renewable energy sources is better for the environment and would decrease the amount of greenhouse gas emissions. Producing electricity from fuel sources such as: the sun, wind, moving water, organic plant and waste material (eligible biomass), and the earth's heat (geothermal) have a zero-emission profile and would help reduce the carbon footprint created by energy production. Renewable energy could provide energy security (efficient/cost effective), combat climate change, and provide economic opportunities. People have been using solar power since the beginning of human history, by developing technologies to capture the energy of the sun for heating and cooking. Scientists and engineers are now working to make these technologies more efficient and more useful every day.[3] The essential question for students is: how can we innovate ways to use the sun to produce energy on Earth? Throughout the unit students will learn about solar power, how solar panels/cells work, how batteries can be used to store solar energy, and solar electric innovations. This unit will also include instructions for a hands-on activity, where students can build/design a solar car to race against other students. Solar energy is one of the fastest growing renewable energy sources because solar power is efficient and provides

environmental benefits. I believe students would be interested in learning how this technology is evolving and paving the way for solar electric innovations.

School Demographics

I teach at East Central Middle School in East Tulsa. It is the highest-populated middle school in the Tulsa Public Schools district. Our student body is just under a thousand (981) sixth, seventh, and eighth grade students. The student population represents various ethnicities, which helps create a highly diverse atmosphere. The school's minority enrollment is 90.5%, representing the following populations, respectively: 59.2% Hispanic/Latino, 13% Black or African American, 9.5% White/Caucasian, 8.1% Two or more races, 4.6% Asian, 4% American Indian or Alaska Native, and 1.7% Native Hawaiian/Pacific Islander. The student-to-teacher ratio is approximately 24:1, and the student population comprises 50% female and 50% male students.[4] East Central Middle School is considered a Title I school, and 89% of students are economically disadvantaged.

My class is an elective for gifted and talented students in the sixth, seventh, and eighth grade. As a gifted and talented educator, I teach students different ways of thinking critically and creatively while analyzing topics across multiple subjects. In class, I use problem-based learning projects to teach course content within the framework of a realistic problem. These projects allow students to learn about a subject by collaborating in small groups to design and create solutions to open-ended problems. In class, I encourage students to look at things from multiple perspectives or points of view. Students learn to apply the critical thinking skills of deduction, analysis, and reasoned judgment while learning course content.

Content Objectives

The unit is divided into four sections: 1) Introduction to solar power and how solar panels/cells convert solar energy into electricity, 2) Solar storage technologies for storing solar energy collected from sunlight, 3) Innovations in solar power and solar thermal technologies, and 4) Solar powered and electric transportation. Solar energy must be converted into electricity before we use it to power our electronics or provide heating in homes. Solar panels are needed to convert solar energy into electricity that we can use. We can capture energy using photovoltaics and solar thermal technology. Solar panels produce power during the day when the sun is out and produce no electricity at night. To use solar energy at night, the energy needs to be stored in some way. Pumping water uphill or hydro storage, batteries storage, thermal energy storage and chemical bonds are all different ways we can store solar energy from the sun to use later. These storage technologies can provide electricity from solar energy even when the sun isn't shining. Scientists and engineers are always trying to innovate new and more efficient ways to collect, store, and power our homes and businesses using electricity and heat produced from solar energy. These innovations in design and efficiency are creating more possibilities and opportunities to create new and interesting ways to use solar energy in our everyday lives. Innovations in solar energy storage, such as lithium-ion batteries and fuel cells are helping pave the way for future advancements in electrification and solar powered transportation.

Solar Power

Solar power is one of the most promising renewable energy sources today.[5] Solar power comes from electricity that is generated by harnessing the energy of the sun. Solar panels are often used to convert sunlight into energy. A solar panel is composed of photovoltaic (PV) cells, also known as solar cells, or nonmechanical devices that convert sunlight directly into electricity. Some PV cells can convert artificial light into electricity.[6] Sunlight is made of photons or particles that contain energy. When photons strike a solar cell, they can be absorbed, reflected, or pass through it. When photons are absorbed, electrons inside the cell start to move, which creates an electrical current. The electricity travels through an inverter, which converts the DC current into AC current, or a type that can be used in your home. One of the biggest challenges in using solar energy is creating a solar panel that can transfer photons into electricity efficiently. Scientists, researchers, and engineers are continuing to innovate ways to improve the design and efficiency of solar panels. The first solar cells were invented in 1954 at Bell Laboratories in New Jersey by three scientists who created the cells using silicon. These early solar panels were not very efficient and only 5 percent of the sunlight that reached the panel's surface was converted into electricity. Today, solar panels have greatly improved, and they have become more efficient in converting sunlight into electricity. Researchers and engineers are continuing to innovate and improve solar panel designs. A solar panel created in 2015 at the National Renewable Energy Laboratory in Colorado keeps up to 45 percent of solar energy.[7] As solar panels continue to become more efficient, fewer panels will be needed to power entire homes, businesses, or cities. Solar energy does not produce carbon emissions and has less of a negative impact on the environment. Aside from the production of solar panels and batteries to store energy, solar energy has a relatively small carbon footprint. Solar power provides environmental and cost benefits, which is why this makes solar one of the renewables with the most potential for continued growth. Capturing energy using photovoltaics and converting sunlight into electricity is just one way we can harness the energy of the sun. Solar power is carbon neutral and does not make or emit carbon dioxide into the atmosphere and is better for the environment. However, solar panel waste could potentially become a problem if they end up in landfills. This could be hazardous and have a negative impact on the environment because solar cells contain toxic heavy metals such as lead, selenium and cadmium. These metals could potentially end up contaminating groundwater.[8] On average solar panels can last for 30 years and many parts of solar panels can be recycled. Solar thermal technology is another way to capture the energy of the sun and turn it into heat. Concentrated solar power is a type of solar thermal technology that uses mirrors to reflect sunlight onto a designated area. The concentrated light heats water and converts it to steam. The steam is then used to power a generator to produce electricity. Passive solar technologies convert sunlight into usable heat and cause air movement for ventilating to heat and cool living spaces without active mechanical or electrical devices.[9] Another technique uses black surfaces or pipes to heat water by placing the pipes in direct sunlight to save energy. Solar energy is one of the fastest growing technologies in the world and as a result scientists and engineers are becoming more innovative in how we could use solar in our homes and everyday life. Engineers are trying new ways of utilizing solar panels by placing them on windows, sidewalks, driveways, and paths. As solar power becomes more efficient and cost effective, there will be more and more innovative ways to use solar in our daily lives. Solar powered and electric transportation are becoming increasingly more popular because of innovations and advancements in solar electric technology. Transportation is the largest source of greenhouse gas (GHG) emissions in the U.S and, as such, any plan to achieve a net-zero GHG economy must reduce transportation GHG emissions to near zero.[10]

Storing Solar Energy

Storage refers to technologies that can capture electricity, store it as another form of energy (chemical,

thermal, mechanical), and then release it for use when it is needed. During the day, solar energy can be collected from sunlight and used to produce electricity but at night or on cloudy days solar panels do not produce electricity because the sun is not out. This means solar energy is not always produced at the time energy is needed most. Peak power usage often occurs on summer afternoons or evenings, when solar energy generation is failing. Temperatures can be hottest during these times, and people who work daytime hours get home and begin using electricity to cool their homes, cook, and run appliances.[11] Solar energy storage technologies are how solar energy can be used to produce electricity even when the sun isn't shining. There are various ways solar energy can be stored from the sun, but some ways are more efficient or better depending on the environment or geography. Some methods of mechanical solar energy storage include pumped hydro, gravity storage technologies, compressed air, and flywheel. Mechanical energy storage is the storage of energy by applying force to an appropriate medium to deliver acceleration, compression, or displacement (against gravity). This process can be reversed to recover the stored kinetic or potential energy. Currently, the most widely used large-scale mechanical energy storage technology is pumped hydro-storage.[12] Battery energy storage systems and fuels cells are two common types of chemical energy storage systems. These systems store energy in chemical bonds, rather than electrical energy. Battery energy storage systems store and release energy electrochemically using a series of battery cells. Lithium-ion batteries are a common type of batteries used in solar energy systems to store electricity generated by solar panels because they are rechargeable. In fuels cells, hydrogen gas can be used to store energy in fuel cells for both short and long periods of time. Hydrogen is created from electrolysis, which uses electricity to split hydrogen and oxygen. Thermal energy storage systems use materials such as water, molten salts, or sand to store heat in an insulated tank. The energy is then used to generate electricity or produce heat. One type of thermal storage is using focused sunlight to heat water, called concentrated solar thermal power. A direct application is solar thermal water heaters that use solar collectors to heat water in a storage tank.[13] Things to consider when looking at solar energy storage are cost, storage capacity, efficiency, and lifespan. Scientists and engineers are continuously researching new and more efficient ways we can store solar energy. One method scientists are working on is storing solar energy in an artificial leaf. Artificial photosynthesis uses solar energy to produce hydrogen from water.[14]

Solar energy can be stored using pumped hydro storage or pumping water uphill. Pumped hydro storage is a method of solar power storage that involves using water and gravity to store excess solar electricity. The process of pumped hydro storage involves pumping water uphill during periods of low electricity demand and storing it in a reservoir or other holding tank. When there is an energy demand, the stored water is released and flows downhill through turbines, generating electricity.[15] This method of storing solar energy has several benefits: hydro storage systems can store large amounts of energy, they are long-lasting, and highly efficient. One disadvantage to pumped hydro storage is it requires geographical features such as hills or mountains and enough water to work effectively, which means this method may not work in all locations.

Solar battery storage is another method that involves the use of rechargeable batteries to store energy generated from solar panels. This method is also highly efficient, by storing solar power during the day (peak generation period) and using it at night you can save money on energy bills. There are various types of batteries that can be used for solar power storage such as lead-acid batteries, lithium-ion batteries, nickel-cadmium batteries, and flow batteries. However, lithium-ion batteries seem to be the most frequently used because they can be recharged.[16] Lithium-ion batteries can store a lot of energy, and they hold a charge longer than other kinds of batteries. The cost of lithium-ion batteries is dropping because more people are buying electric vehicles that depend on them. While lithium-ion battery systems may have smaller storage capacity in comparison to other storage systems, they are growing in popularity because they can be installed

almost anywhere and have a small footprint.[17] Storing the sun's energy in batteries that can be used later is one of the biggest challenges scientists and engineers are working on.[18] There are also some disadvantages to using lithium-ion batteries as a method for solar energy storage. One major drawback of lithium-ion batteries is the significantly higher initial cost to consumer. Also, if installed incorrectly they have the potential to catch fire.[19] Besides cost and safety, another thing to consider is the lifespan of batteries, which is shorter than solar panels. Batteries degrade overtime and in environments with extreme heat/cold, affecting storage capacity and performance.

Hydrogen storage is another type of energy storage that uses a process called water electrolysis. An electric current splits water into hydrogen and oxygen. If the electricity is produced by renewable sources, such as solar or wind, the resulting hydrogen will be considered renewable as well, and have numerous emissions benefits.[20] The hydrogen gas can then be compressed and stored inside underground tanks. When needed, this process can be reversed to produce electricity from the stored hydrogen. Hydrogen can be stored as a gas or liquid. As a gas, hydrogen storage requires high-pressure tanks, while liquid hydrogen requires storage at cryogenic temperatures to prevent it boiling back into a gas. Hydrogen may also be stored on the surface of solid materials (known as adsorption), or within them (known as absorption). Underground hydrogen storage technology is also being developed that can re-infuse the geology of the earth to safely store large volumes of green hydrogen.[21] Using hydrogen is a sustainable renewable energy source and could help in the fight against climate change because it emits no greenhouses. Currently, there is a need for clean hydrogen production. Developing new hydrogen electrolysis equipment, creating new plant designs, or changing manufacturing practices could lower the capital costs of electrolysis equipment. Hydrogen fuel cells could be used instead of batteries and even electric cars could be powered with hydrogen tanks.[22]

Plants absorb light and use it to produce energy through a process called photosynthesis. Artificial photosynthesis is a chemical process that captures and stores energy from sunlight, producing solar fuel, like the natural process of photosynthesis. The solar energy can then be stored when the energy from the sunlight is converted into chemical energy for storage. Scientists are working on developing a new way to store solar energy with an artificial leaf. Researchers at Yale University's West Campus developed a photoelectrochemical (PEC) device that mimics the photosynthesis of plants. The process uses two electrodes to split water molecules to create protons, electrons, and oxygen. The second electrode recombines the electrons and protons to make hydrogen gas. This green renewable energy technology is still being developed and the lab is working specifically on increasing efficiency. Using hydrogen is a sustainable source of energy but it can be expensive and challenging. This is why scientists and researchers are looking for more efficient ways to split water molecules into oxygen and hydrogen.[23]

Solar Innovations

Solar is one of the fastest growing renewable energy technologies around the world. With the increase of efficiency of solar panels, less solar panels may be needed to power houses and businesses. Fewer panels, or smaller panels will make the design and implementation of these solar technologies easier and create more opportunity for innovations. Solar trackers are a recent innovation that helps increase the amount of energy produced by solar panels. These trackers sense the direction of the sun and rotate or tilt solar panels for maximum exposure to sunlight.[24] Green engineers and architects are also creating unique ways to make solar passive energy for use in homes and buildings, while using solar thermal energy technologies. A solar passive home must include properly orientated windows or devices to collect solar energy, thermal mass (concrete, brick, stone) to absorb heat, distribution mechanisms to move air, and control strategies for air flow.

Designers also consider insulation, window type, thermal mass location, and auxiliary heating and cooling systems. Landscaping can also keep passive solar homes cool in the warmer months.[25] Solar farms require large areas of land to produce enough electricity to power cities. Agrivoltaics is a way of using land for other purposes, such as growing crops, while producing energy from sunlight simultaneously. This process promotes natural vegetation and pollinators. Scientists and farmers are working on innovative ways to combine land and solar. Many solar farms have raised solar panels with plants growing underneath. The panels are tilted at an angle which allows sunlight to reach the plants.[26]

Solar powered cars are made with solar panels attached to the top of the car. These photovoltaic cells convert sunlight into electricity and send energy to the car battery. Solar cars are better for the environment, reduce transportation costs, and have longevity. Most solar-powered cars are used for racing and the first race was in Switzerland in 1985 (Tour de Sol). Solar cars are mostly used for racing because they are expensive to manufacture and there are currently no affordable solar-powered cars on the market.[27] Solar cars test the ultimate boundaries of energy efficiency; they also provide incredible insights into the capabilities of everyday vehicle technology. These innovations are at the heart of all electric cars, whether that power comes from hydrogen fuel cells, hybrid engines or even fully commuter cars that draw power from solar cells on the garage roof.[28] One of the difficulties with manufacturing a solar powered car for everyday drivers is the surface area needed on the car for solar cells to provide enough driving range needed for commuting and driving longer distances. This is a challenge for engineers and why there are not very many commercial solar powered cars.

As battery storage efficiency increases, electric cars will continue to grow in popularity. Most of the energy system could theoretically be decarbonized through electrification: converting equipment that currently runs on fossil fuels to equipment powered by electricity. We see this starting in our everyday lives with electric cars and electric home heating.[29] Electric or green vehicles are more efficient and less polluting than gas powered vehicles. Historically, gasoline or diesel power cars and trucks have accounted for most sales, but recently electric cars are on the rise. New models of both electric vehicles and plug-in hybrid electric vehicles are entering the market in increasing numbers each year.[30] Switching from a gas-powered car to an electric car is one-way consumers could reduce their carbon footprint and contribute to helping achieve a net-zero future. The transportation sector- which includes all modes of travel through land, air, and sea to move people and goods- accounts for nearly a third of all domestic GHG (greenhouse gas) emissions.[31] Fully electric planes are also being developed; the most recent is a 90-passenger plane that can fly 500 miles, has eight propeller engines, a wingspan of 138 feet, requires several batteries to power the plane. It is called Elysian's electric regional aircraft and is a collaboration with Delft University of Technology.[32] The majority of the energy systems could be decarbonized through electrification by converting equipment that currently runs on fossil fuels to equipment powered by electricity. We can start to see this in our everyday lives with electric cars and home heating. This conversion needs to take place on a wider scale, in industries such as freight transportation and within the industrial sector.[33]

Figure 1: Elysian electric airplane [34]

Solar power has a lot of potential as a renewable energy source but there are some negatives that should be considered. The metals needed to build solar cells and batteries are something we need to consider. Solar panels use silicon, silver, aluminum, and copper. Drilling and mining for these metals have a negative impact on the environment. The environmental impact and potential for solar panel and battery waste could potentially be solved with more innovative or better ways to recycle these materials.

Teaching Strategies

The essential question for students is: how can we innovate ways to use the sun to produce energy on Earth? Throughout the unit, students will learn how solar panels and photovoltaic cells capture sunlight to create electricity. Students will research the various types of solar energy storage systems and investigate the pros and cons for each method. Students will brainstorm and try to think of innovative ways to use solar panels or creative ways to generate solar thermal energy. Finally, students will design a product that uses solar power technology and present the idea to the class.

Close Reading

Close reading is a strategy that allows students to analyze and interpret text. This strategy can help readers

comprehend complex text, gain a deeper understanding of the text, fully understand the author's message, focus on patterns or details in the text, and analyze text while developing critical thinking skills. To introduce the unit, students will read sections from Chapter One "Sunlight, Sunlight, Is It Too Bright?" in the book *Renewable Energy: Power the World with Sustainable Fuel, With Hands-on Science Activities for Kids*. This reading will introduce the topic of solar power and how scientists and engineers are working on making these technologies more efficient and useful for every day. Students will learn how humans have been capturing the sun and harnessing solar energy all throughout history. The sun's rays have been used to help build fires as early as 700 BCE. It is believed Archimedes, a Greek mathematician and scientist, developed a "heat ray" weapon using mirrors to concentrate the sun's energy to burn the sails of enemy ships around 214-212 BCE.[35] This book is a great resource for teaching renewable energy and providing hands-on activities. For this unit, we are going to focus on the solar power section. The unit is divided into four sections: 1) Introduction to solar power and how solar panels/cells convert solar energy into electricity, 2) Solar storage technologies for storing solar energy collected from sunlight, 3) Innovations in solar power and solar thermal technologies, and 4) Solar powered and electric transportation.

Research-based

Research-based teaching strategies include comparing/contrasting, classification, summarizing, notetaking, and testing hypothesis. Students search and use multiple resources, materials, and texts to explore important, relevant, or interesting topics or challenges. This strategy helps build reading skills and vocabulary as well as allows the student to find, process, organize and evaluate information on their own. In this unit, students will read articles or information from the Environmental Protection Agency website (epa.gov) and research the different types of renewable energy resources. They will compare green power to conventional power and explore the difference in cost and environmental impact. Not all renewable resources have the same benefits and costs. Students will explore which are most beneficial and create a pros and cons list. After completing their research, students will share their findings in a presentation given to the class.

Gallery Walk

A gallery walk aims to create a thought starter or spark a class discussion around a topic. This strategy allows students to be actively engaged and move around the classroom. Students work together in groups, sharing ideas, answering questions, looking at documents or images, and problem-solving situations or texts. Gallery walks help students develop higher-order thinking, debating, writing, analysis, and evaluation skills. In this unit, I will hang up five posters around the classroom with pictures and information on the different types of renewable energy sources. The posters will have information on efficiency, cost analysis, and areas/locations or countries that use these renewable sources. At each station, students will answer the following prompt: do you think this renewable resource is used in Oklahoma and do you think it is an efficient source of energy based on our geography/location? Why or why not?

Brainstorming

Brainstorm is a group activity to discuss ideas or solve problems. This strategy is a technique for students to develop creative problem-solving skills. Students respond to prompts with a list of suggestions or ideas. It is best to generate lots of ideas, including ideas that may seem impossible or unlikely. Brainstorming helps encourage new ways of thinking and creating solutions to problems. This technique helps create an open and innovative learning environment, where students can think freely without judgement. This is usually a group activity but can also be useful for individuals to explore ideas or solutions on their own. For the unit, students

will consider the essential question and brainstorm new and interesting ways we can use the sun to produce energy on Earth. Ideas may be unique ways to use solar panels to create electricity or solar thermal technology to produce heat. The brainstorming ideas students come up with can be used later for the Solar Invention: Design Project.

Think-Pair-Share

Think-Pair-Share is a collaborative learning strategy that is useful for coming up with ideas and then discussing or sharing the ideas in a small group. This strategy can be used before reading or teaching a concept and is sometimes used to develop fluency. Students respond to a prompt in the form of a question or problem. The first step is to give students time to think and gather their thoughts. Then students are paired up with partners to share their ideas or thoughts with each other. This gives students the opportunity to listen and consider their peer's perspective or point of view. This technique is a good way for students to practice communicating their thoughts and sharing ideas.

Classroom Activities

Solar Invention: Design Project

After learning about solar power electric innovations, students will think of ways the sun or solar panels can be used in everyday life or in their home, school, or community. First, students will brainstorm interesting and different ways solar panels could be used to power things with electricity. The idea is to come up with a list of as many possibilities they can think of, either individually or as a group. Students will then choose one idea to expand on and create or design a solar power invention. They can create a drawing or sketch on paper, use a digital drawing program, or create a 3D model/prototype of their invention as a final product. Things for students to consider when designing their invention is the location or environmental conditions.

Solar Car Races: Hands-on Project

Solar powered cars are mostly used for racing and there are very few production solar powered cars or vehicles. Solar power cars have proven to be challenging for engineers to design because of the large size of solar cells needed to provide adequate power. For this activity, students will design and build a solar car to race against another student or team. Solar car kits can be purchased online and should include a base, wheels, motor, battery, and solar cell. Students can work in partners or individually and build solar cars before racing them. This activity is best outside on a sunny day, or you can use a UV flashlight to race solar cars indoors. Things for students to consider when building their solar car are the size and placement of the solar cell. This is a variable students can explore and try to find the best angle or direction to face the solar cell.

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Appendix on Implementing District Standards

NAGC Standards: Evidence-Based Practices

- 3.1.3. Educators adapt, modify, or replace the core or standard curriculum to meet the interest, strengths, and needs of students with gifts and talents and those with special needs such as twice exceptional, highly gifted, and English language learners.
- 3.1.4. Educators design differentiated curriculum that incorporates advanced, conceptually challenging, in-depth, and complex content for students with gifts and talents.
- 3.4.2. Educators provide opportunities for students with gifts and talents to explore, develop, or research in existing domain(s) of talent and/or in new areas of interest.
- 3.4.3. Educators use models of inquiry to engage students in critical thinking, creative thinking, and problem-solving strategies, particularly in their domain(s) of talent, both to reveal and address the needs of students with gifts and talents.

Oklahoma Academic Standards (Science)

- Standard 1: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- Standard 2: Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
- Standard 3: Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.
- Standard 4: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
- Standard 5: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
- Standard 6: Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
- Standard 7: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
- Standard 8: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and our of organisms.

Oklahoma Academic Standards (English Language Arts)

- Standard 1: Speaking and Listening- Students will speak and listen effectively in a variety of situations including, but not limited to, responses to reading and writing.
- Standard 3: Critical Reading and Writing- Students will apply critical thinking skills to reading and writing.
- Standard 4: Vocabulary- Students will expand their working vocabulary to effectively communicate and understand texts.
- Standard 7: Multimodal Literacies- Students will acquire, refine, and share knowledge through a variety of written, oral, visual, digital, on-verbal, and interactive texts.
- Standard 8: Independent Reading and Writing- Students will read and write for a variety of purposes including, but not limited to, academic and personal, for extended periods of time.

Notes

[1] (“System of Registries | US EPA,” n.d.)

[2] (“What Is Green Power? | US EPA” 2024)

[3] (Sneideman and Twamley 2024, 13)

[4] (US News n.d.)

[5] (United States Environmental Protection Agency 2013)

[6] (“System of Registries | US EPA,” n.d.)

[7] (Sneideman and Twamley 2024, 17-18)

[8] (Kisela 2022)

[9] (“Passive Solar Technology Basics,” n.d.)

[10] (“Why We Need to Decarbonize Transportation | US EPA” 2023)

[11] (“Solar Integration: Solar Energy and Storage Basics,” n.d.)

[12] (Unknown 2021)

[13] (Lozanova 2024)

[14] (“The Energy Sciences Institute: Developing Tomorrow’s Energy” 2016)

[15] (Villamar 2023)

[16] (Brown 2023)

[17] (“Solar-Plus-Storage 101,” n.d.)

[18] (Sneideman and Twamley 2024, 23)

[19] (Crail 2023)

[20] (“Alternative Fuels Data Center: Hydrogen Production and Distribution,” n.d.)

[21] (“What is renewable energy storage” 2023)

[22] (Goldstein-Rose 2020, 131-133)

[23] (“The Energy Sciences Institute: Developing Tomorrow’s Energy” 2016)

[24] (Sneideman and Twamley 2024, 19, 23)

[25] (“Passive Solar Homes,” n.d.)

[26] (Sneideman and Twamley 2024, 29)

[27] (Sneideman and Twamley 2024, 19)

[28] (“History | World Solar Challenge 2025,” n.d.)

[29] (Goldstein-Rose 2020, 117)

[30] (“Learn About Green Vehicles | US EPA” 2023)

[31] (“Why We Need to Decarbonize Transportation | US EPA” 2023b)

[32] (Prisco 2024)

[33] (Goldstein-Rose 2020, 117)

[34] (Figure 1)

[35] (Sneideman an