Biofuel Life Cycle Analysis: Teacher Manual

Learning Goals:

- Students will understand the underlying rationale and basic process of life cycle analysis
- Students will understand points of differentiation in the life cycles of biodiesel and ethanol

Background:

Ethanol

Ethanol is a colorless transportation fuel that mixes with gasoline. Low concentrations of ethanol, such as E10 (10% ethanol, 90% gasoline) can be burned in most gasoline engines. A flex-fuel vehicle is required to use higher concentrations of ethanol, such as E85.

Ethanol can be made from many plant-based sources. In the United States, it is most commonly produced from starch in corn grains. In Brazil, ethanol is commonly made from sugar cane. Although the technology is being developed for large-scale production, ethanol can also be made from cellulose, a structural compound found in plants. Examples of feedstocks currently being investigated for cellulosic ethanol production include fast-growing gasses and trees, as well as waste products such as corn stover (the stems left on the field after harvest) and wood chips. Because ethanol is made from plants that can be regenerated, it is a renewable fuel.

To make ethanol, the starches or cellulose are first converted to sugars. The sugars are then fermented (recall that fermentation is a form of anaerobic respiration) to produce alcohol. The alcohol is purified via distillation, a process that separates liquids based on their boiling points.

Biodiesel

Biodiesel is a liquid transportation fuel that mixes with diesel (not compatible with gasoline engines). It can be burned in any concentration (B1 to B100) in most unmodified diesel engines.

Like ethanol, biodiesel is also made from organic sources. Biodiesel can be made from plant-, algae- or animal-derived fats. Common plant-based biodiesel feedstocks include soy (the most common biodiesel feedstock used in the United States), canola, and palm oil. Other biodiesel producers use waste products such as waste vegetable oil from restaurant fryers or rendered animal fat. The large-scale production of biodiesel from algal oil is still being developed. Because biodiesel can be produced from a variety of organic sources, it is also a renewable fuel.

To make biodiesel the oils or fats, both of which are composed of triglyceride molecules, are modified through a chemical transformation called transesterification. In transesterification, the glycerin portion of the triglyceride molecule is separated from and the fatty acid chains and the fatty acid chains are methylated forming fatty acid methyl esthers (or biodiesel!).

Biofuels and life cycle analysis

Ethanol and biodiesel have both received praise and skepticism. Their supporters tout the fuels as solutions to the environmental problems associated with burning gasoline and diesel, such as global climate change. This is because biofuels are thought to reduce net emissions of carbon dioxide because plant-based feedstocks capture carbon dioxide from the atmosphere via photosynthesis during their growth. However, skeptics believe that the benefits of this "carbon credit" are dwarfed by emissions incurred during the production, distribution, and use of biofuels. One tool, life cycle analysis (LCA), has been particularly useful in generating information about the environmental benefits and constraints of biofuels.

LCA examines the environmental impact of a product from "the cradle to the grave". Specifically, LCAs quantify and evaluate all raw materials and energy consumed as well as wastes discharged beginning with product design and the sourcing of the raw materials from the earth through manufacturing, distribution, use, maintenance, and disposal.

LCAs can be used in various ways. They are often used to compare two products. For example, questions about the environment impacts of paper vs. plastic bags have been explore using LCA. LCAs can be used by a product's manufacturer to identify processes or materials used that have a high environmental impact and make substitutions to lower the impact, or to educate consumers about a product. In this activity, you will construct the life cycles of two renewable fuels, ethanol and biodiesel. Then, using information from published LCAs, you will evaluate and compare their environmental impacts.

Materials:

- Colored Beads – 20 of Each per Group
    - Green, Blue, Red, Orange, and Yellow

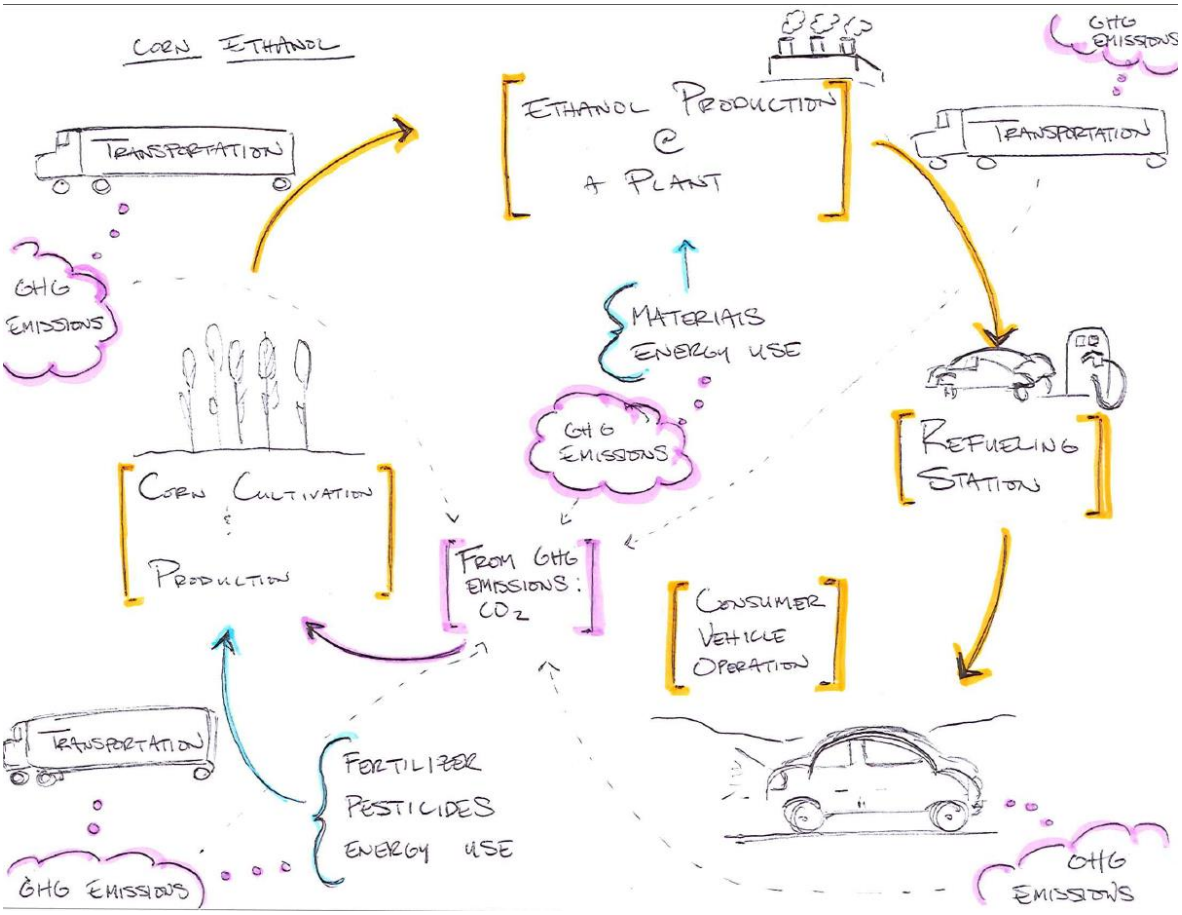
Activity:

1.) The steps, inputs, and outputs involved in the production of ethanol and biodiesel are listed below. On the next page, arrange these processes or materials in a diagram that you feel best describes the life cycle of each fuel.

For corn grain ethanol and biodiesel from soy:
Ethanol/Biodiesel production at a plant
Consumer vehicle operation
Fertilizer
Pesticides
Energy use
Materials
Refueling station
Carbon sequestration
GHG Emissions
Transportation
Corn/Soybean cultivation and production
Water

NOTE: *Some of these are processes and some are physical materials. Also, some items may be used once and some will be used multiple times.*

2.) Draw your diagram below:



Wait for further instructions before proceeding

4.) Your diagrams illustrate that in the production and use of biofuels environmental impacts are incurred. However, the amount of resources used or pollutants generated varies greatly between fuels. You will now represent the relative amounts of resources used or pollutants generated by ethanol and biodiesel production and use in your diagrams.

You have 20 green, blue, red, orange, and yellow beads. Each represents a different resource used or pollutant generated in your life cycle diagram.

Green = Fertilizer Use (20 beads)
Blue = Water Use (20 beads)
Red = Pesticide Use (20 beads)
Orange = Energy Use (20 beads)
Yellow = GHG Emissions (20 beads)

As a group, divide the beads among your two diagrams based on your predictions of the relative amounts of a pollutant produced or resource used. For example, you have 20 beads representing fertilizer use. Do you know something about corn (ethanol) that would lead you to believe that its cultivation requires more fertilizer than that of soy (biodiesel)? If so, place more green beads on your drawing representing ethanol production and use. Distribute all of your beads in a similar matter.

Tell you instructors when you have finished distributing the beads between your ethanol of biodiesel production diagrams. They will give you some actual values of the relative amounts of GHG emissions, and fertilizer, pesticide, energy, and water use involved in the life cycle of the two fuels. Use this data to redistribute the beads between your diagrams.

Proper Bead Distribution:

Ethanol – 75 Beads Total

- Green – 17 Beads
- Blue – 10 Beads
- Red – 17 Beads
- Orange – 15 Beads
- Yellow – 16 Beads

Biodiesel – 25 Beads Total

- Green – 3 Beads
- Blue – 10 Beads
- Red – 3 Beads
- Orange – 5 Beads

- Yellow – 4 Beads

Questions:

How did your predictions compare to the actual values?

Are their certain inputs or outputs that you feel are less harmful for the environment? Justify.

What do you conclude about the relative environmental impacts of biodiesel and ethanol? Justify.

References:

Hill, J., E. Nelson, D. Tilman, S. Polasky, and D. Tiffany. Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels. PNSS. 103(30): 11206-11210. 2006.

Biofuel Life Cycle Analysis: Student Activity

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