Chemical Differences in Emergency Energy Sources Unit Overview

Examining Hurricane Maria's effect on Puerto Rico's power grid as a phenomenon to investigate energy resilience

AUTHOR

Melody Childers

DESCRIPTION

Students develop atomic and molecular models of energy resources, analyze combustion of various fuels and build circuits with Photovoltaic (PV) modules to evaluate and suggest revisions to a disaster preparedness supply list. They then research and evaluate the impacts of converting natural resources into PV cells. Finally, students engineer a hand warmer that uses an exothermic chemical reaction to meet defined criteria. The unit employs varying reading levels, unique formatting of information resources, and open-ended processes for model development as differentiation tools. Some students will develop complex mathematical models, while others will build conceptual understandings, depending upon their readiness. The forms of the modeling utilized differentiation for an array of learning styles: hands-on manipulatives, drawing, verbal, and written modeling of atomic and molecular structure and thermal energy. This unit includes a circuitry exploration activity with suggestions for extension by using additional lessons in the CE online educator library, authored by other teachers.

GRADE LEVEL(S)

7, 8

SUBJECT AREA(S)

atomic and molecular structure, circuits, thermal energy, PV cells, engineering, design, inquiry, chemistry, natural resources, conservation of mass, energy transformations, models, combustion

LEARNING GOAL(S)

1. To build empathy for people in emergency situations and an understanding of how access to energy resources can increase one's safety, health, and comfort.
2. To understand the nature of a variety of energy needs and how different applications have different optimal solutions.
3. To develop models to explain the molecular and extended structures of energy resources, including how the resources change when energy is generated (Electron movement in PV cells, combustion reactions in fuel).
4. To understand that the properties of substances depends upon the atomic / molecular structure, which changes with chemical reactions.
5. To build a circuit that includes a solar module and measure the voltage and current.
6. To gather and evaluate information to describe the impact on society of converting natural resources into PV cells.
7. To design, build and test a device that uses a chemical reaction to generate or absorb thermal energy.
8. Evaluate and revise a plan for the energy resources one should store to prepare for a natural disaster.

UNIT EXPERIENCES

Table 1. Suggested Teaching Times.

Lesson/Experience	Time
Engage/Explore	
L1: When the Grid Goes Down and Stays Down	80 min (1 hr 20 min)
Explain	
L2: Developing a Model of Thermal Energy, Atoms, and Molecules	80 min x 11 = 880 min (14 hr 40 min)
L3: Fuels and PV Cells	80 min x 4 = 320 min (5 hr 20min)
Elaborate/Evaluate	
L4: Research and Evaluate the Impact on Society of Converting Natural Resources into PV Cells.	80 mins x 3 = 240 min (4 hr)
L5: Engineering a Hot Pack	80 mins x 4 = 320 min (5 hr 20 min)
Total	30 hr 40 min

Guiding Phenomenon	Examine the conditions in Puerto Rico following Hurricane Maria to understand the needs that existed in this situation and how our understanding of chemistry and energy resources can help one become more prepared for natural disasters.	
Supplementary Phenomena	What makes water so hard to heat?	
	Is all fire the same?	

Table 2. Next Generation Science Standards Assessed in This Unit

Performance Expectation	**How is this Assessed?**
MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures.	L2: Students will use drawings and 3D models to represent atoms, molecules, and crystalline structures. Students will be assessed on their explanation of how the model accurately represents these structures as we understand them to exist, while differentiating them from how these structures function in reality.
MS-PS1-2: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	L3: Students will compare and contrast properties of fuels and water in the context of survival settings before and after interactions to classify processes as physical or chemical changes.
MS-PS1-5: Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.	L3: Students will analyze chemical reactions for combustion reactions, both mathematically and with manipulatives, to illustrate that the same atoms exist before and after the chemical change(s) occur.
MS-PS1-4: 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.	L2: Students engage in collaborative inquiry to characterize the changes in temperature when water is heated, particularly in the context of cooking and sterilization.

MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	L4: Students describe the process of obtaining energy from PV cells, evaluating the impact on societies to both harness and use solar energy.
MS-PS1-6: Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.	L5: Students, design, construct, test, evaluate, and redesign a hand warmer device to meet criteria and constraints.
MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	L5: Gain sufficient background knowledge to define the criteria and constraints of the problem. L5: Present mathematical evidence that the proposed device will generate thermal energy in the required range.
MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	L5: Systematically compare results for different iterations of the hand warmer to select the design features that best meet the criteria.
MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	L5: Complete two full iterations of the engineering design cycle to create chemical hand warmers, comparing the costs and benefits of each in regard to meeting the criteria for success.
MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	L5: Design a testing procedure for a chemical hand warmer to produce data that can be used to evaluate the device's effectiveness.

THREE DIMENSIONAL LINKAGES

NGSS focuses not only on content, but also on process and on building bridges between concepts within and across disciplines. The following tables outline the way in which this unit addresses this three-dimensionality.

Table 3. Three-Dimensionality: Disciplinary Core Ideas (DCIs)

Disciplinary Core Ideas	**Linkage in Unit**
PS1.A: Structure and Properties of Matter Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. Gasses and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.	L2-L3: Students construct an understanding of atomic and molecular structures, including during changes in temperature, toward the goal of developing an energy readiness plan for a natural disaster situation.
PS1.B: Chemical Reactions Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others store energy.	L3: Students will focus on combustion to develop an understanding of energy being stored in chemical bonds, which can be used later in a variety of situations (burning fossil fuels, consuming food, etc.). Additionally, students will use models to demonstrate how atoms are regrouped in chemical reactions.

PS3.A: Definitions of Energy The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary to MS-PS1-4) The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material.	L2: Students investigate energy transfer involved in heating water. L5: Students evaluate the amounts of matter used in their designs of a hand warmer and the how that related to the measured temperature change.
ETS1.B: Developing possible solutions A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. Models of all kinds are important for testing solutions.	L5: Students will design, build, and evaluate a hand warmer.

ETS1.C: Optimizing the design solution Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3) The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)	L5: Students will evaluate testing results and redesign their hand warmer.

Table 4. Three-Dimensionality: Science and Engineering Practices (SEPs)

Science and Engineering Practices	**Linkage in Unit**
Developing and using models	L2: Modeling molecular and extended structures L3: Modeling regrouping of atoms in chemical reactions L3: Modeling PV cells
Analyzing and Interpreting Data	L2: Explaining water's heat curve data using models of molecular kinetic energy; analyzing substances before and after interaction to determine if a chemical reaction occurred. L5: Analyzing results from testing hand warmer.
Constructing Explanations and Designing Solutions	L3: Explain the reasoning for including each item in the energy preparedness inventory. L5: Design solutions for the hand warmer design; explain rationale for design decisions. L2: Use data to predict the amount of time required to boil a sample of water; practice claim, evidence, reasoning; collaborative inquiry.
Obtaining, Evaluating, and Communicating Information	L4: Students research and communicate the impact of producing and using PV cells.
Asking questions and defining problems	L3: Students will ask questions about chemical reactions, solar modules, circuits, and loads. L3: Students will ask questions about needs that can be met by various portable energy resources.

Constructing explanations and designing solutions	L3: Students explain the effects of changing solar modules on the performance of a device. L3: Student explain how PV cells convert light energy into electrical energy. L5: Students explain their results and redesign their first iteration to optimize outcomes.
Developing and using models	L2: Students develop models to explain simple and extended structures. L3: Students develop and use a model to understand chemical reactions and the PV effect.
Obtaining, Evaluating, and Communicating Information	L4: Students will research and evaluate the impact on society of converting natural resources into PV cells, compared to the impact of fossil fuels. L3: Students communicate a plan for energy preparedness.
Engaging in argument from evidence	L2: Students will present their evidence-based claim for a prediction of how long it will take for a sample of water to boil. L5: Students will present evidence from testing their hand warmer and argue the value of their design. L3: Students will argue the value and appropriate use of the portable energy resources recommended in their preparedness plan.
Analyzing and interpreting data	L2: Analyze and interpret data to make a prediction in water heating lab. L3: Analyze data to evaluate the performance of their hand warmer.

Table 5. Three-Dimensionality: Cross Cutting Concepts (CCCs).

Crosscutting Concepts	Linkage in Unit
Cause and effect: mechanism and prediction	L5: Student will use cause and effect as they problem solve through the building of the hand warmer.
Scale, proportion, and quantity	L2: Students will use scale and proportions as they model molecular and extended structures as well as the effect of scale on heating water to boiling. L5: Scale, proportion and quantity of reactants required to generate desired temperature change.
Influence of science, engineering, and technology on society and the natural world	L1: Impact of natural disaster on safety, health and comfort of a community before and after a natural disaster. L4: Students will research and communicate the impact of producing PV cells on the environment and on people.

	L3: Students will articulate the benefit of obtaining and storing specific types and quantities of energy resources based on their understanding of the characteristic of each resource.

COMMON CORE STATE STANDARDS

- CCSS.ELA-LITERACY.WHST.6-8.1. Write arguments focused on discipline specific content.
- CCSS.ELA-LITERACY.WHST.6-8.1.B. Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.
- CCSS.ELA-LITERACY.WHST.6-8.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
- CCSS.ELA-LITERACY.WHST.6-8.9. Draw evidence from informational texts to support analysis, reflection, and research.

CONTENT BACKGROUND

STUDENT BACKGROUND

At the start of this unit, students are expected to have some familiarity with the following scientific practices:

- The engineering design process
- Reading non-fiction text for detail and understanding
- Inquiry: interpreting graphs, developing explanations of data to incorporate background knowledge (Claim, Evidence, Reasoning), developing procedures and identifying variables.

EDUCATOR BACKGROUND

ENGINEERING DESIGN CYCLE

There are many variations on the design cycle. One that has been developed by the Hasso Plattner Institute of Design at Stanford (https://engineering.stanford.edu/get-involved/give/hasso-plattner-institute design) uses the steps:

- Empathize
- Define
- Ideate
- Prototype
- Test

The portion of this design cycle that suits this project exceptionally well is “empathize.” When teaching students to imagine what it might be like to be off-grid for an extended time, or “define the problem” in NGSS terms, it is a perfect opportunity to encourage students to think beyond their own wants and consider how one can use technology to increase the safety, health, or comfort of others. Launching the unit with videos highlighting the situation on Puerto Rico following Hurricane Maria will provide perspective of the struggles faced when people who are accustomed to reliable modern technology are suddenly without. It is from this perspective that students then learn about the properties of energy resources in a chemical context.

ELECTRICAL BACKGROUND KNOWLEDGE

This unit depends on students developing an understanding of the relationship between atomic and molecular structure of energy resources and our ability to use the resource for our safety, health, or comfort. Students will begin to explore the concepts of power, voltage, and current, and how these values relate to each other and determine the devices that can run on a given circuit. Students have a general understanding that bigger devices require more energy and will begin to explore this mathematical relationship expressed as P=IV.

An introductory video that goes much more in depth than this unit plan requires is available here: https://youtu.be/mc979OhitAg (“How Electricity Works by “The Engineering Mindset”). Power (P) is the ability to do work in a given amount of time, or energy used per unit of time. The unit, watts, is 1 joule per second. Devices are rated on their power demand. A 40W light bulb continuously demands 40W to light up. Solar modules are rated on the watts that they can produce in peak sun conditions. A portable module that measures 16” x 20” might be rated for 25W, while a large panel that is part of a home installation is typically rated for 200W.

Current (I) is the rate at which charge is flowing through a circuit. It is measured in amps. Batteries with a finite amount of charge are rated in amp hours, or milliamp hours, depending on the size of the battery. A small deep cycle 12V battery for a motorcycle might be rated for 7 amp hours. It can provide one amp for 7 hours or 7 amps for one hour. This information will help students to understand that portable batteries are ideal for charging devices or generating light, but insufficient for needs such as providing warmth, sterilizing water by heat, or cooking.

Example: 12V battery, 7 amp hours: If students want to run an LED light (4W /12V = 0.33 amps) and an electric blanket (50W /12V = 4.16 Amps), for the purpose of living without home electricity after an earthquake, they are drawing a total of 4.69 amps. They would either run out of energy after just under 90 minutes, or they need a larger battery bank.

Voltage is the difference in electric potential between two points. Just as a cart at the top of a hill has gravitational potential energy, the electrons in the negative terminal of a battery have potential energy. The greater the difference in potential between the terminals, the higher the voltage. The voltage of a single discrete solar cell is 0.5 V, always. To have more voltage, solar cells are assembled into modules (often called "panels"), and modules can be strung together into large-scale arrays.

The flow of electricity is often compared to running water. In this analogy, the battery, solar module or outlet would be a pump that creates pressure in a pipe. In this example, the pressure pushing on the water in the pipe is the *voltage* and the power combines the pressure and the motion to make the water turn a mill wheel.

PV GENERATION:

PV cells absorb sunlight in photons of the exact energy needed to excite an electron out of the outer electron orbital of an atom. The electron is then drawn to the opposite side of the PV cell. This potential difference is created by doping (introducing impurities) the silicon (four valence electrons) with an element with 5 valence electrons (phosphorus) on the top layer and three valence electrons (such as boron) on the bottom layer. When photons enter the impure silicon crystal, the "extra" valence electron is excited and kicked free within the crystal. If you apply the analogy of a battery, this "N-type" layer makes the negative pole electrode.

On the bottom layer, the introduction of boron to the silicon crystal means that the crystal structure has vacancies in the valence shells. These vacancies are called holes. The positive electronegativity of these holes draws neighboring electrons.

When the two layers are connected in a PV cell, the electrons diffuse to fill holes in the crystal until a potential barrier is formed and additional electron movement is prevented. This process forms a depletion layer. The depletion layer prevents electrons from crossing directly from the n-type layer to the p type layer until sunlight hits the p-n junction and knocks an electron free, leaving a positive hole.

The excited electron flows around the depletion layer from the N-type silicon into the P-type silicon. This is a one-way flow that will make a complete circuit that can flow with the input of sunlight.

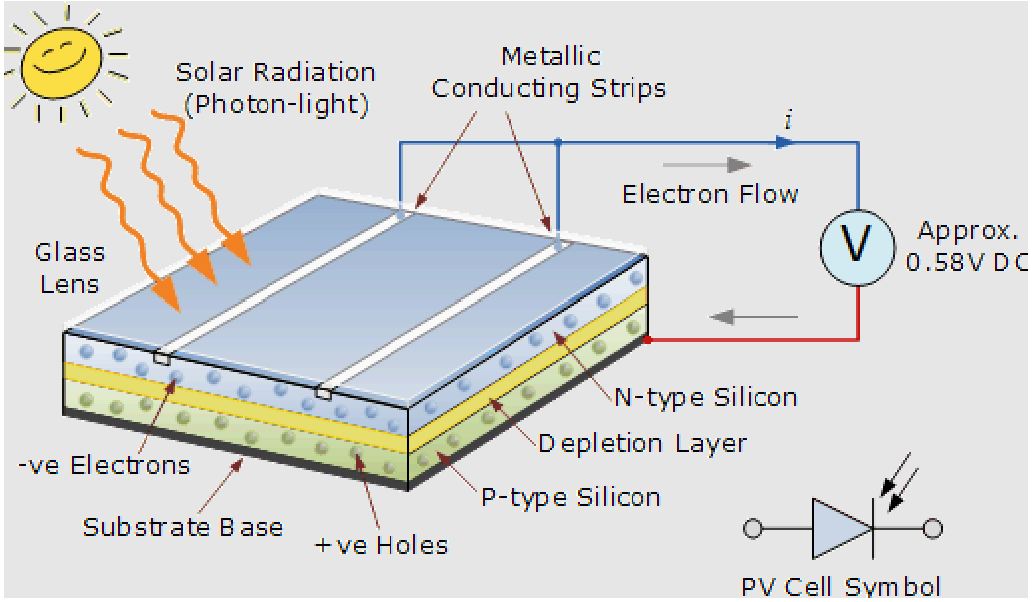

Image credit: Alternative Energy Tutorials
(http://www.alternative-energy-tutorials.com/images/stories/solar/alt3.gif)

CHEMISTRY BACKGROUND KNOWLEDGE:

This unit draw heavily from the Middle School Chemistry (http://www.middleschoolchemistry.com/) curriculum made available freely by the American Chemical Society. A goal of this unit is to contextualize many of the topics and projects from this curriculum. Additionally, there are some aspects of the ACS curriculum that are not in the NGSS performance expectations. This unit seeks to streamline the concepts and content while creating the phenomenon-based storyline. It is advised that teachers familiarize themselves with chapters 1 and 2, along with portions of chapters 4, 5, and 6 linked in the daily lesson plans of this unit.

VOCABULARY

Amp	Ampere; unit of measurement for electric current
Amp Hour	The current potential of a battery or battery bank in reference to an hour.
Array	A group of two or more PV modules connected in series or parallel for additional Voltage or Amperage.
Battery Bank	A group of two or more batteries connected in series and or parallel to increase Voltage or Amp Hour capacity.

Circuit	A complete and closed path through which a circulating current can flow
Conductor	A material or object that conducts electricity
Current	The rate at which charge is flowing; measured in amps.
Electricity	A flow of electrons, often through a circuit
Multi-meter	A device to measure the current, voltage, and resistance.
Resistance	The opposition to electrical flow in a material
Voltage	Difference in electric potential between two points
Watt	Unit of electrical power: Joules per second

REQUIRED MATERIALS

HANDOUTS/PAPER MATERIALS

- Lesson 1: When the Grid Goes Down and Stays Down
    - University of Colorado, Boulder article: Students who fled Hurricane Maria face storm of issues on the mainland (https://www.colorado.edu/today/2018/09/17/students-who-fled-hurricane-maria-face-storm-issues-mainland)
    - NPR Article with audio: Desperation in Puerto Rican Town Where 60 Percent are Now Homeless *https://www.npr.org/2017/09/25/553532405/in-puerto-rican-town-situation-turns-dire-at-packed-shelter*
    - CNN news clip with accompanying print article: Puerto Rico'sPower Outages are the Worst in US History *https://www.cnn.com/2017/10/26/us/puerto-rico-power-outage/index.html*
- Lesson 2: Developing a Model of Thermal Energy, Atoms, and Molecules
    - Lab #1: Water Exploration
    - Investigation Planning Sheet
    - Thermal Energy lab report writing guide and rubric
    - Phase change foldable layout and rubric
- Lesson 3: Fuels and PV Cells
    - Combustion Activity handout
    - PV cell extended structure lesson: 3D modeling graphic organizer
    - Powering Small Loads Lab Handout
    - Emergency Preparedness Assessment: Outline for content of product, Assessment Rubric

- Lesson 4: Research and Evaluate the Impact on Society of Converting Natural Resources into PV Cells
    - If students do not have access to internet connected devices, print resources from the links provided in the lesson, or obtain print resources from your local or school library.
    - Research outline for the process of producing PV cells, as well as their impact on the environment and the people who use the resource.
    - Assessment Rubric
- Lesson 5: Engineering a Hot Pack
    - Engineering guide and rubric: Hand warmer project

CLASSROOM SUPPLIES

• Internet-enabled devices for research or library / print resources

• Rulers

• Calculators

• Large (2’x3’) whiteboards and markers, erasers, one per group.

• Index cards covered in wax paper or laminated, one per student

• Brown paper towel

ACTIVITY SUPPLIES (PER GROUP OF 3 - 4 STUDENTS)

• (4) Plastic pipettes

• (3) plastic cups or beakers

• Food coloring, yellow and blue

• Hot plate

• Digital or triple beam balance

• Glass beaker, 150-250 mL

• Beaker tongs

• Graduated cylinder

• Thermometer

• Timer

• 2-quart size Ziploc bags

• Water

• Magnifying glass

• Plastic strips

• 9-volt battery

• Salt

• Isopropyl alcohol

• Multi-meter, one or two per group.

• Alligator clip leads (at least 32 to provide 4 per group of 4 students)

• Solar Modules: provide students 2 each of at least three different voltages. It is reasonable to have 8 sets of varying sizes and have groups trade to assemble different combinations.

- Loads: LEDs, radios, small motors / fans; items that can be modified by swapping in different sizes or numbers of solar modules, and items that students may wish to run with their group designs: radios, toys, etc.
- Rechargeable batteries & chargers
- Hotplates
- Thermometers
- Glass beakers, 100mL - 250mL capacity, 1 - 2 per group.
- Timers
- Balances with 0.1g precision
- Calcium Chloride
- Sodium Polyacrylate
- Candle
- Baking soda

UNIT PROGRESSION

The unit will begin by setting the context for the unit: building empathy for people in natural disaster situations by examining news reports from Puerto Rico after Hurricane Maria. The hurricane occurred on September 20th, 2017. After four months, a million people still didn't have power. After ten months, there are still people without reliable electricity. Knowing that this is reality for a million people, students will brainstorm energy needs and think about how they might provide long term solutions to these needs. At this point, all ideas are accepted without evaluation. We return to this initial brainstorm in lesson three.

Lesson two allows students to develop models to understand that the physical and chemical properties of matter depend upon the atomic and molecular structure of the materials. Students will build the foundation of learning subatomic particles and how they are arranged. In addition, students will examine the changes that occur when heat is added to a substance.

In lesson three, students examine how atoms are rearranged during chemical reactions. This learning continues developing students' understanding of the energy context, examining molecules such as propane and CO_2, and combustion reactions. Students more directly experiment with solar modules and fuels. They will compare the quantities and nature of energy available in easy-to-store sources, such as candles, camp fuel, Sterno, and solar modules. This portion of the unit is differentiated to allow students to build either a conceptual or mathematical understanding of the amounts of energy.

Students will increase the complexity of modeling by using a model of a PV cell to show the movement of electrons between the layers. This portion of the unit culminates with students evaluating and revising a plan for energy preparedness in a natural disaster setting.

The remainder of the unit asks students to apply their learning to evaluate, design, and plan. Lesson four is a Socratic seminar in which students discuss the impacts on the environment and society of obtaining materials for, processing, and using PV cells after researching the topics. If teachers are not familiar with Socratic Seminars, The Literacy Cookbook (https://www.literacycookbook.com/page.php?id=31), by Sarah Tantillo, offers a good starting point for running a Socratic seminar, including checklists and rubrics.

Finally, students will engineer a hand warmer that relies upon the heat generated from a chemical reaction in lesson 5. They are given criteria for success and monitor the impact of various modifications on the strength of their warmer.

LESSON SUMMARIES

LESSON 1: THE NEED FOR ENERGY EMERGENCY PREPAREDNESS

One 80-minute block:

Establish the context for the unit and foster empathy for people coping with extended power outages after natural disasters. Have students brainstorm the needs that would be most crucial to them in situations such as these and how the needs would change as the power outage wears on. Based on existing knowledge, ask students to come up with a reasonable way to meet these energy needs.

LESSON 2: DEVELOP MODELS TO EXPLAIN THE ATOMIC, MOLECULAR AND EXTENDED STRUCTURES OF MATTER; EXPLAIN THE EFFECT OF ADDING THERMAL ENERGY TO A SUBSTANCE

Eleven (11) 80-minute blocks:

Day 1: Students explore properties of water and thermal kinetic energy to begin to develop a model of the atomic nature of matter.

Day 2: Students prepare a concept map from an informational text on thermal energy, molecular motion and phase change.

Day 3-5: Students engage in collaborative inquiry to explore how matter changes as thermal energy is added.

Day 6 -7: Students collect temperature data on water as it transforms from ice to steam and prepare a foldable to model the changes at the molecular level as thermal energy is added.

Day 8: Students explore atomic structure and the periodic table.

Day 9: Students add complexity to their understanding of electron configuration.

Day 10: Students clarify the difference between ionic and covalent bonding. Day 11:

Students explore the polar nature of water.

LESSON 3: HOW DO FUELS AND PV CELLS GENERATE ENERGY?

Four (4) 80-minute blocks:

Day 1: Students will explore combustion reactions to develop an understanding of chemical changes, conservation of mass, energy storage in chemical bonds, and the generation of CO_2 when fuels are burned (as demonstrations).

Day 2: Students explore the variables involved in operating solar modules and the structure of circuits. On a sunny day, students will use multimeters and discover the placement and arrangement of the modules to yield maximum energy transformation. The learning goal is for students to understand the potential application of small, affordable solar modules. Students will build and explain a circuit with a radio and solar module, or make their circuit more complex, depending upon their readiness. They will explain their circuit qualitatively, comparing the effect of swapping larger solar modules into a circuit on the speed of a motor, brightness of a lamp, etc. A fun adaptation for this lesson is to provide students will a variety of battery-operated toys (available low cost at Goodwill). After the qualitative exploration, students will quantify their observation of circuits using multimeters.

Day 3: Once students explore PV modules in circuits, students will examine the structure of PV cells with a 3D model with moving “electrons.” They will read an informational text to support the learning with the model and prepare a representation of their understanding in the form of a diagram and a paragraph.

Day 4: Students work individually to evaluate and revise an energy preparedness plan with justification provided for each of their revisions. A possible summative assessment for this portion of the unit would be to describe the most effective use of different resources that they explore, as they apply to the needs outlined in lesson 1.

LESSON 4: RESEARCH AND EVALUATE THE IMPACT ON THE ENVIRONMENT AND SOCIETY OF CONVERTING NATURAL RESOURCES INTO PV CELLS

Three (3) 80-minute blocks:

Students will engage in guided research to learn about the natural, human, and energy resources involved obtaining, processing, and using PV modules. Students will evaluate the impact on the environment and economy and compare and contrast the impact on people who produce these resources vs. use these resources. Opportunity for differentiation exists in the level of assistance in guiding the research, the language and reading level of the texts, the depth of research, and the product expected. The lesson plan is developed for assessing student understanding during a Socratic seminar, but one could easily adapt this research opportunity to meet writing or speaking requirements for a co-curricular collaboration. This lesson also provides an opportunity to shorten or lengthen the designated time by adjusting the scope of the research or assessment product.

LESSON 5: DESIGN, BUILD, AND EVALUATE A HAND WARMER THAT USES A CHEMICAL REACTION TO RELEASE HEAT.

Four (4) 80-minute blocks

Students will complete guided exploration of the materials available, and then design, build, and test a hot pack that generates heat through an exothermic reaction. This lesson is an engineering lesson written by Susan Holveck, adapted by Berkeley Gabdaw, and based on a similar activity developed for high school students by Jomae Sica. The version shared in this unit involved progressive writing by all three educators.

Day 1: Explore the reaction through guided inquiry.

Day 2: Plan, build and test iteration #1

Day 3: Gallery walk of Claim, Evidence, Reasoning explanations of data from testing of preliminary designs. Redesign, build, and test iteration #2.

Day 4: Complete testing of final design; Evaluate final performance of the hand warmer and suggest further changes for an optimal final design proposal.

ASSESSMENT AND EXTENSIONS

FORMATIVE ASSESSMENTS

Each day will have formative assessment questions that can be asked verbally or turned in on exit slips, written in engineering notebooks, or via digital classroom tools.

Examination of student models and explanations as lessons progress
Whiteboard diagrams, models, and explanations during collaborative inquiry.

SUMMATIVE ASSESSMENTS

Lesson 2: Written or verbal assessment of using models to explain the molecular and extended structure of energy resources; Lab Report: Effects of Adding Thermal Energy to a Substance.

Lesson 3: Students will be evaluated on the scientific accuracy of their recommendations for emergency energy preparedness and the clarity of their justification.

Lesson 4: Preparation for and participation in Socratic seminar

Lesson 5: Completion of two iterations of design cycle, including the use of testing data to inform design changes. Lab workbook and rubric included in unit.

UNIT EXTENSIONS

Lesson 1: Invite an emergency relief organization representative to speak to students about the needs of people following a disaster, or a guest who has lived through a natural disaster.

Lesson 3: Explore the solar battery charging unit in the CE library for a possible additional engineering project that goes more in depth with circuitry.

Lesson 4: Expand the scope of the research to include an examination of the carbon footprint of generating the PV cells, the mining and production of batteries to increase the application of solar electric production, and the application of solar energy in refugee camps, such as the for the Rohingya refugees in Bangladesh (https://www.globalcitizen.org/en/content/rohingya-refugees-solar-panels/). One could also do a side-by-side comparison of solar cells with batteries to current use of fossil fuels.

Lesson 5: Instant cold packs are also a possibility using simple, safe chemical reactions.

Lesson 6: Students collaborate to produce video PSAs. Invite a local relief organization or emergency preparedness organization to a presentation of the final recommendations.

REFERENCES

Allen, Greg, and Marisa Penaloza. "Desperation In Puerto Rican Town Where 60 Percent Are Now Homeless." NPR.org, National Public Radio, 25 Sept. 2017, https://www.npr.org/2017/09/25/553532405/in-puerto-rican-town-situation-turns-dire-at-packed-shelter.

BOSCH Solar How It's Made. (2018). Retrieved from https://www.youtube.com/watch?v=2iRfbWOJtog.

Gabdaw, B. and Holveck, S. (2017). Engineering a Hot Pack (MS-PS1-6).

Galvan, Patti, et al. Middle School Chemistry. 2018, www.middleschoolchemistry.com.

Hasso Plattner Institute of Design at Stanford. "An Introduction to Design Thinking Process Guide." Stanford University, 26 Oct. 2017, dschool-old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf.

How ELECTRICITY works - working principle. (2017). Retrieved from https://www.youtube.com/watch?v=mc979OhitAg&feature=youtu.be

Knier, Gil. "How do Photovoltaics Work?" Science.NASA.gov, NASA, 26 Oct. 2017, science.nasa.gov/science-news/science-at-nasa/2002/solarcells.

Levenson, Eric. "Puerto Rico's power outages are the largest in US history, report says." CNN.com, Cable News Network, 26 Oct. 2017, www.cnn.com/2017/10/26/us/puerto-rico-power-outage/index.html.

New Electric. "QUICK TIP — What's the difference between Amps, Volts and Watts?" New Electric, 26 Oct. 2017, http://www.newelectric.com/whats-the difference-between-amps-volts-and-watts/. No longer available, replaced with: "What Are Amps, Watts, Volts and Ohms?" from How Stuff Works (https://science.howstuffworks.com/environmental/energy/question501.htm)

Northern Arizona Wind & Sun. "Glossary." Northern Arizona Wind and Sun, 26 Oct. 2017, forum.solar-electric.com/discussion/5001/glossary .

"Photovoltaic Solar Cells." Alternative Energy Tutorials, Alternative Energy Tutorials, Oct. 2017, https://www.alternative-energy-tutorials.com/photovoltaics/photovoltaics.html#google_vignette.

"Puerto Rican students face hardships after Hurricane Maria." Newsela.com, Newsela, 4 Feb. 2018, newsela.com/read/puerto-rico-schools-without power/id/40033/. - no longer available - replaced with: Students who fled Hurricane Maria face storm of issues on the mainland, University of Colorado, Boulder (https://www.colorado.edu/today/2018/09/17/students-who-fled-hurricane-maria-face-storm-issues-mainland)

Tantillo, S. (2012). The Literacy Cookbook. Retrieved May 27, 2018, from https://www.literacycookbook.com/page.php?id=31

"Teacher Learning Center." CE Clean Energy Bright Futures, Bonneville Environmental Foundation, 26 Oct. 2017, www.CEbrightfutures.org