Lesson Title: Clean Energy

Lesson Overview: This lesson will cover the following topics:

- Concepts of renewable energy and clean energy.
- Types of clean energy and harvesting methods for each type.
- How a fuel cell works.
- How to break up water molecules to obtain hydrogen and use hydrogen to fuel cars.
- How to harvest solar energy and use solar energy to drive cars.

Lesson Objectives:

- Students will understand the Atomic Theory and how electrons move to create electricity.
- Students will be able to identify forms of alternative energy such as Hydrogen, water, and wind energy.
- Students will explore the components of a fuel cell and use solar energy to power a vehicle.

NSF Subject Classification: Engineering, Chemistry

National Next Gen Standards:

- **HS-PS1-1 Matter and its Interactions**

  Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

- **HS-PS3-3 Energy**

  Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

- **HS-PS4-3 Waves and their Applications in Technologies for Information Transfer**

  Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

North Dakota Standards:

- **Performance Standard HS-PS3-3** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

- **Performance Standard HS-ET1-1** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

- **Performance Standard HS-ET1-2** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Grade or Grade Band: Grades 9-12

Time Needed (estimate): 50 minutes per topic (2 topics)

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Scientist/K12 Collaborator & University: K12 Collaborator: Daniel Tuhy (9-12 Science, Minnewaukan Public School)

Scientist Bio: Majura Selekwa - Associate Professor at North Dakota State University, **Research Interests:** Control Systems, Dynamics, Robotics & Mechatronic Systems.

Summary of Research and/or Problem Being Studied: With the uncertainty and stability of fossil fuel prices and availability, it is more important than ever to develop alternative energy sources to power our future. These lessons will allow students to explore the possibilities of wind, solar, and hydrogen fuel power sources. Students will first design a wind turbine blade to generate the most electricity while following specific parameters. Then, students will build and test a hydrogen fuel cell vehicle to discover the possibilities of using hydrogen gas to power a vehicle.

Topic #1 "Atoms, Electrons, and Electricity" Preparation/Materials

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Background knowledge students must have to be successful: Students should have a basic understanding of the structure of atoms and the characteristics of electrons. This material can be reviewed in the accompanying PowerPoint on slides 3-9.

Essential Terminology:

1. **atom-** the smallest component of an element

*All elements are composed of tiny indivisible particles called **atoms**.*
the smallest part of an element that retains its identity in a chemical reaction

2. **atomic theory-** a theory of the structure of the atom

*According to Dalton's **atomic theory**, atoms of different elements can physically mix together or chemically combine in simple whole-number ratios to form compounds.*
John Dalton, and English chemist and school teacher, used hypotheses and theories to form the first scientific theory of atoms.

3. **electron-** an elementary particle with negative charge

***Electrons** are distributed around the nucleus of the atom and occupy almost all the volume of the atom.*
Electrons are negatively charged subatomic particles.

4. **cathode ray-** a beam of electrons emitted by the cathode of an electrical discharge tube

*A **cathode ray** is deflected by either a magnet or electrically charged metal plates.*
a glowing beam of electrons that passes from a cathode to an anode within a vacuum tube

5. **proton-** a stable particle with positive charge

***Protons** and neutrons form the nucleus of an atom.*
protons are positively charged subatomic particles

6. **neutron-** a subatomic particle with zero charge

*Although protons and **neutrons** are exceedingly small, theoretical physicists believe that they are composed of yet smaller particle called quarks.*
neutrons are subatomic particles with no charge

7. **nucleus-** the positively charged dense center of an atom

*Protons are fundamental particles found inside the atomic **nucleus** that can be focused much more accurately than X-rays.*
The nucleus is the tiny central core of an atom and is composed of protons and neutrons.

8. **atomic number-** quantity of protons in the nucleus of an atom of an element

*The number of neutrons in an atom is the difference between the mass number and **atomic number** for that atom.*
The atomic number is the number of protons in the nucleus of an atom of that element.

9. **mass number**- the sum of the number of neutrons and protons in an atomic nucleus

*The composition of any atom can be represented in shorthand notation using atomic number and **mass number**.*
The total number of protons and neutrons in an atom is called the mass number.

10. **isotope-** atom with same atomic number, different number of neutrons

*Because **isotopes** of an element have different numbers of neutrons, they also have different mass numbers.*
Isotopes are atoms that have the same number of protons but different numbers of neutrons.

11. **atomic mass unit-** unit of mass for expressing masses of atoms or molecules

*The mass of a single proton or neutron is about 1 amu (**atomic mass unit**).*

The atomic mass unit (amu) is defined as one twelfth of the mass of a carbon-12 atom.

12. **atomic mass-** the property of an atom that causes it to have weight

*You can calculate **atomic mass** given the number of stable isotopes of the element, the mass of each isotope, and the natural percent abundance of each isotope.*

The atomic mass of an element is a weighted average mass of the atoms in a naturally occurring sample of the element.

13. **periodic table-** arrangement of chemical elements according to atomic number

*Each horizontal row of the **periodic table** is called a period.*

A periodic table is an arrangement of elements in which the elements are separated into groups based on a set of repeating properties.

14. **period-** the interval to complete one cycle of a repeating phenomenon

*In the periodic table, the number of elements per **period** ranges from 2 (hydrogen and helium) in **Period** 1, to 32 in **Period** 6.*

Each horizontal row of the periodic table is called a period. There are 7 periods in the modern periodic table. Within a given period, the properties of the elements vary as you move across it from element to element. This pattern of properties then repeats as you move to the next period.

15. **group-** any number of entities (members) considered as a unit

***Group** 2A contains the elements beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), and radium (Ra).*

Each vertical column of the periodic table is called a group, or family. Elements within a group have similar chemical and physical properties. Each group is identified by a number and the letter A or B which represent specific trends in the periodic table.

Resources: Science Olympiad "Wind Power"

Websites: https://www.soinc.org/wind-power-b

https://scioly.org/wiki/index.php/Wind_Power

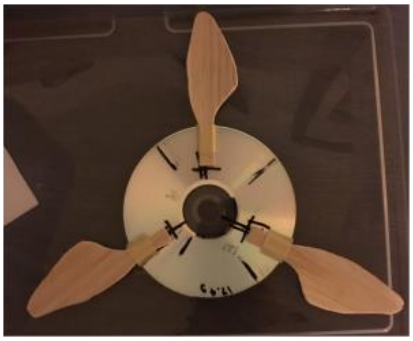
Materials needed:

-Wind turbine testing apparatus, found at wardsci.com.
https://www.wardsci.com/store/product/16981206/2016-2017-science-olympiad-wind-turbine

- Box Fan

-Multimeter
-multiple CD disks
-materials for constructing fan blades such as cardboard, cardstock, paper plates, or pie tins
-adhesive materials such as various types of tapes and glues

PowerPoint – found as separate attachment



Procedure/Activities

Lesson 1: Students will use the provided materials to create a wind turbine that will generate the most electricity using wind power from a box fan. The electricity will be generated using the wind turbine testing apparatus with attached multimeter to read the resulting voltage. The provided materials will be shaped into turbine blades by the students and attached to a CD disk which may not be modified. The turbine may not have an overall diameter of more than 40 cm. Students may have as few or as many attempts as the teacher allows to create a competitive atmosphere.

Extensions for above average students: The teacher may require readings from multiple speeds of the fan, taking an average voltage from the multiple speeds. This will require students to think about blade designs that are best for lower wind speeds.

Mediation/Support for students that need it: Teachers may provide blade design templates commonly found online, to students that are struggling to design their own.

Lesson Outline (for research-based lessons)

1) Observe Phenomena
2) What questions should we be able to answer?
3) Write a Hypothesis
4) Come up with a Research Plan
5) Carry out investigation
6) Revisit the Background Research
7) Construct Explanations. (TASKS-Publish/Communicate Findings)

Topic #2 "Test the Performance of the Fuel Cell Car"
Preparation/Materials

Background knowledge students must have to be successful: Students should understand how a hydrogen fuel cell works and how the energy produced by the fuel cell is used to power electric motors.

Essential Terminology:
Alkali: A chemical "base" (loosely, the opposite of an acid). Certain types of alkalis (especially potassium hydroxide) have been used as fuel cell electrolytes.
Anion: A negative ion. Alkali, molten carbonate and solid oxide fuel cells are "anion-mobile" cells – anions migrate through the electrolyte toward the anode.
Anode: One of two electrodes in a fuel cell or battery. In a fuel cell it is where the fuel reacts or "oxidizes", and releases electrons.
Capital Cost: The purchase price of a power generating system.
Carnot Limit: A theoretical limit on the efficiency of an engine based on the flow of heat between two reservoirs. Named for its discoverer Sadi Carnot (1796-1832) of France, this limit stems from basic physical laws and applies to all steam engines. Fossil fuel and nuclear power plants are bound by this limit, but most fuel cells are not.
Catalyst: A substance that causes or speeds a chemical reaction without itself being affected.
Cathode: One of two electrodes in a fuel cell or battery. In a fuel cell, it is where oxygen (usually taken from the air) "reduction" occurs.
Cation: A positive ion. Phosphoric acid and PEM fuel cells are "cation-mobile" cells – the cation migrates through the electrolyte toward the cathode.
Cogeneration: The use of waste heat from industrial processing, a steam turbine, or a fuel cell to generate electricity. Harnessing otherwise wasted heat boosts the efficiency of power-generating systems.
Direct Fuel Cell: A type of fuel cell in which a hydrocarbon fuel is fed directly to the fuel cell stack, without requiring an external "reformer" to generate hydrogen.
Electrode: An electrical terminal that conducts an electric current into or out of a fuel cell.
Electrolyte: A chemical compound that conducts ions from one electrode to the other inside a fuel cell.
Electron: A sub-atomic particle carrying a negative charge.
Fuel Cell: A device for generating electricity by the chemical combination a fuel and oxygen.
Generating Capacity: The maximum amount of electric power produced by a generator.
Graphite: A soft form of the element carbon. It is used for pencil leads, as a lubricant, as a moderator in nuclear reactors, and for other products. It does not burn easily or fuse at high temperatures, and is an important material in the construction of phosphoric acid fuel cells.
Hydrogen: A chemical element consisting of one proton and one electron. Two hydrogen atoms combine with one oxygen atom to form a molecule of water. Hydrogen serves as the fuel for most fuel cells.
Inverter: A device used to convert direct current electricity produced by a fuel cell (or other source) to alternating current.
Ion: An atom that carries a positive or negative charge due to the loss or gain of an electron.
kW: Kilowatt (1,000 watts). A measure of electric power.
kWh: Kilowatt-hour (1,000 watts for one hour). A measure of electric power consumption.
Matrix: A framework within a fuel cell that supports an electrolyte.

Molten Carbonate: A type of fuel cell electrolyte that contains carbon, oxygen and another element. Solid at room temperature, it must be melted in order to function.
MW: Megawatt (1,000,000 watts). A measure of electric power.
MWh: Megawatt-hour (1,000,000 watts for one hour). A measure of electric power consumption.
Nafion: A sulfuric acid in a solid polymer form. It is usually the electrolyte of PEM fuel cells.
O&M Costs: Operations and Maintenance. The cost of keeping a power plant running and in good repair.
Oxygen: A chemical element consisting of eight protons, eight neutrons and eight electrons. Two hydrogen atoms combine with one oxygen atom to form a molecule of water.
Peak Load: The maximum demand for electricity from an electrical system in a given period of time.
Phosphoric Acid: A solution of the elements phosphorus, hydrogen, and oxygen that serves as the electrolyte for one type of fuel cell. Chemically: $4H_3PO_4$.
Polymer: A natural or synthetic compound composed of repeated links of simple molecules.
Potassium Hydroxide: A solution of the elements potassium, hydrogen, and oxygen that serves as the electrolyte for one type of fuel cell. Chemically: KOH.
Proton Exchange Membrane (PEM): A polymer sheet that serves as the electrolyte in one type of fuel cell.
Reformer: A device that extracts pure hydrogen from hydrocarbons.
Regenerative Fuel Cells: Several fuel cell types in which fuel and, in some types, the oxidant are regenerated from the oxidation product.
Solid Oxide: A solid combination of oxygen and another element (often zirconium) that serves as the electrolyte for one type of fuel cell.
Stack: Individual fuel cells connected in series within a generating assembly.

Websites: **https://www.youtube.com/watch?v=LSxPkyZOU7E**

Materials needed:
-Hydrocar Fuel Cell Car found at https://www.homesciencetools.com/product/hydrocar-fuel-cell-car-science-kit/?gclid=CjwKCAjw97P5BRBQEiwAGflV6ZolE0lkhxTpMPuSVVwdwq1yr48t8_7kk9wpdDSyDbW9tdxmGURS3BoCUYAQAvD_BwE
-Distilled water

PowerPoint – found as separate attachment

Procedure/Activities

Lesson 1: Students will follow the building instructions included with the kits to build their hydrogen fuel cell cars. Students will then fill their cars with distilled water and connect their car to a power source to generate hydrogen gas. When the car has generated adequate hydrogen gas, the power source will be disconnected, and the car will be able to drive using only the hydrogen gas generated and the fuel cell on board the car.

Extensions for above average students: Students may be able to calculate the efficiency of the hydrogen fuel cell by determining the amount of electricity needed to produce the hydrogen gas.

Mediation/Support for students that need it: The teacher may pre-build the model cars ahead of time to help students that need extra support.

Lesson Outline (for research-based lessons)

1) Observe Phenomena
2) What questions should we be able to answer?
3) Write a Hypothesis
4) Come up with a Research Plan
5) Carry out investigation
6) Revisit the Background Research
7) Construct Explanations. (TASKS-Publish/Communicate Findings)

Topic #3 "Fuel Cells with Solar Energy" Preparation/Materials

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Background knowledge students must have to be successful: Students should understand how a hydrogen fuel cell works and how the energy produced by the fuel cell is used to power electric motors. For more information, please view the video on slide 19 of the accompanying PowerPoint.

Essential Terminology: The Essential Terminology will be the same as that from the previous topic (topic #2).

Websites: https://www.ucsusa.org/resources/how-solar-panels-work

Materials needed: The materials will be the same as from the previous topic, except this time they will be using solar power to generate the electricity needed to generate hydrogen gas for the fuel cell.
-convergent lenses
-multimeter
-light source

PowerPoint – found as separate attachment

Procedure/Activities

Lesson 1: Students will use the car built in the previous topic, this time they will use solar energy from the provided solar panel to produce the electricity needed to generate hydrogen gas for the fuel cell. Students will follow the instructions to connect the solar panel to their cars. Once connected, the students will use the convergent lens in conjunction with their light source to charge their solar panel. They will focus the light source on their solar panel until enough hydrogen gas is produced to power the vehicle.

Extensions for above average students: Above average students may use the multimeter to experiment with multiple light sources and lenses to determine the most efficient method of producing electricity.

Mediation/Support for students that need it: Students that need support may benefit from the teacher building the vehicle and attaching components for them.

Lesson Outline (for research-based lessons)

1) Observe Phenomena
2) What questions should we be able to answer?
3) Write a Hypothesis
4) Come up with a Research Plan
5) Carry out investigation
6) Revisit the Background Research
7) Construct Explanations. (TASKS-Publish/Communicate Findings)

Additional Lesson Resources / Materials

References:

Wind Power, Science Olympaid, www.soinc.org/wind-power-b.

"Wind Power." *Scioly.org*, scioly.org/wiki/index.php/Wind_Power.

Toyota Europe. "TOYOTA Fuel Cell - How Does It Work?" *YouTube*, 14 Nov. 2014, www.youtube.com/watch?v=LSxPkyZOU7E.

"How Solar Panels Work." *Union of Concerned Scientists*, 11 Sept. 2015, www.ucsusa.org/resources/how-solar-panels-work.

Websites for purchasing materials

Wind Turbine tester: https://www.wardsci.com/store/product/16981206/2016-2017-science-olympiad-wind-turbine

Hydrogen Fuel Car Kit: https://www.homesciencetools.com/product/hydrocar-fuel-cell-car-science-kit/?gclid=CjwKCAjw97P5BRBQEiwAGflV6ZolE0lkhxTpMPuSVVwdwq1yr48t8_7kk9wpdDSyDbW9tdxmGURS3BoCUYAQAvD_BwE