



Investigating Fuel Sustainability



Overview

This set of lessons addresses the socio-scientific issue of sustainable fuels. Like most socio-scientific issues, there is no simple answer and even more complex solutions do not apply equally everywhere. Students address the complexity by first exploring the meaning of sustainability and how it applies to fuel production and use. Students then research the steps involved in producing multiple fuels or energy sources for vehicles including fossil fuels, biofuels, and electricity produced in a number of different ways. They explore the environmental impacts of each step with particular emphasis on carbon emissions. Students dig one step deeper as they examine data on the yields of different biofuel crops.

Lesson Objectives and Alignment with NGSS

Objectives

Students will be able to:

- Define sustainability as it applies to fuel use
- Describe the steps involved in the production and use of multiple fuels and energy sources for vehicles
- Evaluate the environmental impacts of those steps
- Use data to compare biofuel crops

NGSS Performance Expectations Addressed

MS-ESS3- Apply scientific principles to design a method for monitoring and minimizing a human
3. impact on the environment.

HS-ESS3- Evaluate or refine a technological solution that reduces impacts of human activities on
4. natural systems.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on
the environment and biodiversity.

How to use this lesson

Timing

Activity	Recommended classroom time
1. What do we mean by sustainable fuels?	50 minutes
2. Where do fuels come from?	2 x 50 minutes
3. Environmental impacts of fuel use	50 minutes
4. A closer look at biofuels	50 minutes

Please note that the guides for each activity have suggestions for variations that may take more or less time.

Combining this lesson with other units

This lesson could be used to complement any of the following units or topic areas:

- Human energy systems and uses
- Human impacts on the environment (such as global climate change)
- Energy in ecosystems

This lesson is designed to stand alone, requiring no particular prerequisite knowledge.

However, it can be combined with any of the following GLBRC classroom materials

(<https://www.glbrc.org/education/classroom-materials>):

- This lesson is an ideal extension of the [Biofuels vs Fossil Fuels Unit](#) which examines the matter and energy changes associated with biofuels and fossil fuels (photosynthesis, respiration, fermentation, combustion) and their effects on the global carbon cycle.
- [The Biofuels Story](#) could be used before the lesson as an introduction to fuels made from plants or after the lesson to summarize the role of biofuels in lessening our carbon footprint.
- [Global Energy Flows](#) could be used after the lesson to broaden students' understanding of energy use beyond transportation.
- In a biology or environmental science course, [Exploring Energy Transformations in Plants](#) could be combined with this lesson so that students could examine the energy transformations that make plants a sustainable fuel source.
- Students can gain a more quantitative understanding of the carbon footprint of biofuels in [Quantitative Modeling of Biofuels Life Cycles](#).
- [Research Story: The Science of Farming](#) is a brief reading that explains the science behind the data in Activity 4.

Activity 1: What do we mean by sustainable fuels?

Guiding Question

What do we mean by sustainable fuels?

Activity Description

Students define “sustainable” and discuss how sustainability applies to fuel use. The activity is designed to get students to think beyond the idea of sustainability as simply meaning not running out.

Objectives

- The students will express their own ideas about the meaning of “sustainable” and compare these to formal definitions.

Background Information

Sustainability is not an uncommon term, but it is a multifaceted term and different people emphasize different facets. This means that discussions of sustainability of a process need to begin with definitions of the term. How many people are going to do the process? For how long? What negative consequences are we trying to avoid? One answer to the latter question is that we are trying to avoid adverse environmental, social, and economic impacts – a lot to keep in mind.

Materials

- *Presentation 1 - What do we mean by sustainable fuels?*
- *Sustainable Fuels Pretest*

Directions

1. **Pretest.** Give students the *Sustainable Fuels Pretest*. This gives students a chance to organize their own ideas before discussion and gives you an idea of the range of their ideas.
2. **Introduction to sustainability.** Show *Presentation 1 - What do we mean by sustainable fuels?* This will guide the class towards a working definition of sustainability which you can capture on the last slide for future reference.

Assessment

Use the pretest to assess students' incoming understanding of sustainability and how it applies to fuel use. You should not grade the pretest or expect your students to know the correct answers. Sample accurate responses are shown below. At this time, the main goal of the assessment is for you as a teacher to understand how your students think of sustainability.

Pretest: Sample Accurate Answers

Every year in the United States, 200 billion gallons of fuel are used for transportation. This includes moving people and freight by car, truck, plane and boat.

Is this use of fuels sustainable?

- Define sustainable. *Being able to do something for a long time that doesn't use up resources or harm the environment in a way that prevents others (now or in the future) from meeting their needs.*
- Explain why you think the United States' use of fuels is or is not sustainable. *We are not using fuels sustainably because our use of fossil fuels is transferring carbon from underground reservoirs to the atmosphere. In the atmosphere, this carbon acts as a greenhouse gas contributing to global climate change. Global climate change has detrimental effects on many people because of things like coastal flooding, unstable agriculture yields, and extreme weather events. In addition, extraction and transportation of fossil fuels can be associated with negative environmental impacts such as earthquakes resulting from fracking or oil spills harming animal and plant life.*
- What information would help you better answer this question? *Many possible answers. Examples: The proportion of miles traveled or tons moved using fossil fuels (as a primary or secondary) source of energy vs renewable energy sources. The cost of alternative fuels. Other effects of global climate change.*

Activity 2: Where do fuels come from?

Guiding Question

Where do fuels come from?

Activity Description

Students will explore the inputs, outputs, and production methods of different energy sources for transportation.

Objectives

- Students will compare and contrast the steps involved in production and use of different energy sources for transportation including fossil fuels, biofuels, electricity made from fossil fuels, and electricity made from renewable energy sources.

Materials

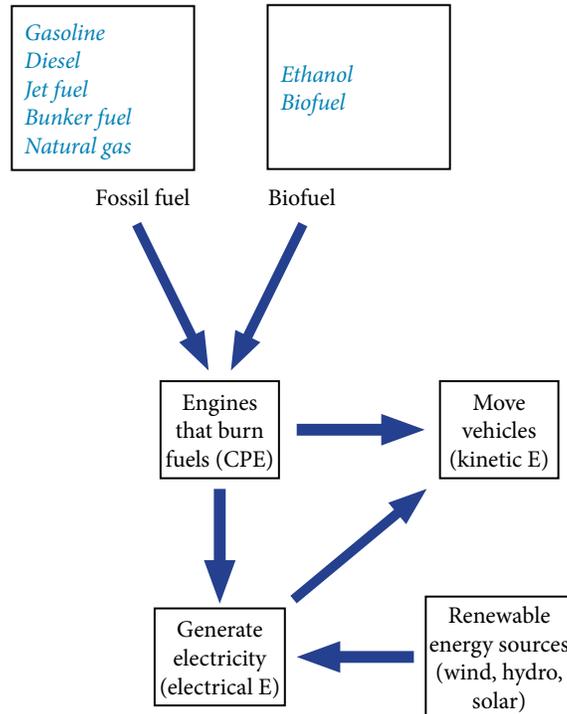
- *Presentation 2 - Where do fuels come from?*
- *Activity 2 Worksheet - Where fuels come from*

Directions

- 1. Presentation 2 - Where do fuels come from?** Show slides 1 and 2. These will get students thinking about different energy sources for transportation. It is helpful to start with whatever they are familiar with in their own community. If students have trouble getting started, have them simply name different types of vehicles (cars, trucks, buses, trains, etc.) and then think about different fuels for these. **Options:** have students expand their list with research or simply use what they come up with in class.
- 2. Energy for transportation.** Show slide 3. This organizes the many types of transportation into a few categories that are convenient for analysis of sustainability.
- 3. Fuel production and use.** Show the remaining slides. **Options:** have students research the ways different energy sources are produced by assigning different sources to different groups. Alternatively, you can use the videos listed in the notes section of each PowerPoint slide as sources of information for the whole class. It will be useful for later activities to ***collate the basic steps of production for each fuel on posters for further reference.*** There is also room to investigate other energy sources such as biodiesel.

Assessment

Give students *Activity 2 Worksheet: Where fuels come from*. Have them place the different energy sources that they studied in the appropriate places on the diagram. Answers are shown in blue below. The goal is to assess students' ability to see patterns in the wide variety of transportation energy sources.



Activity 3: Environmental impacts of fuel use

Guiding question

How does the production and use of different fuels impact the environment?

Activity Description

Students will map the environmental impacts associated with each stage of fuel/energy production and use previously identified in Activity 2.

Objectives

- Students will identify and analyze the environmental impact of each step associated with the production or use of different fuels and energy sources.
- Students will compare the contributions of biofuel and fossil fuel use to atmospheric carbon dioxide levels.

Background Information

Each type of fuel has some negative impacts on the environment. Some, such as coal, have multiple negative effects. One of the main concerns with fuel use is production of carbon dioxide that contributes to global climate change. The use of both fossil fuels and biofuels produces carbon dioxide. However, the carbon dioxide from biofuels came from the atmosphere a short time before. It was taken up by plants and then released again when the fuel made from the plants was burned. On the other hand, use of fossil fuels results in the net movement of carbon from the fossil fuels underground to the atmosphere. Humans continuing use of fossil fuels is the primary cause of the increasing levels of atmospheric carbon dioxide, which in turn cause global climate change.

Materials

- *Presentation 3A - Environmental impacts of fuels use*
- *Fuel Life Cycle Analysis Worksheets* (1 per fuel per student)
- Students' posters from Activity 2 or Presentation 2
- *Summarizing Environmental Impacts of Fuel Use Worksheet* (1 per student)
- *Presentation 3B – Biofuels and Global Climate Change*

Directions

- 1. Presentation 3A - Environmental impacts of fuel use.** Use Presentation 3A to return to the idea of sustainability and focus students on the aspect of environmental impact. Slides 4 - 11 walk students through an example analysis of the environmental impacts of corn ethanol. Students should fill out their own *Fuel Life Cycle Analysis Worksheet* as the class works through this example.
- 2. Life cycle analysis of other energy sources.** Have students work in groups to fill out *Fuel Life Cycle Analysis Worksheets* for the other energy sources that they researched in Activity

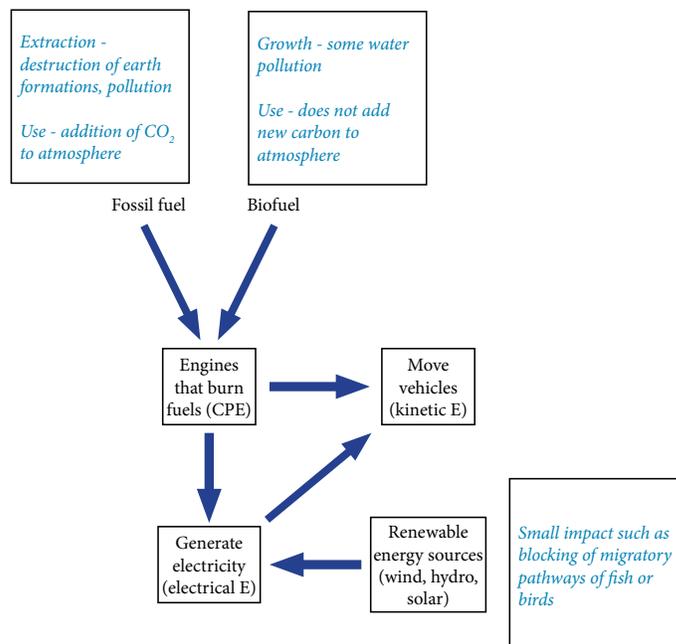
2. Their posters or Presentation 2 should have the steps they will need to analyze. **Options:** Have each group analyze all of the energy sources or some representative sources. Alternatively, assign one or two energy sources to a group and have them present their findings to the class. Sample accurate responses are available in *Sample LCA Worksheet Responses*.

3. Summary of environmental impacts. Once students have analyzed the environmental impacts of all of the transportation energy sources, have them summarize their findings using the *Summarizing Environmental Impacts of Fuel Use Worksheet*. They should see similarities between all of the energy sources associated with a particular arrow. For example, combustion of any fossil fuel is associated with negative environmental impacts due to: 1) extraction (for example, earth quakes linked to fracking) and 2) combustion which leads to build up of CO₂ in the atmosphere. This is true whether the combustion happens in a vehicle or in an electrical power plant. **Options:** Individual students or groups of students can work on the Worksheet before a whole-class discussion. If you think students will struggle with this, you can work through one of the three fuel types (fossil, bio-, and renewable) as a whole class and then have students fill out the rest before discussing the results together.

4. Biofuels and global climate change. Use Presentation 3B to emphasize the most important difference between fossil fuels and biofuels – that biofuel use does not add additional carbon dioxide to the atmosphere.

Assessment

Use Summarizing Environmental Impacts of Fuel Use Worksheet. Answers are shown in blue below. Note that while biofuel use does not add new carbon to atmosphere, not all production of biofuels is carbon neutral.



Activity 4: A closer look at biofuels

Guiding Questions

- What are some of the options for biofuel crops?
- How do their yields compare?

Activity Description

Students will become familiar with a variety of biofuel crops and compare the yields of several of these.

Objectives

- Students will use data to compare the yields of several biofuels crops.

Materials

- *Presentation 4 – Meet the biofuel crops*

Directions

- 1. What do we know so far about sustainable fuel use?** Summarize for students or have them summarize what they have learned so far about sustainable fuel use:
 - Fossil fuel use, whether used directly in a vehicle (or other combustion process) or to produce electricity, moves carbon from underground pools to the atmosphere where it contributes to global climate change.
 - Biofuels and other renewable sources do not have this effect. Biofuels recycle carbon dioxide that was recently in the atmosphere.
 - There are other environmental problems associated with different fuels.
- 2. Biofuels will only be a useful substitute for fossil fuels if we can grow enough of them.** Use Presentation 4 (Slides 1 – 3) to remind students of the problems associated with making ethanol from corn grain and introduce them to a variety of biofuel crops.
- 3. Biofuel crop yields.** Have students look at Slide 4 and discuss the following questions:
 - What is being compared? – *the mass of the dried plant material harvested from a hectare each year*
 - What are perennials and annuals? *Perennials are plants that do not completely die during the winter. They come back from their roots in the spring. Annuals are plants that do die completely during the winter and need to be planted each year.*
 - Note that the yields are different in Michigan and Wisconsin due to differences between the soil and weather in the two places. For each place, which crop gives the biggest yield? *In Wisconsin, the corn yields were biggest. However, in Michigan the Miscanthus grass yielded more than the corn.*
 - What are some reasonable and sustainable scenarios for growing biofuel crops? *In Michigan, once the price of biomass is high enough, farmers could grow miscanthus instead of corn. In Iowa, it probably makes more financial sense to grow corn and use the grain for food and the stover for ethanol. In both states, there may be areas that*

aren't good enough to raise food crops economically that could be used for these alternative crops.

- 4. Summing it all up. In your state, which fuel for your car has the least impact on the environment? Justify your answer.** Have students write responses to this question. Alternatively, you can re-give the pretest. Answers will depend on your location. In places with large amounts of renewable electricity (such as hydroelectricity in the northwest), electricity might be the answer. Biofuels are (or will be) a reasonable alternative to fossil fuels in the middle of the country where the plant biomass does not need to be transported very far to be made into ethanol. In some places where fossil fuel use is the only economically viable option, electricity made from natural gas may become the best option.
- 5. What other information would be helpful in determining environmental impact? What other information do you need to determine which fuel or energy source is sustainable?** It is important that students realize that they have not weighed all of the factors. How does the agriculture of each biofuel crop affect the environment? Will farmers be able to make a living growing biofuel crops? Petroleum is found in multiple places. Is the environmental impact of extraction from each place relatively similar? Right now, there aren't very many options for people wanting electric cars. How is that changing? How quickly are we using up the fossil fuels from different areas?