LESSON PLAN

Chemical Differences in Emergency Energy Sources

Lesson 3: Fuels and PV Cells

AUTHOR
Melody Childers

DESCRIPTION
Students will return to the phenomena of energy resources to support safety, health, and comfort in an emergency situation. They will distinguish between how common materials provide energy and develop an understanding of how the atomic and molecular structure of the resource differs and leads to different optimal applications of the resource in an emergency situation. Students will evaluate, edit, and justify the items on an emergency preparedness supply list as a summative assessment.

GRADE LEVEL(S)
7, 8

SUBJECT AREA(S)
fuels, combustion reactions, PV effect, model, circuits, conservation of mass

ACTIVITY LENGTH
4 class periods (80- minute class periods)

LEARNING GOAL(S)

1. Students explore the conservation of mass in chemical reactions by observing and modeling combustion reactions and exploring the essential question/phenomena, “is all fire the same?”
2. Students will use information resources and a 3D model of a PV cell to understand how solar modules generate electricity. “How do PV cells make electricity?”

3. Students will construct circuits to explore PV modules and variables involved in powering devices.
4. Students evaluate, revise, and justify the energy resources suggested on an emergency preparedness supply list.

EXPECTED CONTENT UNDERSTANDING

STUDENT BACKGROUND

Students should have demonstrated proficiency in lesson two of this unit. In doing so, they are able to explain:

- how to determine the number of protons, neutrons, and electrons for any element.
- Number of valence electrons an element has and how that affects the molecules that element will form.

EDUCATOR BACKGROUND

Refer to the unit plan document for a review of PV cell structure and function.

REQUIRED MATERIALS

HANDOUTS/PAPER MATERIALS

Day 1:

- Combustion activity guided notes and conclusion sheet

Day 2:

- Lab handout "Powering Small Loads"
- "How to Use a Multimeter Cheat Sheet" student handout

Day 3:

- Powering Small Loads Lab Handout
- Multimeter Cheat Sheet

Day 4:

- Emergency Supply Checklist
- Assessment instructions and rubric

CLASSROOM SUPPLIES

- Large whiteboards
- Whiteboard markers

ACTIVITY SUPPLIES (PER GROUP OF 3 – 4 STUDENTS)

Day 1: Inquiry of Combustion (one set for whole class, or use provided photos and data, if it is not safe, practical, or permitted to have open flames in your classroom)

- (1) Candle
- (1) Glass Jar
- (1) Small can of Sterno (gel denatured ethanol)
- (1) Can of camp fuel, either propane or a mix of butane, isobutane, and propane, with an appropriate burner to attach to the fuel can. Propane is chemically easier to explain fully.
- (3) Metal containers of the same size to heat water (small, shallow backpacking pans worked well. borosilicate beakers were not tested. Glass may or may not tolerate the temperature generated by the camp fuel.)
- (3) Thermometers
- (1) Timer
- (3) Ring stands with rings and clamps

Figure 1 Suggested table top lab set up

Day 2: Powering Small Loads with a PV-Module

- Sunlight, or 250 – 500 W halogen shop lights
- (1) mini battery-powered radio
- (2) alligator test leads
- (1) solar module
- (1) multimeter
- Additional Loads, such as battery-operated toys, LEDs, and fans

Day 3: Modeling Solar Cells

See PV Cell model instructions for model building supply list with source recommendations. You will need:

- Ziploc extra small square containers (2 per model)
- Marbles in two colors (24 per model)
- Clear vinyl tubing, ½”OD, 3/8” ID, 10 - 12” per model
- Seed beads or glass granules, 1 tbsp per model
- Strong clear packing tape
- Hot glue gun with glue
- Drill with bits: one slightly larger than the beads you purchase, one ½”
- Scissors

Day 4: Evaluating a Supply List

- N/A

LESSON PROGRESSION

PLANNING AND PREP

Day 1: Obtain fuels and set up experiment as shown. It is not necessary that the same fuels are used as the author used, but the idea is that students develop proportional thinking about the energy released by various fuels as they combust, making different fuels suitable for meeting different needs.

Day 2: Assemble kits for circuits as outlined in the “Powering Small Loads” lesson by Emily Barrett in the CEbrightfutures.org Educator Library. Plan for an outdoor space in which students can work collaboratively with solar modules, loads, and multimeters and document thinking on a white board.

Day 3: Preview video, copy handouts, assemble models of PV cells. Given the nature of the materials used, it is not recommended that students assemble the models, unless one has very small classes of very mature students.

Day 4: Copy emergency supply list, assessment instructions, and rubric.

LESSON SEQUENCE

Day 1: Chemical Reactions: Combustion

1. **(5 min)** Distribute the guided notes sheet. Begin the slideshow. Pose the question, “Is all fire the same?” Students should talk as table groups and write their initial thoughts on a large whiteboard. (slide 1)

2. **(5 min)** Remind students of the first lesson in the unit and the energy crisis in Puerto Rico after Hurricane Maria. Help students recall the conversation about the needs that they brainstormed and the supplies they came up with that might help in that situation. **(Slides 2-3)**

3. **(10 min)** Discuss the items that were found around "your home." All are combustible fuels, but they each have a different purpose **(slide 4).** On **slide 5**, you introduce the idea of a chemical reaction and lead a demonstration of a burning candle as an example of a chemical reaction. On **slide 6**, you access students' prior knowledge that candles require oxygen to burn. **Slide 7** asks where the wax in a candle holder goes. Students know candles get used up, but many have never thought about where the wax goes. You will explain this on **slides 8 - 10**. Wax is not a chemical compound and has a variable formula. For simplicity, the reaction that you teach is methane. (Balancing equations is not a middle school performance expectation.) Assure your students that as long as they can count the atoms of each element on each side, they have met expectations.

4. **(20 min) (Slides 11 – 16)** The class will do a guided inquiry into which fuel one should stash for emergency preparedness. To make the lab safe and manageable, narrow the fuels down to three. Explain that the three items use different molecules as fuel for combustion. The inquiry question is "For its mass, which fuel will produce the most energy?" **Slide 14** lists supplies and picture the set up. Check that students can identify the independent and dependent variables. Once they have, instruct each table to assemble their setup and explain that they will need to monitor the temperature change in water generated by the burning of their chosen fuel sources.

5. **(20 min)** Agree upon a whole group procedure and collect data. It is helpful to have a volunteer keep time. three more volunteers call out temperatures at the agreed upon intervals, and one student per table write down the data. The data that will help students justify their recommendations are the mass of each fuel container before and after burning and the temperature of a set volume of water at measured time intervals. Some students will be able to calculate the degrees of temperature the water increased per gram of each fuel burned, others will communicate their proportional understanding in a more conceptual manner.

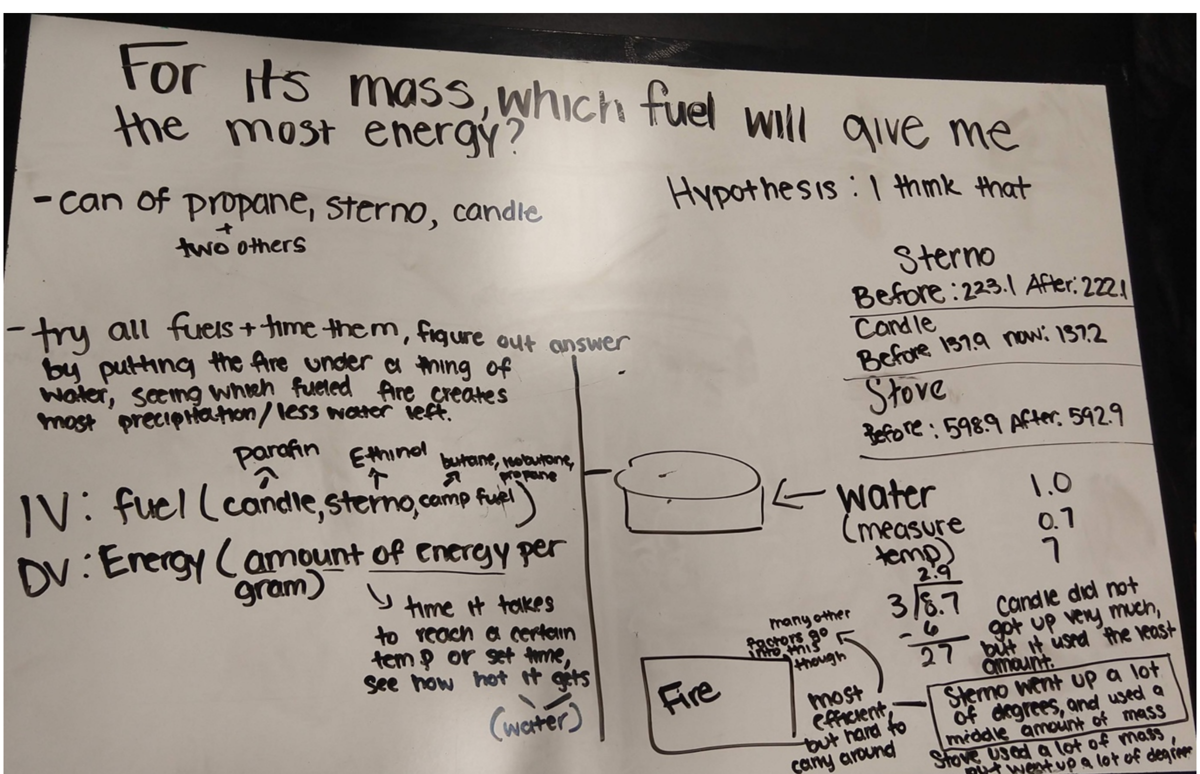
6. (20 min) Students will use their data to justify a recommendation of a fuel to pack for each of the needs listed earlier in the lesson: light, warmth, cooking, and boiling water. In the last 5 minutes of class, have students read their conclusions to a partner, table group, or whole class, depending on classroom culture and student comfort. It may be a good idea to point out that some of the needs listed in lesson one were "communication" and "entertainment." Note that burning things will not meet these needs, which is why our next exploration will be into solar cells.

Sample Data to use if conducting the experiment is not feasible:

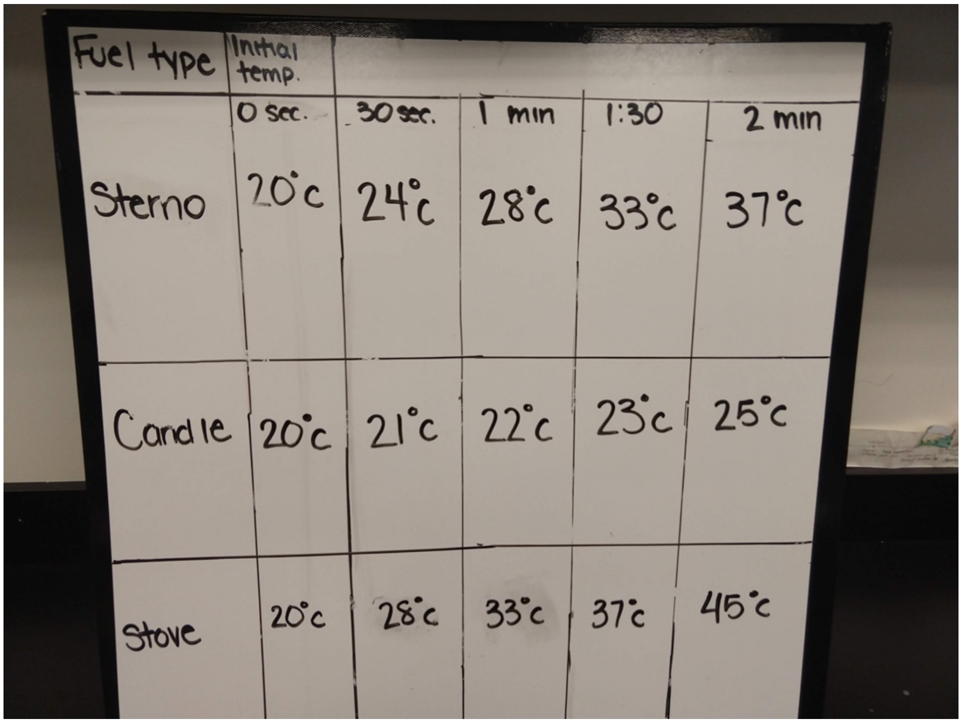
	Beginning Mass (g)	Ending Mass (g)	Temperature (^{O}C)				
			0 sec	30 sec	60 sec	90 sec	120 sec
Candle	137.8	137.2	20	21	22	23	25
Sterno	223.1	222.1	20	24	24	28	33
Power Gas	598.9	592.9	20	28	33	37	45

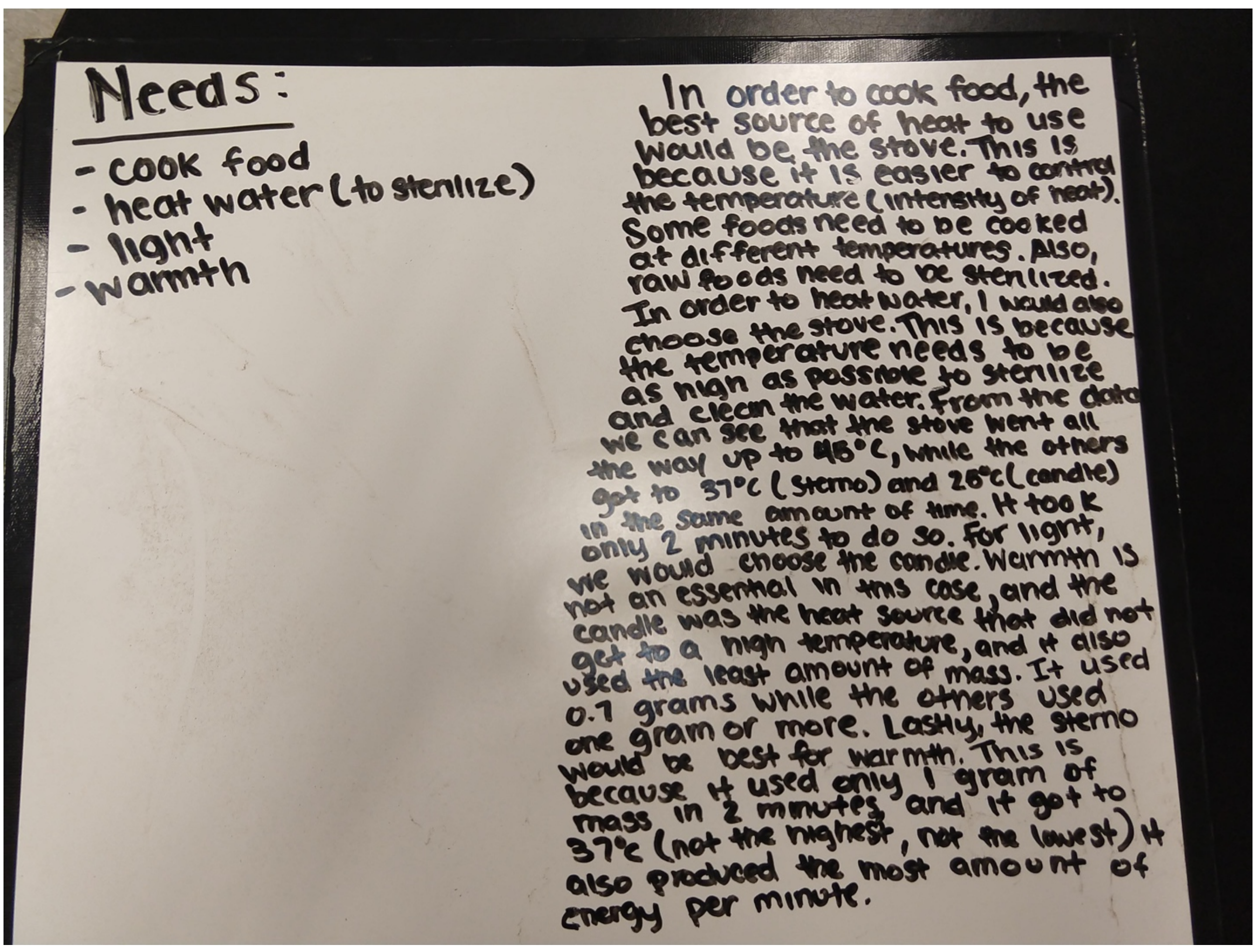
	Beginning Mass (g)	Ending Mass (g)	Temperature (^{O}C)				
			0 sec	30 sec	60 sec	90 sec	120 sec
Candle	137.2	137.0	24	25	26	26	27
Sterno	222.2	218.4	24	25	27	29	33
Power Gas	592.8	587.7	24	29	36	44	53

Examples of student groups' white boards:



My group thinks that the best fuel to be used to meet any criteria would be the fuel with the highest temperature/gram, that being the sterno as it should last the longest. Individually, they would be different. Candle would be efficent for light, not exactly warmth. Stove would be good for warmth and food becouse they burned the hottest. Finally, sterno would atleast be good


Fuel type
Initial temp.
0 sec.
30 sec.
1 min
1:30
2 min
Sterno
20°c
24°c
28°c
33°c
37°c
Candle
20°c
21°c
22°c
23°c
25°c
Stove
20°c
28°c
33°c
37°c
45°c


Needs:
- cook food
- heat water (to sterilize)
- light
- warmth
In order to cook food, the best source of heat to use would be the stove. This is because it is easier to control the temperature (intensity of heat). Some foods need to be cooked at different temperatures. Also, raw foods need to be sterilized. In order to heat water, I would also choose the stove. This is because the temperature needs to be as high as possible to sterilize and clean the water. From the data we can see that the stove went all the way up to 45°C, while the others got to 37°C (sterno) and 25°C (candle) in the same amount of time. It took only 2 minutes to do so. For light, we would choose the candle. Warmth is not an essential in this case, and the candle was the heat source that did not get to a high temperature, and it also used the least amount of mass. It used 0.7 grams while the others used one gram or more. Lastly, the sterno would be best for warmth. This is because it used only 1 gram of mass in 2 minutes and it got to 37°c (not the highest, not the lowest) it also produced the most amount of energy per minute.

Day 2: Powering Small Loads with PV modules

1. **(10 minutes) Load exploration:** Each table group should have their large whiteboards and a variety of voltages of solar modules. Give students the instruction to make device, such as a handheld radio, fan, or toy, work. Encourage collaboration between groups to get every group to have a functioning device. The devices will work by connecting the PV module in the device's battery compartment. The idea is for students to develop proportional thinking about the voltage of the solar panel needed to operate various loads. They should experiment with different combinations of modules and use their white boards to diagram their circuits and describe the functioning of the device qualitatively. For example, "When we used the 3V module, the fan rotated faster.

2. **(10 min)** Students view the first five minutes of this video from The Engineering Mindset (https://www.youtube.com/watch?v=mc979OhitAg&feature=youtu.be). Give students time to add to their white boards to clarify their diagrams and descriptions of the circuits they built during the exploration.

3. **(70 minutes)** Students should work through the "Powering Small Loads" activity, written by Emily Barrett and available on the CE Teacher Activity Center. The activity has its own lesson plan, handout, and "Using a multimeter" cheat sheet. Tell students that they will use the multimeter to quantify the observations that they made with the circuits they built in step one of the lesson. If time permits, students should examine three loads, but two would suffice if students run out of time.

Day 3: The photoelectric effect and PV cells

1. **(5 min)** Show students this video about how PV cells work: https://www.youtube.com/watch?v=xKxrkht7CpY ("How do solar panels work?" by Richard Komp on TedEd).

2. **(30 min)** Students read "How Things Work: Solar Cells" from Newsela (https://newsela.com/read/lib-everyday-products-solar-cell/id/36829) and take notes on the article. An excellent reading strategy for this article is for students to divide their notes into four sections: history, materials, design and function, and applications. Should you not have access to Newsela, you can use just the video above and find others similar to it.

3. **(10 min)** Using the Newsela article and video, students work together in their table groups to complete the diagram of PV cell.

4. **(15 min)** Introduce the 3D model of the PV cell and have students summarize the function of each labeled item on the diagram and complete the graphic organizer. An additional information resource is the Animagraffs Solar Cell module [(https://animagraffs.com/solar-cell-module/)](https://animagraffs.com/solar-cell-module/) and the website [Alternative Energy Tutorials (http://www.alternative-energy-tutorials.com/energy-articles/solar-cell-turns-photons-into-electrons.html).](http://www.alternative-energy-tutorials.com/energy-articles/solar-cell-turns-photons-into-electrons.html)

5. **(20 min)** Evaluation of the model: Students should complete the graphic organizer in which they compare their understanding of how PV cells work to the 3D model.

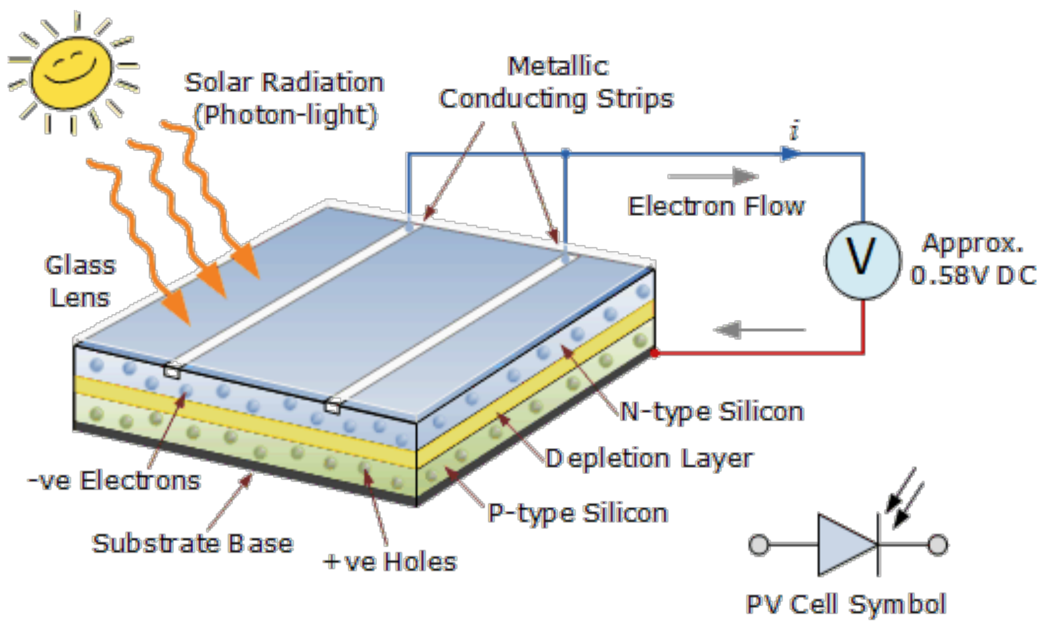


Figure 2 Image credit: alternative energy tutorials, PV Cell Copyright 2010-2018

Day 4: Summative Assessment: Evaluating an emergency preparedness supply list

1. **(15 min)** Return to the idea that students are using their understanding of chemistry to make informed recommendations about the energy resources that people should stash to be prepared for an emergency. Brainstorm the needs or wants that people are going to be responsible for meeting on their own, at least for a little while: warmth, light, cooking, boiling water to sterilize it, communication, cooling, among others.

2. **(15 min)** Introduce the assignment by sharing the document "Checklist to evaluate," which is a comprehensive list of things to have available to be prepared in the case of an emergency. Feel free to use a different checklist that is more current or locally relevant. Walk students through the list and have them highlight all energy resources. Make note of resources that you have evaluated in class, such as candles and Sterno, and those that you have not, such as batteries.
3. **(60 min)** Students complete the assessment, suggesting energy resources to meet the needs selected and explaining why the chemical properties of the resource make it the most suitable choice to meet the need.

ASSESSMENT AND EXTENSIONS

FORMATIVE ASSESSMENT

Day 1: Conclusion paragraph from the collaborative inquiry experiment is preparing students to edit and justify the supply list for the summative assessment.

SUMMATIVE ASSESSMENT

Day 4: Evaluate, edit, and justify the energy resources an emergency preparedness supply list

LESSON EXTENSIONS

The circuitry lessons in this unit are purposely kept conceptual and discovery-based. There are many engineering lessons in the CE teacher library. A highly relevant project that a teacher could add in as written is Brett McFarland's Designing a Solar Phone Charger.

This portion of the unit would lend itself well to an in-depth analysis of photosynthesis and the conversion of biomass to fossil fuels over time as a study into the sun as the ultimate source of all non-geothermal or nuclear energy on the planet.

This lesson would also be an excellent place to teach battery chemistry.

Biofuels Data Nugget: Data Nuggets are summaries of research projects and a small portion of data from the study. Students identify components of the experiment, and then write a data-based claim, evidence, and reasoning summary of the project. The students also come up with further questions for the study. The activities are generated by a team at Michigan State University and include the ability to select the way the data is presented to students: data table with graph pre-formatted, but incomplete, data table with blank graph, or data table and complete graph. Extensive answer keys and teacher notes are available, making this lesson a suitable sub plan to incorporate at any point in the unit.

[Data Nugget: Growing Energy: comparing biofuel crop biomass (http://datanuggets.org/tag/biofuels/)](http://datanuggets.org/tag/biofuels/)

Video that serves as an excellent introduction about the process of making biofuels, produced by Minnesota Agriculture: https://youtu.be/xsROhOMIYdU ("Biofuels as Renewable Energy: Ethanol From Corn")