We are going to go over the chemistry of biodiesel production, as well as talk about lab safety, renewable energy, and work on math skills. We will make small batches of biodiesel in the lab, with emphasis on student understanding of where the ingredients are coming from and why individuals might want to make their own fuel.

At the conclusion of the lesson, students will be able to:
- Explain how energy is generated from fuel
- Explain what is means to be a renewable fuel
- Follow directions and meet lab safety guidelines
- Explain the benefits and risks of making your own fuel

Grades 9-12

3 50-minute class periods

Emphasizing the social/political aspects of alternative energy:
- **C1.2B** Identify and critique arguments about personal or societal issues based on scientific evidence.
- **C1.2f** Critique solutions to problems, given criteria and scientific constraints.
- **C1.2j** Apply science principles or scientific data to anticipate effects of technological design decisions.
- **C1.2k** Analyze how science and society interact from a historical, political, economic, or social perspective.

Emphasizing the chemistry aspects of biodiesel (some are extensions of the activity, and more chemistry benchmarks are applicable):
- **C2.1a** Explain the changes in potential energy (due to electrostatic interactions) as a chemical bond forms and use this to explain why bond breaking always requires energy.
- **C2.1b** Describe energy changes associated with chemical reactions in terms of bonds broken and formed (including intermolecular forces).
- **C2.3x Breaking Chemical Bonds**
  For molecules to react, they must collide with enough energy (activation energy) to break old chemical bonds before their atoms can be rearranged to form new substances.
- **C2.3a** Explain how the rate of a given chemical reaction is dependent on the temperature and the activation energy.
- **C2.3b** Draw and analyze a diagram to show the activation energy for an exothermic reaction that is very slow at room temperature.
- **C3.1x Hess’s Law**
For chemical reactions where the state and amounts of reactants and products are known, the amount of energy transferred will be the same regardless of the chemical pathway. This relationship is called Hess’s law.

C3.1a Calculate the ΔH for a given reaction using Hess’s Law.
C3.1b Draw enthalpy diagrams for exothermic and endothermic reactions.
C3.1c Calculate the ΔH for a chemical reaction using simple coffee cup calorimetry.
C3.1d Calculate the amount of heat produced for a given mass of reactant from a balanced chemical equation.

C3.3x Bond Energy
Chemical bonds possess potential (vibrational and rotational) energy.
C3.3c Explain why it is necessary for a molecule to absorb energy in order to break a chemical bond.

C3.4 Endothermic and Exothermic Reactions
Chemical interactions either release energy to the environment (exothermic) or absorb energy from the environment (endothermic).
C3.4A Use the terms endothermic and exothermic correctly to describe chemical reactions in the laboratory.
C3.4B Explain why chemical reactions will either release or absorb energy.

P4.p2C Separate mixtures based on the differences in physical properties of the individual components. (prerequisite)

MATERIALS

- 50 mL methanol (Heet) per group
- .9 g NaOH (lye) per group
- 250 mL of vegetable oil per group
- 1 100 mL flask per group
- Scale for weighing out NaOH
- 1 100 mL Graduated cylinder per group
- 1 spoon per group for measuring NaOH
- 1 stirring rod per group
- 1 500 mL sep funnel with stopper per group
- 1 ring stand with loop to hold sep funnel per group
- 1 activity sheet per person

Biodiesel is diesel fuel made from vegetable oils that runs in unmodified diesel engines - cars, buses, trucks, construction equipment, boats, generators, and oil home heating units. These oils can be new (soy or canola) or used oils (such as those that are used by fast food restaurants), although the used oils generally need to be filtered more to remove the extra gunk from the food that was fried in it. This is an area of alternative fuels that is less popular than ethanol production, generally because the market for diesel fuel is smaller than the market for gasoline, and the price of vegetable oil has increased in recent years. However, many people have started processing used vegetable oil (mainly from restaurants) as a cottage industry in this country, particularly as fuel prices have risen.

See the link in the resources section for more information on waste vegetable oil biodiesel.

ACTIVITIES OF THE SESSION

Take your class down to the cafeteria to interview your lunch workers to see how much waste vegetable oil they produce every week. The students can also go and visit fast food restaurants to ask how much oil the restaurants use each week. You will use this number later in your calculations.

Contact the transportation headquarters and ask how many gallons of diesel fuel that the district uses each week. You will use this number later as well.
Give a general overview of what biofuels are and what renewable resources are. See the background section for some information, and there is a powerpoint that accompanies the lesson.

- Biofuels are fuels that are produced from harvesting living things (normally plants) instead of fossil fuels.
- They are renewable to some extent, since they come from carbon that is more recent and is still cycling.
- Biofuels have the potential to contribute less than fossil fuels to increases in atmospheric greenhouse gases.
- However, there can be environmental impacts from biofuels, too, since you often have to use fossil fuels to process and make the biofuels and sometimes we lose soil carbon when biofuels are farmed.
- There are also benefits from energy security standpoints, since we won’t have to import as much oil. This discussion should take about 15-20 minutes.

Go over the chemical reaction for biodiesel. If students have less of a chemistry background, you will be less concerned with some of the details and more with the idea of splitting the molecules into smaller pieces that can be used separately. If they have had more chemistry, you can talk about transesterification and some of the specifics of the reaction. This would include the breaking of chemical bonds, releasing energy, exothermic reactions, stoichiometry, chemical formulas, and the like.

Go over the procedure for making biodiesel which is as follows:
1. Put 50 mL methanol (Heet) into a beaker or flask
2. Weigh out .9g NaOH (lye) and add it to the methanol
3. Stir vigorously until all solid is dissolved (notice it is exothermic)
4. Pour 250mL oil into the sep funnel
5. Add methanol/NaOH solution to sep funnel with oil
6. Stopper sep funnel and shake like mad for 4-5 minutes (venting often)
7. Let it settle with stopper removed

Emphasize the safety issues with your students, especially if they are younger or have less lab experience. Most of these chemicals are ones that they will be using later in life, and can pick up at Walmart, but it is still good to keep everyone safe.

**A few words on SAFETY:**
You will be working with DANGEROUS/POISONOUS chemicals. Common sense MUST be used. **You are responsible for your actions and the safety of yourself and everyone/everything around you!**

**METHANOL**

**POISON!** Causes eye and skin irritation. May be absorbed through intact skin. This substance has caused adverse reproductive and fetal effects in animals. **Danger! Flammable**
liquid and vapor. Harmful if inhaled. May be FATAL or cause BLINDNESS if swallowed. May cause central nervous system depression. May cause digestive tract irritation with nausea, vomiting, and diarrhea.

### Sodium Hydroxide

**POISON! DANGER! CORROSIVE. MAY BE FATAL IF SWALLOWED. HARMFUL IF INHALED. CAUSES BURNS TO ANY AREA OF CONTACT. REACTS WITH WATER, ACIDS AND OTHER MATERIALS. [MSDS]**

#### Recommended Safety Gear:

The minimum is chemical proof gloves, apron, and eye protection. However, many safety experts also add lab coat.

Do NOT inhale any vapors.

Now that I have managed to scare you, just realize that Methanol is the fuel used in most Model airplanes. In the USA methanol is available in small quantities as **HEET** brand fuel line antifreeze (Yellow bottle). Lye is an every-day drain cleaner. Both are freely available in most large shopping centers.

### Clean up

You can use the glycerol for making soap with the students, or use the glycerol for further chemistry lessons. The biodiesel should be allowed to sit for a few days with its stopper removed to allow any excess water to “dry”. It can then be used, but it is best to “wash” biodiesel before putting it in a diesel engine. There are directions for this online if you would like to use the biodiesel.

The students could present their findings to the school board, and lobby that biodiesel production from the waste vegetable oil in the district be undertaken by one of the vocational education programs. This presentation could be in the form of powerpoint or as posters or letters to the school administration.

You could talk about bond energy and why hydrocarbon chains are so often used as a fuel source. You can also talk about bonds being broken and formed in the chemical reaction of the biodiesel production.

You could talk about Hess’s law and build a calorimeter to measure how much energy is released by the reaction.

You could talk about density in the separation of the glycerin from the biodiesel.

#### Resources

http://www.biodiesel.org/
http://en.wikipedia.org/wiki/Biodiesel
http://www.biodieselnow.com/
http://www.wmich.edu/biodiesel/
http://kzoobiofuels.org/index.html
How many gallons of diesel fuel do you think your school district uses every day?
Predicted_________ gallons/day       Actual _____________gallons/day

How many gallons of waste cooking oil do you think your school district produces every day?
Predicted _______ gallons/day       Actual________gallons/day

How many gallons of waste cooking oil do you think McDonalds makes every day?
Predicted: __________gallons/day       Actual__________gallons/day

What are biofuels?

Are these renewable or non-renewable resources?

Biodiesel is made when you take waste vegetable oil (like what is used in your cafeteria), and make it into diesel fuel (like what runs in your school buses). Chemically, it looks like this:

Those R’s represent chains of carbon. Transesterification= switching around the R groups on molecules to go from one type of alcohol to another and one type of ester to another.

\[
\text{Triglyceride} \xrightarrow{\text{cat. base} \text{ EtOH}} \text{R}_1\text{COOEt} + \text{R}_2\text{COOEt} + \text{R}_3\text{COOEt} + \text{C}_3\text{H}_6(\text{OH})_3
\]

Ethyl esters of fatty acids         Glycerol

Those R’s represent chains of carbon. This is called transesterification, or switching around the R groups on molecules to go from one type of alcohol to another and one type of ester to another.

Biodiesel takes oil (triglyceride), adds alcohol and a base, and knocks the long chains off the triglyceride molecule. The long chains are what we want to burn, and the glycerol is a left over.

This is an example of a triglyceride (oil) molecule. We want to take it, and cut the chains off of it to separate the glycerol from the side chains.
The general procedure for making the biodiesel looks like this:
1. Put 50 mL methanol (Heet) into a beaker or flask
2. Weigh out .9g NaOH (lye) and add it to the methanol
3. Stir vigorously until all solid is dissolved (notice it is exothermic)
4. Pour 250mL oil into the sep funnel
5. Add methanol/NaOH solution to sep funnel with oil
6. Stopper sep funnel and shake like mad for 4-5 minutes (venting often)
7. Let it settle with stopper removed

How much biodiesel did the 250mL of vegetable oil produce?________

This is an conversion rate of : _________mL/250mL = _______ %

So how many gallons of biodiesel would we be able to make from the vegetable oil from the cafeteria? _______gallons/day x _______% /100=_________gallons/day

So how many gallons of biodiesel would we be able to make from the vegetable oil from McDonald’s? _______gallons/day x _______%/100=_________gallons/day

How much would that save the school district every day?
_______gallons/day x $_____/gallon= $_________/day
What do you think the McDonalds and your cafeteria does with their waste oil now?

Do you think it would be worthwhile for the school district to use the waste oil to make biodiesel? Why or why not?