Into the Outdoors

HIGH SCHOOL
DISCUSSION GUIDE

CLASSROOM DISCUSSION GUIDE
FOR PEER-DRIVEN LEARNING
USING VIDEO & CRITICAL THINKING

DECODING THE SCIENCE OF BIOFUELS

ENERGY EDUCATION

GRADE LEVELS
High School - Grades 9-12

ENDURING KNOWLEDGE
Students should know about the science in the production of ethanol and biodiesel and the roles these products play in society.

LEARNING TARGETS:

1. Students should know that biofuels are primarily liquid-phase fuels made by converting plant-based carbohydrates into ethanol and biodiesel.
2. Students should know that renewable or recycled biofuels can be used to replace non-renewable hydrocarbon-based fuels that are made from crude oil.
3. Students should understand the significance of biofuels in powering vehicles and the recycling of atmospheric carbon dioxide.
4. Students should understand the fundamental technologies that are used to manufacture ethanol and biodiesel.
5. Students should understand that the production of biofuels also yields valuable co-products and what those co-products are used for.
6. Students should understand that the production of biofuels represents potential career pathways in science and engineering.

DISCUSSION GUIDE FOR VIDEO

TEACHER BACKGROUND

The Science and Technology of Biofuels – Ethanol & Biodiesel

Note: This discussion guide is designed to be used before and after watching any or all of the following online biofuels videos that explore the science of making ethanol and biodiesel.

- http://intotheoutdoors.org/topics/biochemical-reactions/
- http://intotheoutdoors.org/topics/bioenergy-two-for/
- http://intotheoutdoors.org/topics/waste-oils-into-biodiesel/
- http://intotheoutdoors.org/topics/biodiesel-reactions-in-action/

History

Biofuels in the "solid" form of wood have been used ever since humans discovered how to create fire for cooking and heating. Rudolf Diesel was the German inventor of the diesel engine who designed his diesel engine in the 1890's to run in peanut oil. Henry Ford later designed the Model T car that was produced from 1903 to 1926 and was designed to run on biofuel made from hemp. However, the discovery and production of fuels made from crude oil almost eliminated the need for producing "biofuels".

During World War II, the high demand for all kinds of fuels, especially in Germany, rekindled the manufacturing of biofuels. Britain also began making grain alcohol then that was mixed with petroleum fuels.

After World War II, the countries reverted back to using mostly petroleum-based fuels. But between 1973 and 1979, OPEC manipulated the supply and price of crude oil that created fuel shortages around the world. These petroleum shortages in turn created a renewed interest to manufacture biofuels that continues to this day. More recently, the widespread concern about human-induced climate change has also contributed to society's interest in fuels that reduce atmospheric carbon dioxide… such as biofuels.

TEACHER BACKGROUND *(continued)*

Science and Technology of Ethanol

Most of the fuel we burn in our cars and trucks is made from ancient sequestered solar energy that was converted into crude oil millions of years ago. But up to 10 percent of that blended fuel actually contains modern renewable solar energy that's been converted into what's called ethanol - a type of biofuel that can help cars and trucks run cleaner and more efficiently than petroleum fuels alone.

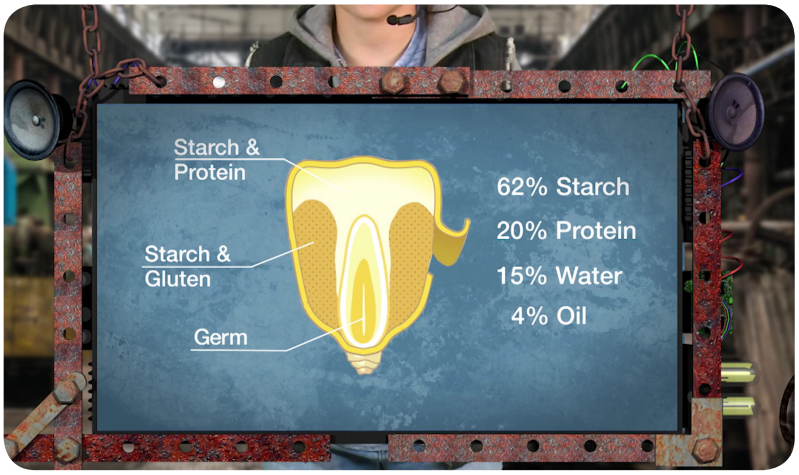
During the process of photosynthesis, plants use solar energy in the chloroplasts in their leaves to covert atmospheric carbon dioxide, water and nutrients into carbohydrates; the starches and sugars that make up the plant. And during the process, plants give off oxygen, which is vital to many forms of live on the Planet, including humans.

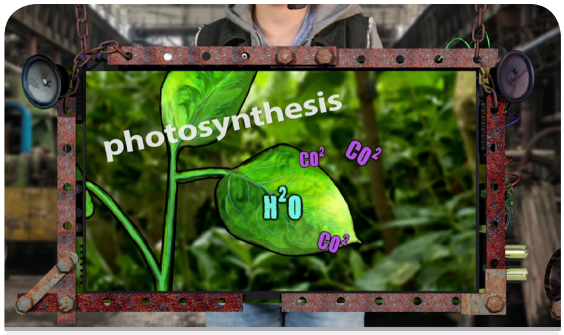
In corn plants, it's the corn seeds or kernels that have the greatest concentration of carbohydrates. That's why they feed it to fatten livestock and poultry. Each kernel contains 62% starch, 20% protein and fiber, 15% water, and 4% oil. And it's that converted and stored solar energy that ethanol refineries use to make ethanol.

Learning Focus: What are the two major processes used in producing ethanol and what are the major differences in those processes? (One uses living organisms, while the other uses heat and pressure).

First major phase in the ethanol production process is fermentation. This whole process is centered on living yeast consuming the carbohydrates in the corn mash then converting it into ethanol and carbon dioxide. It's these football-shaped microscopic critters that actually perform the conversion. Of course the engineers and scientists help the process by breaking down the components of the corn mash using enzymes and heat. Then they create the ideal temperature environment for the yeast to thrive. They end up with a giant caldron of hot, bubbling corn mash packed with ethanol-producing yeast.

The next major phase is distillation. Similar to fractional distillation of hydrocarbons, they use heat and pressure to separate the ethanol from the other components of the mash. They end up with basically three products; 1) water, 2) ethanol, 3) corn mush. All three products are then processed differently to into co-products or recycled.





SPECIAL CONSIDERATIONS:

This activity is richest when completed in the classroom with discussion shared within the whole class. It may be helpful to create a guide sheet for notes with headings and questions to help guide students in picking out significant information.

TEACHER BACKGROUND *(continued)*

VOCABULARY (ETHANOL):

- **Ethanol:** Also called alcohol, ethyl alcohol, and drinking alcohol, is a chemical compound with the chemical formula C 2H 5OH
- **DDG:** dried distiller's grain, a corn-based co-product produced during the manufacture of ethanol. Primarily used as an animal feed.
- **Enzyme:** any of various proteins, as pepsin, originating from living cells and capable of producing certain chemical changes in organic substances by catalytic action
- **Fermentation:** The chemical breakdown of a substance by bacteria, yeasts, or other microorganisms that typically results in the production of alcohol and carbon dioxide.
- **Photosynthesis:** the process of plants using the energy of the sun to covert water and carbon dioxide to create their food, grow, and release excess oxygen into the air.
- **Distillation:** a chemical process where a mixture of two or more liquids (called "components") with different boiling points can be separated from each other using heat and pressure.

Science and Technology of Biodiesel

Biodiesel is biofuel used to blend with petroleum-based diesel to power diesel engines (mostly used in larger trucks such as semis). Using new technology, scientists and engineers can now create crystalline clear biodiesel from a variety of discarded cooking oils and even animal fat. One term they use in this process is called working with flexible feedstocks. A prime feedstock they use in making biodiesel is also one of the co-products from making ethanol – DCO or distiller's corn oil. Whether the feedstock is animal fat derived from animals eating plant (corn) carbohydrates, discarded cooking grease (that likely contains corn oil) and distiller's corn oil, they all connect with renewable corn crops grown in America's heartland that recycle CO2 from the atmosphere.

Some biodiesel manufacturing plants use ENSEL technology, a patented catalytic process for refining various feedstocks such as animal tallow, recycled cooking oil and distillers corn oil into high-quality biodiesel. During the refining process, they also produce a valued co-product that almost everyone uses… glycerin. Also known as glycerol, this sugary oil separates out during the process and is used in a variety of products from toothpaste, to soaps, to cosmetics. Glycerol is a trihydroxy sugar alcohol that is an intermediate in carbohydrate and lipid metabolism. It is used as a solvent, emollient, pharmaceutical agent, and sweetening agent.

Learning Focus: How can the production of biodiesel recycle various kinds of feedstocks while also creating other valued co-products?

BEFORE VIEWING THE VIDEO:

TEACHER BACKGROUND *(continued)*

The various feedstocks are run through an innovative catalyst that combines "esterification" with "transesterification" into a one-step process. It also allows the plant to be feedstock flexible because DCO, UCO, animal tallow all have high free fatty acids that are difficult to breakdown using traditional biodiesel refining methods.

Besides producing biodiesel, glycerin is the main co-product. Glycerin(or glycerine, glycerol, with the molecular formula C3H8O3) is a neutral, sweet-tasting, colorless, thick liquid which freezes to a gummy paste and has a high boiling point. It can be dissolved into water or alcohol, but not oils. On the other hand, many things will dissolve into glycerol easier than they do into water or alcohol. So it makes an excellent solvent.

Glycerine has lots of uses besides being used to make nitroglycerin. Some uses include: conserving preserved fruit, as a base for lotions, to prevent freezing in hydraulic jacks, to lubricate molds, in some printing inks, in cake and candy making, and (because it has an antiseptic quality) sometimes to preserve scientific specimens in jars in your high school biology lab.

Pure glycerol has a melting point of 17.8°C. Its boiling point is 290°C but it also decomposes at that temperature. The presence of three hydroxyl groups makes the compound hygroscopic, with a tendency to absorb moisture from the air. This also makes it useful as a humectant in cosmetics and food, retaining water and preventing the substance from drying out.

VOCABULARY (BIODIESEL):

- **Biodiesel:** a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, and designated as a B100 fuel.
- **Tallow:** a fatty substance consisting of a mixture of glycerides, including stearic, palmitic, and oleic acids and extracted chiefly from the suet of sheep and cattle
- **Glycerin:** a sweet syrupy trihydroxy alcohol obtained by saponification of fats and oils
- **Glycerol:** a colorless, odorless, viscous liquid that is sweet-tasting and non-toxic. The glycerol backbone is found in all lipids known as triglycerides. It is widely used in the food industry as a sweetener and humectant and in pharmaceutical formulations
- **Esterification:** a reaction of an alcohol with an acid to produce an ester and water. Bio-diesel is produced by converting the vegetable oils into methyl esters by subjecting them to esterification and trans-esterification

VIEWING AND DISCUSSION GUIDE:

Before Viewing the Video:

Ask the students to discuss what they currently know about:

- How biofuels are produced
- What products are used to make them
- How they are used as fuels

It may be helpful to complete **a KWL chart** and have students fill in the K and W before watching the video and the L after watching the video. (What I **Know**. What I **Want** to Know. What I **Learned**). Also ask them to discuss what they know about how the production and use of biofuels affects their lives. You can either create a KWL chart or use the example on the last page of this discussion guide.

Before viewing the video, it may also be helpful to **create a "guide sheet"** for students to take notes on while watching the video. From your Teacher Background information, select key headings and questions that will help guide students in picking out significant information from the video. Include questions about how the topic could impact their lives and how the topic relates to other areas of science.

Here are some examples:

History:

- When were biofuels first invented and used?
- What political forces shaped the evolution of biofuels?
- What environmental factors might affect the future of biofuels?

VIEWING AND DISCUSSION GUIDE (continued):

Technology:

- What feedstocks are used to produce ethanol and biodiesel?
- What technologies are used in the production of ethanol and biodiesel?
- What co-products are produced during the production of ethanol and biodiesel?
- What properties of ethanol and biodiesel impact engine performance?

Environment:

- How can using biofuels make a difference in atmospheric carbon dioxide?
- What is the carbon cycle difference between petroleum-based fuels and biofuels?
- How might the use of biofuels influence climate change?
- What factors limit the increase or widespread use of biofuels?

After Viewing the Video

After viewing the video, guide a student discussion about the key points and questions in the Discussion Guide. Also explore what the students Learned and the significance of the topic to their lives.

If the topic is potentially controversial or involves different stakeholder groups, divide the students into "stakeholder groups". Have the different groups prepare a presentation of their viewpoints or goals for a classroom presentation and debate. Focus the discussion to address the critical questions presented in the beginning of the videos or key points in the Teacher Background.

EVALUATION:

1. An informal assessment can be made from students' notes and their participation in the before and after viewing discussions.
2. Activities can be assessed using rubrics based on good research, presentation, and material construction.

EXTENDED LEARNING:

1. Complete the L part of the KWL chart after the discussion.

2. Have students research the answers to the questions they had in their KWL chart or Discussion Guide that were not covered in the discussion.

3. Students can group together and research a sub-topic related to the main topic. These sub-topics could include the following: history, innovation or technology, careers, and impacts on the environment or society. Students have the option on the method to present their findings to the class.

4. Have the student "stakeholder groups" prepare posters or media presentations as part of their classroom presentations.

5. Explore the other three biofuels science videos on this topic and have students make a short presentation on which biofuels career interests them the most, and what educational goals might help them in pursuing that career.

6. For additional information, explore our educational partner's website: **Flint Hills Resources**

K-W-L Chart

Topic: _____

What I Know	What I Want to Know	What I Learned

whysospecial.com