UNC INSTITUTE FOR THE ENVIRONMENT

Fueling the Future: Evaluating the Sustainability of Biofuels

Overview

Biofuels are one solution to reducing humans' use of non-renewable fossil fuels and to reducing the greenhouse gases that result from their burning. In this activity, students will assess the sustainability of different biofuels. Students will be asked to evaluate how the life cycle (production, transport, and use) of each biofuel feedstock impacts the economy, the environment, and society. Finally, students will learn about bioelectricity and how converting biomass to electricity may be the more efficient way to fuel cars in the 21st century.

Courses

Biology; Earth and Environmental Science

North Carolina Essential Standards for Biology

- 2.2: Understand the impact of human activities on the environment.

North Carolina Essential Standards for Earth and Environmental Science

- 2.2: Understand how human influences impact the lithosphere.
- 2.2.5: Explain how human activities affect air quality.
- 2.4.2: Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
- 2.6.3: Analyze the impacts that human activities have on global climate change (such as burning hydrocarbons, greenhouse effect, and deforestation).
- 2.7.3: Explain how human activities impact the biosphere.
- **2.8.1: Evaluate alternative energy technologies for use in North Carolina.**

Essential Questions

- What are the different feedstocks that can be used to produce biofuels?
- What are the properties of an ideal biofuel?
- Which biofuel is most sustainable? Least sustainable?
- Which biofuel feedstock do you recommend be used for biofuel production?
- What is bioelectricity?

Materials

- Internet access or other current biofuel resources (books, articles, brochures, etc.)
- *Sustainability of Biofuels: Comparison Chart*, student worksheet, one per student
- *Biofuel Life Cycle* diagram, provided
- Bioelectricity article of choice (see Procedure Step 8), one per student

Teacher Preparation

This activity should be preceded by a discussion of sustainability and students should be familiar with the definitions for and examples of renewable and non-renewable energy sources.

Duration

Time for independent research (in class or as homework)
Time for in-class presentations & discussion (90 minutes)

Procedure

1. Introduce students to the different classes of biofuels:

   First-generation biofuels are made from food crops (seeds or grains) or animal feedstocks. Crops such as corn, soy, palm and sugarcane have sugars, starches and oils that can be transformed into biofuels.

   Examples: ethanol, biodiesel, biogas (e.g., methane).

   Second-generation biofuels are made from non-food crops. These fuels are made from lignocellulosic biomass which includes switchgrass and agricultural waste (wheat stalks).

   Example: cellulosic ethanol.

   Third-generation biofuels are made from algae and other plants that have been genetically engineered to yield biofuels.

2. Next, introduce students to the simplified biofuel lifecycle below. Ask them if any steps appear to be missing from the diagram (*YES! Feedstocks are typically pre-processed prior to conversion (e.g., seeds are crushed for biodiesel) and there is a transportation step to distribution to consumers*).

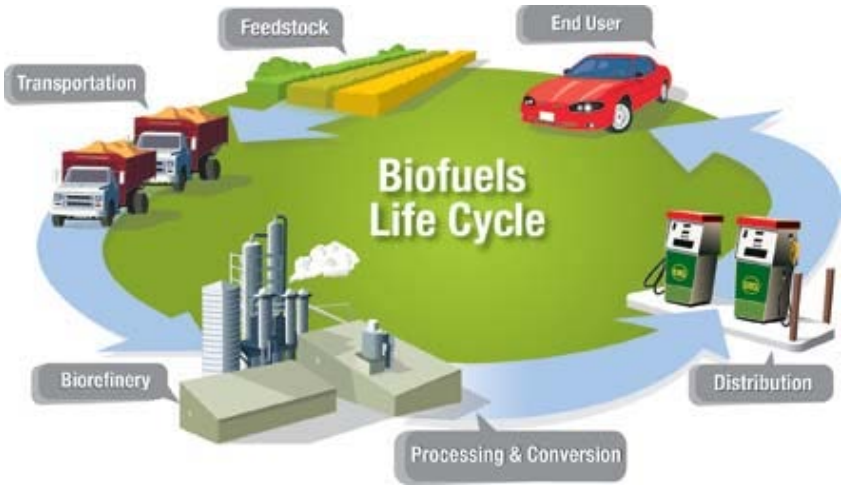

Image from http://www1.eere.energy.gov/biomass/

3. Invite students to work in pairs or small groups and assign each group one of the following biofuels (the feedstock is indicated in parentheses):

   - Corn-based Ethanol (Corn)
   - Cellulosic Ethanol (Switchgrass)
   - Biodiesel (Soybean)
   - Biodiesel (Palm)
   - Biodiesel (Waste Animal Fat or Vegetable Oil)
   - Algal

4. Either in class or as a homework assignment, students should be directed to conduct independent research to answer the following questions about their assigned biofuel. Students should prepare to present their findings to the class. Below are sample questions your students could answer to guide their research:

   - How does this biofuel compare to gasoline/diesel?
     - Net energy yield?
     - GHG emissions?
     - Production Costs?
   - To what extent is this biofuel being used currently in the US? Globally?
   - What are the factors that limit production of this feedstock (if applicable)?
   - Summarize any relevant government regulations pertaining to your biofuel.
   - Describe any potential roles of biotechnology in your improving your biofuel.
   - What by-products are produced as a result of converting this feedstock into a biofuel?
   - Describe the market for any by-products.
   - Is your biofuel making news headlines? Why?

5. Once students have compiled some basic facts about their biofuel, invite them to **consider the life cycle of their biofuel and assess the sustainability of producing this feedstock and converting it into a biofuel**. Direct students to answer the following questions (adapted with permission from the lesson *"Is It Sustainable?"* from *Engaging Students through Global Issues*, by Facing the Future, (c) 2006) and review current news articles in evaluating the sustainability of their assigned biofuel. Students may enjoy drawing the life cycle of their assigned biofuel on large sheets of paper in preparation for their presentation to the class. Alternatively, you may choose to ask students to summarize their analysis in writing and include a visual description of the life cycle of their biofuel.

What are the positive and negative impacts on the environment?

- What resources are used in the life cycle of this biofuel?
- Are the resources used able to be renewed or regenerated?
- Are plants and/or animals damaged during the production of this biofuel?
- Is biodiversity maintained?
- Does biofuel production cause air pollution, water pollution, or soil erosion?
- Does biofuel production generate waste? If so, what happens to the waste?
- Will biofuel production help to conserve natural resources (air, water, land)?

What are the positive and negative impacts on the economy?

- What is the economic impact of biofuel production?
- Does biofuel production create meaningful and satisfying work for individuals?
- Does biofuel production allow people to do their jobs more efficiently?
- Does biofuel production contribute to a community's economic development?
- Does biofuel production rely on products or services that have negative effects on the environment or society?

What are the positive and negative impacts on society?

- Does biofuel production contribute to people's quality of life?
- Do some people benefit from biofuel production at the expense of others?
- Does biofuel production affect people's cultures?
- Are individuals and communities involved in making decisions about biofuel production?
- Does biofuel production offer more options/opportunities to certain groups of people than others?

6. Ask student groups to briefly present their findings to the class. You may consider asking the students to create a short Powerpoint presentation or design a poster about their biofuel. One teacher who piloted this lesson had students go on a "gallery walk" and view each group's biofuel poster (*see photo*). Students can complete the *Sustainability of Biofuels: Comparison Char*t as they hear from each group.

7. Conclude this activity with an in-class discussion. You may consider asking any or all of the following questions depending on student responses:

- Based on our findings, what are the properties of an ideal biofuel?
- Based on our findings, which biofuel appears to be most sustainable? Least sustainable?
- Based on our findings, which biofuel feedstock do you recommend be used for biofuel production?
- Which generation of biofuels has the greatest promise to power our future energy needs?

8. Based on their analyses, students may come to the conclusion that even biofuels aren't the perfect solution. A study released in May 2009 suggests that biomass converted into electricity is more efficient than converting corn into ethanol for use in vehicles (See *Driving on Biomass* in *News Section* below). Invite students to read one of the following documents related to this report (listed in order of increasing reading difficulty).

Which Is Better—Biofuels or Bioelectricity?
http://www.businessweek.com/lifestyle/content/may2009/bw20090521_951123.htm?chan=top+news_top+news+index+-+temp_lifestyle

Study suggests biomass converted into electricity could be more efficient than ethanol
http://www.eurekalert.org/pub_releases/2009-05/um-ssb050509.php

Driving on Biomass
http://www.sciencemag.org/cgi/content/full/sci;324/5930/1019

Greater Transportation Energy and GHG Offsets from Bioelectricity Than Ethanol (primary literature article)
http://www.sciencemag.org/cgi/content/abstract/sci;1168885v1?maxtoshow=&HITS

9. Conclude this lesson by asking the class to discuss the overall sustainability of converting biomass to electricity ("bioelectricity") compared to biofuels. Which do they think has more promise, using biofuels or bioelectricity to meet our transportation needs?

Culminating Activities

Guest Speakers/Tours

- Invite someone who works in the biofuel industry to speak to the class.
- Tour a local biofuel facility. Find a facility in your area by visiting the Biofuels Center of North Carolina's database titled Biofuels Related Companies in NC.
- Ask a local corn or soybean farmer to speak to the class about how the biofuel industry is impacting farming.
- Invite a local government representative to discuss the adoption or potential adoption of biofuels for use in municipal vehicles.

Research-based Writing Assignments

- Have students investigate the role of government in addressing the following issue: "Huge demand for biofuels has created tension between using land to produce fuel and using it for food" (From *A New, Global Oil Quandary: Costly Fuel Means Costly Calories* – see News Articles section below).
- Have students investigate the role of government in setting biofuel standards: "Different biofuels vary enormously in how eco-friendly they are," said William Laurance, a staff scientist at the Smithsonian Tropical Research Institute "We need to be smart and promote the right biofuels." (From *Europe May Ban Imports of Some Biofuel Crops* – see News Articles section below).
- Have students investigate the economic impact of the following issue: "Huge demand for biofuels has created tension between using land to produce fuel and using it for food" (From *A New, Global Oil Quandary: Costly Fuel Means Costly Calories* – see News Articles section below.

Differentiation

Students with Special Needs

- Place students in mixed ability partners for activity completion.

AIG

- Students can work individually.
- Ask students to summarize their biofuel evaluation in writing.
- Ask students to evaluate the use of biofuels in their local community. Are biofuels available to consumers? Which ones? Are municipal vehicles utilizing biofuels? To what extent?

News Articles

National Geographic: Green Dreams
http://ngm.nationalgeographic.com/ngm/2007-10/biofuels/biofuels.html

U.N.: Not so fast with ethanol, other biofuels
http://www.msnbc.msn.com/id/18551000/

Corn boom could expand 'dead zone' in Gulf
http://www.msnbc.msn.com/id/22301669/

A New, Global Oil Quandary: Costly Fuel Means Costly Calories
http://www.nytimes.com/2008/01/19/business/worldbusiness/19palmoil.html

Europe May Ban Imports of Some Biofuel Crops
http://www.nytimes.com/2008/01/15/business/worldbusiness/15biofuel.html

The future of dirt
http://www.boston.com/bostonglobe/ideas/articles/2008/04/27/the_future_of_dirt/

Driving on Biomass
http://www.sciencemag.org/cgi/content/full/324/5930/1019

Resources

Move Over, Gasoline: Here Come Biofuels
http://www.nrdc.org/air/transportation/biofuels.asp

National Biodiesel Board
http://www.biodiesel.org/

National Geographic: Biofuels Compared
http://ngm.nationalgeographic.com/ngm/2007-10/biofuels/biofuels-interactive.html

National Renewable Energy Laboratory (NREL)
http://www.nrel.gov/learning/re_biofuels.html

NC Biofuels Center
http://www.biofuelscenter.org/

USDA
Bioenergy and Biofuels
http://afsic.nal.usda.gov/farm-energy-options/bioenergy-and-biofuels

Biofuels of the Future
http://webarchives.cdlib.org/sw1vh5dg3r/http://ers.usda.gov/AmberWaves/November07/Features/Biofuels.htm

US Dept of Energy
Biomass Programs
http://www1.eere.energy.gov/biomass/

Sustainable Biodiesel Alliance
http://www.sustainablebiodieselalliance.com/

Alternatives Journal, *Biofueling the Future*
http://www.alternativesjournal.ca/energy-and-resources/editorial-biofuelling-future

Acknowledgements
Thanks to the following individuals who thoughtfully reviewed and/or piloted this lesson:

Phil Cox, Science Teacher, Jordan Matthews High School
Lyle Estill, Co-founder, Piedmont Biofuels
Christie Hinson, Project Director, NC Civic Education Consortium, UNC School of Government
Dacia Harris, Science Teacher, Asheville High School
Jessica Hoffmire, Educator, NC Zoological Park
Leanna Kendall, Science Teacher, McDougal Middle School
Andrew McMahan, Bio-fuels Coordinator, Central Carolina Community College

Sustainability of Biofuels: Comparison Chart **NAME:** _____

Complete the chart below as you hear about each biofuel source from your classmates.
Conclude by circling the column of the biofuel that you think is most sustainable.

	Corn-Based Ethanol	*Cellulosic Ethanol*	*Biodiesel (Soybean)*	*Biodiesel (Palm)*	*Biodiesel (Waste fat or Oil)*	*Algal Fuel (algae)*
Net Energy Yield						
GHG Emissions (compared to gasoline or diesel)						
Extent of Use in US						
Environmental Impact						
Economic Impact						
Societal Impact						

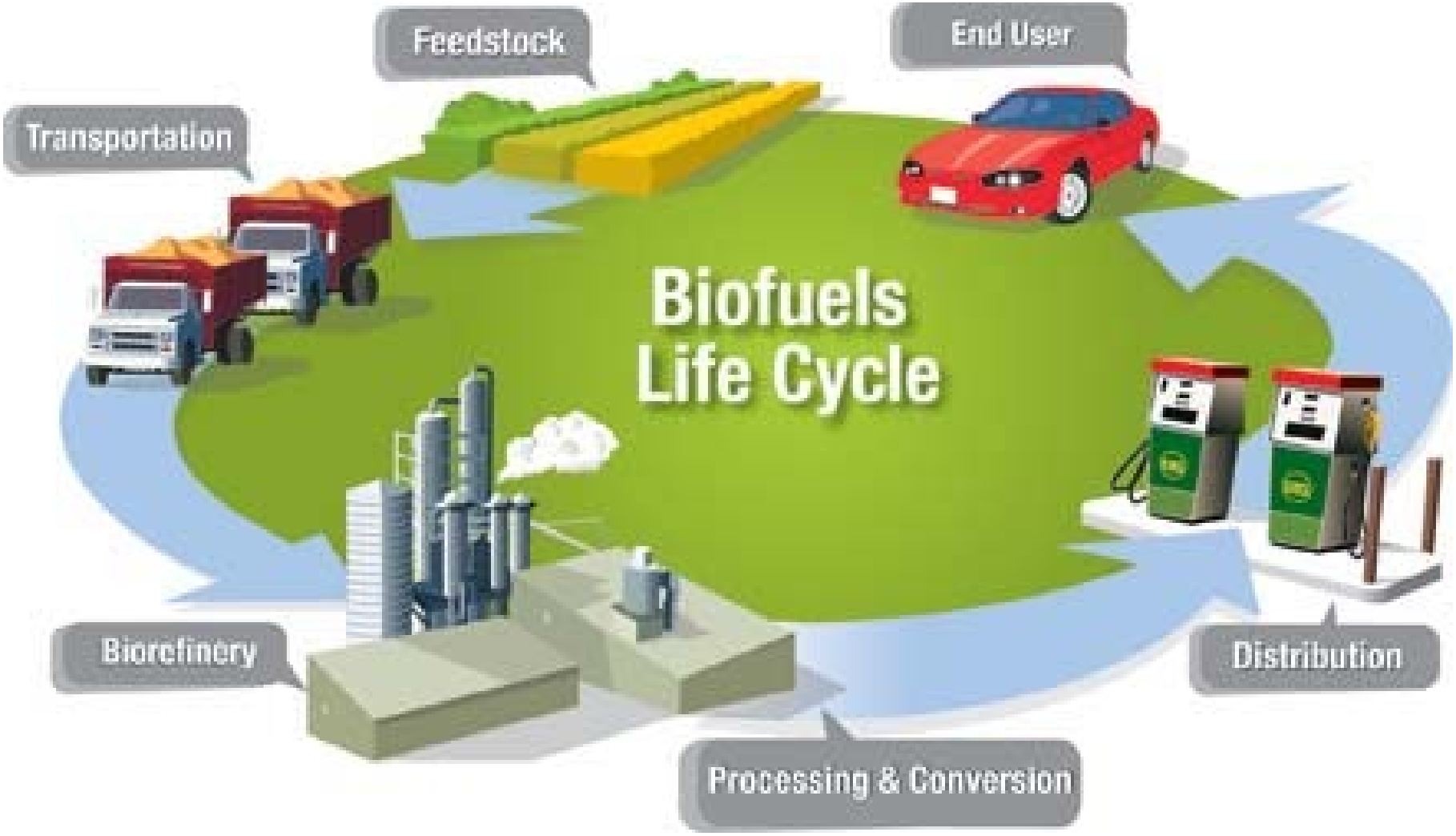

Image from the U.S. Department of Energy