Biofuels Unit Plan  
Kim Misyak-Chumney

**Target grade and subject:**  10th - 12th grade Chemistry

**Unit Overview:** This unit on biofuels was created to introduce the basic information about the different types of renewable and non-renewable hydrocarbon energy. Biofuel can be produced in different forms and all have different sources, structures and environmental impacts. A power point was created to begin the informational stage and students continue with a group investigation of petroleum products, biomass and wind power. A class discussion will encourage students to discuss their findings and clear up any additional questions students may have. Students will then build hydrocarbon molecule models and balance equations. The unit is concluded by conducting an experiment making biofuel and comparing it to other sources of energy. The goal of the unit is to connect chemistry with real time events in the classroom. Energy and environmental factors are prominent topics in today’s society; it is important that students understand all of the alternatives in order to make educated decisions when they go to the polls and vote or make decisions in their everyday lives. The purpose is not to encourage or discourage specific types of energy usage but to educate students about the benefits and risks.

**References:** (included in each of the separate activities)  
LAB-AIDS KIT 39S – Biofuels: Investigating Ethanol Production and Combustion  
“Technology for Processing Woody Biomass to Biofuels” powerpoint by Michael Brodeur-Campbell *Department of Chemical Engineering* from Future Fuels Teacher Institute, July 12-16, 2010  
Lawrence, Richard “Why Teach About Biodiesel?” Green Teacher,

**Learning Objectives:** SWBAT

- Explain biomass and the types of energy produced.  
- Describe and explain hydrocarbon molecules.  
- Write and balance combustion reactions.  
- Construct models of the hydrocarbon gases that compose raw natural gas.  
- Compare and Contrast different types of renewable and nonrenewable resources.  
- Research renewable and nonrenewable types of energy resources.  
- Interpret information on locations of resources, recovery of sources, uses, environmental impact and important facts for energy resources.  
- Interpret new vocabulary.  
- Analyze data collected from laboratory experiments.  
- Compare and Contrast data collected from laboratory experiments.
Classroom Activities

**Day one:** Biomass Power point and note page: Present power point to students and have them take notes.

**Day two:** Intermediate/Secondary Activity: Chemical Models: write simple hydrocarbon molecules, build the hydrocarbon models, write and balance combustion reactions. Students will submit lab questions for a grade.

**Day three:** Computer Research on renewable and non-renewable energy resources. Students will complete the information in groups. Students will be allowed one day in the computer lab.

**Day four:** Classroom discussion and sharing of research information. Information will be posted on the walls in the classroom and students will be required to share their research information with the class. The class will take notes and have an opportunity to use other students posted notes on the wall. Questions will be addressed at this time as well.

**Day five:** Making Biofuel Lab; questions will be submitted for a grade. Students must adhere to proper safety rules and lab techniques for full credit.

**Day six:** How much energy can be obtained from alternate substances versus biofuels? Questions and lab will be submitted for a grade. Students must adhere to proper safety rules and lab techniques for full credit.

Chemistry HSCE

C1.1C Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).

C1.1E Describe a reason for a given conclusion using evidence from an investigation.

C1.2A Critique whether or not specific questions can be answered through scientific investigations.

C1.2B Identify and critique arguments about personal or societal issues based on scientific evidence.

C1.2C Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.

C1.2k Analyze how science and society interact from a historical, political, economic, or social perspective.

C3.1d Calculate the amount of heat produced for a given mass of reactant from a balanced chemical equation.

C3.4 Chemical interactions either release energy to the environment (exothermic) or absorb energy from the environment (endothermic).

C4.2e Given the formula for a simple hydrocarbon, draw and name the isomers.

C5.8 The chemistry of carbon is important. Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

Unit Assessment:

1. Completion of Research Investigation and class discussion.
2. Complete and submit chemical model sheet.
3. Making Biofuel from new vegetable oil lab; questions and lab technique.
4. How much energy can be obtained from alternate substances versus biofuels? Questions and lab technique.
5. A final overall grade will be given based on student participation in class discussions, using class time properly, following safety rules and lab techniques.
1. What is biomass?

2. List some types of biomass (2 slides):
   a. 
   b. 
   c. 
   d. 
   e. 
   f. Most plentiful:

3. Biomass produces what type of energy?

4. Additional forms of energy from biomass:
   a. 
   b. 
   c. 

5. Methane:

6. Ethanol:

7. Biodiesel:

8. Wood and Waste Notes:

9. Biomass and the environment:

10. Benefits:

11. Additional Research:
Goals
• To construct models of the hydrocarbon gases that compose raw natural gas.
• To balance chemical equations of the combustion of hydrocarbon gases.

Concepts
• The gases that compose natural gas are hydrocarbons.
• When burned, hydrocarbons produce carbon dioxide and water.

Materials
• Copies of student worksheets
• Molecular model set or three colors of clay and toothpicks for each group

Preparation
• Gather the needed materials.
• Divide the students into groups of two to three.
• Review with students the process for balancing chemical equations.

Procedure
1. Explain to the students that raw natural gas is typically a mixture of gases. These gases are hydrocarbons consisting of carbon and hydrogen atoms.
2. The gases found in raw natural gas are alkanes; the prefix of the alkane indicates the number of carbon atoms present. Review the background information with the students.
3. Distribute the worksheet and have students look at the list of alkane prefixes. Ask the students if they have any questions and give them time to complete the Molecular Formulas section of the worksheet.
4. Review the molecular formulas with the students. Allow students time to complete the Molecular Models and Balancing Equations sections of the worksheet.
5. Review the equations with the students. Allow students time to complete the Hydrocarbon Combustion section. Make the connection between the balanced equations and the combustion models.
6. Review and discuss in terms of the concepts listed above.

Extensions
• Have students explain what impact burning hydrocarbons has on the environment. Emphasize that carbon dioxide is the major greenhouse gas associated with global climate change.
• Have students determine the molecular formulas for gasoline and diesel. Discuss the environmental impact of using these fuels and possible alternatives to hydrocarbon fuels (biodiesel, ethanol).

Answer Key: Molecular Formulas: Methane: CH4 Ethane: C2H6 Propane: C3H8 Butane: C4H10
Balancing Equations & Models:

$$\text{CH}_4 + 2 \text{O}_2 \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O}$$
$$2 \text{C}_2\text{H}_6 + 7 \text{O}_2 \rightarrow 4 \text{CO}_2 + 6 \text{H}_2\text{O}$$
$$\text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O}$$
$$2 \text{C}_4\text{H}_{10} + 13 \text{O}_2 \rightarrow 8 \text{CO}_2 + 10 \text{H}_2\text{O}$$
HYDROCARBONS (Student Sheet)

**Background**
Hydrocarbons are molecules composed only of carbon and hydrogen atoms. Carbon atoms have four electrons available to bond. When one carbon atom bonds with hydrogen, it needs four carbon atoms. This hydrocarbon is known as methane. When a hydrocarbon molecule has as many hydrogen atoms bonded as possible, it is considered saturated and is part of the alkane group. Alkanes are named for the number of carbon atoms present. The alkanes form a straight chain of carbon atoms with hydrogen atoms bonding with the remaining open electrons. The generic formula for alkanes is $C_nH_{2n+2}$. This formula can be used to determine the molecular formula for the gases that typically compose raw natural gas.

**Alkane Series Prefixes**
- meth- one carbon atom
- eth- two carbon atoms
- prop- three carbon atoms
- but- four carbon atoms

**In your science journal, write the answers to the following problems:**

**Molecular Formulas**
Use the generic formula for alkanes to determine the molecular formula for the following gases: methane, ethane, propane, and butane.

**Molecular Models**
Use the model sets or colored clay to make three-dimensional models of the four alkanes. Use one color to represent hydrogen and another for carbon. Use the third color to make several oxygen molecules, which consist of two oxygen atoms bonded together ($O_2$). Draw a picture of each model (methane, ethane, propane, butane, oxygen) in your science journal.

**Balancing Equations**
When a hydrocarbon burns, it combines with oxygen to form carbon dioxide and water. Write and balance each chemical reaction equation for methane, ethane, propane and butane.
Heat alkane + $O_2 \rightarrow CO_2 + H_2O$

**Hydrocarbon Combustion**
Using the chemical combustion of methane and oxygen, determine the products of methane combustion.
Draw models of the molecules formed in the reaction. Repeat this procedure for ethane, propane, and butane.
Research Renewable and Nonrenewable Energy Resources

Teacher Instructions

Adapted from Intermediate Energy Activities (www.need.org)

Purpose: Students will research renewable and nonrenewable types of energy resources. Students will be responsible for a brief description, location of resources, recovery of source, uses, environmental impact and important facts.

Materials: Student Sheets and computers

Time: One day in the computer lab; one day of class discussion

Procedure:

Step one: Choose which info sheets you will use with your class. Instead of having each student fill out a series of sheets; group students and give each group an info sheet to fill out.

Step two: Read over the sheets with the students. Discuss the concepts and any new vocabulary. Have students work to complete the sheets; one day in the computer lab (especially if students work in groups), should be plenty. Collect final sheets from student groups at the end of class to look over and use for the next day.

Day Two

Post the final sheets in the classroom; have students go to stations to fill out individual forms or turn them into overheads to share. Wrap up with a class discussion talk about any misconceptions students have and answer any final questions.
BIOMASS ANSWERS

Description of biomass:
   Any organic material that can be used for its energy content - wood, garbage, yard waste, crop waste, animal waste, even human waste

Renewable or nonrenewable:
   Renewable

Ways we turn biomass into energy we can use:
   Burning to produce heat, fermentation into alcohol fuel (ethanol), bacterial decay into methane, conversion to gas or liquid fuels by addition of heat or chemicals

Who uses biomass and for what purposes:
   Industry burns waste wood to make products, homes burn wood for heat, waste-to-energy plants burn organic waste products to produce electricity, gasohol is used as a fuel

Effect of using biomass on the environment:
   Burning biomass can produce air pollution and does produce carbon dioxide, a greenhouse gas. It can also produce odors. Burning biomass is cleaner than burning fossil fuels.

Important facts about biomass:
   Biomass gets its energy from the sun through the process of photosynthesis.
   Using biomass reduces the amount of organic material placed in landfills.
   Fast-growing crops can be grown for their energy content.
   Using biomass does not contribute to the greenhouse effect, since the amount of carbon dioxide produced equals the amount taken in during growth.

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COAL ANSWERS

Description of coal:
   Coal is a black, solid hydrocarbon (fossil fuel) formed from the remains of ancient plants in swamps millions of years ago.

Renewable or nonrenewable:
   Nonrenewable

Where coal is located and how we recover it:
   Coal is located underground in many areas of the country. Shallow coal seams are surfaced mined. Coal buried deep is reached through underground mine shafts.

Ways we turn coal into energy we can use:
   Most coal is burned to produce heat.

Who uses coal and for what purposes:
   Power plants burn most of the coal to produce electricity. Industries also burn coal to make products, especially steel and iron.

Effect of using coal on the environment:
   Burning coal can pollute the air and cause acid rain. Burning coal also produces carbon dioxide, a greenhouse gas.

Important facts about coal:
   Coal produces half of the electricity in the U.S.
   The U.S. has the largest reserves of coal in the world.
   Coal is found in Appalachian states and some western states.
   Wyoming, West Virginia, Kentucky, Pennsylvania, and Texas are the top coal-producing states.
   Coal is transported mainly by train and barge. Transporting coal is a huge expense.
NATURAL GAS ANSWERS

Description of natural gas:
Natural gas is a colorless, odorless gas formed millions of years ago from tiny plants and animals. It is a fossil fuel.

Renewable or nonrenewable:
Nonrenewable, though some sources of methane are renewable - such as landfill gas

Where natural gas is located and how we recover it:
Natural gas is located in underground rock formations in sedimentary basins. We drill wells to reach it and pipe it from the ground.

Ways we turn natural gas into energy we can use:
Usually we burn natural gas to produce heat.

Who uses natural gas and for what purposes:
Industry burns natural gas to manufacture products. Homes and businesses burn natural gas to heat buildings and water and for cooking. Power plants burn natural gas to produce electricity.

Effect of using natural gas on the environment:
Natural gas is a clean-burning fossil fuel, but it produces some air pollution and carbon dioxide, a greenhouse gas.

Important facts about natural gas:
Mercaptan, an odorant that smells like rotten eggs, is added to natural gas so leaks can be detected. Natural gas is shipped by millions of miles of underground pipelines. Natural gas can be used as a transportation fuel if it is put under pressure and engines are modified.

PETROLEUM ANSWERS

Description of petroleum:
Petrolium is a liquid hydrocarbon, a fossil fuel formed millions of years ago from the remains of tiny sea plants and animals. It can be thin and clear like water or thick and black like tar.

Renewable or nonrenewable:
Nonrenewable

Where petroleum is located and how we recover it:
Petroleum is located underground in rocks in sedimentary basins. Much is under water. We drill wells to find it, then must pump it from the ground.

Ways we turn petroleum into energy we can use:
Petroleum is refined into many different fuels which are burned to produce heat. When gasoline is burned in vehicles, it causes small explosions that push pistons to produce motion.

Who uses petroleum and for what purposes:
Most petroleum products are used by the transportation sector to move people and goods. Industry burns petroleum to manufacture products and also uses petroleum as a feedstock to produce many products.

Effect of using petroleum on the environment:
Burning petroleum can cause air pollution and carbon dioxide, a greenhouse gas. Drilling for and transporting petroleum can cause damage to the land and water if there are leaks or spills.

Important facts about petroleum:
We use more petroleum than any other energy source.
The U.S. does not produce enough petroleum to meet our needs. We import about two-thirds of the petroleum we use from foreign countries. The Middle East has huge reserves of petroleum.
Petroleum is moved over land mostly by pipeline, and over water by tanker.
PROPANE ANSWERS

Description of propane:
Propane is a colorless, odorless fossil fuel found with petroleum and natural gas. It was formed millions of years ago from the remains of tiny plants and animals.

Renewable or nonrenewable:
Nonrenewable

Where propane is located and how we recover it:
Propane is found with petroleum and natural gas deposits and is separated from both fuels during refining and processing.

Ways we turn propane into energy we can use:
We put propane in tanks under pressure to turn it into a liquid so that it is more easily moved from place to place, then we burn it to produce heat.

Who uses propane and for what purposes:
Industry uses propane to make products; farmers use propane for heat in rural areas; homes use propane for outdoor grills; businesses use propane to fuel indoor machinery and as a fleet fuel.

Effect of using propane on the environment:
Propane is a clean-burning fossil fuel, but burning it does produce some air pollutants and carbon dioxide, a greenhouse gas.

Important facts about propane:
Propane is an LPG - liquefied petroleum gas.
Propane is easily turned into a liquid under pressure. It takes up 270 times less space as a liquid.
Propane is stored in underground caverns and moved by pipelines and trucks.
Propane is called the portable fuel because it is easily transported as a liquid.

WIND ANSWERS

Description of wind energy:
Wind is the circulation of air caused by the uneven heating of the earth's surface.

Renewable or nonrenewable:
Renewable

How wind energy is produced and how we recover it:
Wind is produced when the sun shines on the earth, heating the land more than the water. The warmer air over land rises and cooler air moves in to take its place, producing convection currents.

Ways we turn wind into energy we can use:
We use wind machines that slow the motion of the wind, turning turbines to produce electricity.

Who uses wind energy and for what purposes:
Usually, independent power producers (not big utilities) build wind farms to produce electricity.

Effect of using wind energy on the environment:
Wind machines are very clean, producing no air or water pollution. They take up a lot of land, but most of the land can be used for other things at the same time for things such as farming and grazing cattle.

Important facts about wind energy:
Wind machines do not produce a lot of electricity, and do not produce it all the time.
Wind machines cannot be used in many areas. There must be stable, continuous wind resources.
BIOMASS

Description of biomass:

Renewable or nonrenewable:

Ways we turn biomass into energy we can use:

Who uses biomass and for what purposes:

Effect of using biomass on the environment:

Important facts about biomass:

COAL

Description of coal:

Renewable or nonrenewable:

Where coal is located and how we recover it:

Ways we turn coal into energy we can use:

Who uses coal and for what purposes:

Effect of using coal on the environment:

Important facts about coal:
NATURAL GAS

Description of natural gas:

Renewable or nonrenewable:

Where natural gas is located and how we recover it:

Ways we turn natural gas into energy we can use:

Who uses natural gas and for what purposes:

Effect of using natural gas on the environment:

Important facts about natural gas:

PETROLEUM

Description of petroleum:

Renewable or nonrenewable:

Where petroleum is located and how we recover it:

Ways we turn petroleum into energy we can use:

Who uses petroleum and for what purposes:

Effect of using petroleum on the environment:

Important facts about petroleum:
PROPANE

Description of propane:

Renewable or nonrenewable:

Where propane is located and how we recover it:

Ways we turn propane into energy we can use:

Who uses propane and for what purposes:

Effect of using propane on the environment:

Important facts about propane:

WIND

Description of wind energy:

Renewable or nonrenewable:

How wind energy is produced and how we recover it:

Ways we turn wind into energy we can use:

Who uses wind energy and for what purposes:

Effect of using wind energy on the environment:

Important facts about wind energy:
Making Biofuel Lab
Teacher Sheet
Adapted from “The biofuel Project” (http://www1.eere.energy.gov/education/lessonplans/)

Review the history, background, materials, safety, and process for making biodiesel. Emphasis the importance of safely using KOH or NaOH and methanol.

An inquiry-based activity that could be added in lieu of the provided activity is to have the student groups come with their own history, background, material, safety, and process for making biodiesel and an additional experiment that they developed. Students should discuss whether they would use KOH or NaOH and why they made that decision. After students present their findings they can be given the brief.

Background information:
Biodiesel is a renewable fuel made from any biologically based oil, and can be used to power any diesel engine. Now accepted by the federal government as an environmentally friendly alternative to petroleum diesel, biodiesel is in use throughout the world. Biodiesel is made commercially from soybeans and other oilseeds in an industrial process, but it is also commonly made in home shops from waste fryer grease. The simple chemistry involved in small-scale production can be easily mastered by novices with patience and practice. In this exercise, students will learn the process of making biodiesel and practice some analytical techniques.

Dr. Rudolf Diesel first demonstrated his diesel engine, which ran on peanut oil, to the world in the early 1900’s. The high compression of diesel engines creates heat in the combustion cylinder, and thus does not require a highly flammable fuel such as that used in gasoline engines. The diesel engine was originally promoted to farmers as one for which they could “grow their own fuel.” Diesels, with their high torque, excellent fuel efficiency, and long engine life are now the engine of choice for large trucks, tractors, machinery, and some passenger vehicles. Diesel passenger vehicles are not presently common in the United States due to engine noise, smoky exhaust, and cold weather starting challenges. However, their use is quite normal in Europe and Latin America, and more diesels are starting to appear in the US market.

Over time, the practice of running the engines on vegetable oil became less common as petroleum diesel fuel became cheap and readily available. Today, people are rediscovering the environmental and economic benefits of making fuel from raw and used vegetable oils. Fuel made from waste fryer grease has the following benefits when compared to petroleum diesel:

• Using a waste product as an energy source
• Cleaner burning: lower in soot, particulate matter, carbon monoxide, and carcinogens
• Lower in sulfur compounds: does not contribute to acid rain
• Significant carbon dioxide reductions: less impact on global climate change
• Domestically available: over 30 million gallons of waste restaurant grease are produced annually in the US

In addition, the use of well-made biodiesel fuel can actually help engines run better. Petroleum diesel fuels previously relied on sulfur compounds in the oil to keep engines lubricated. However, sulfur tailpipe emissions are a significant contributor to the formation of acid rain, so regulators have forced the reduction of sulfur in diesel fuel. Biodiesel made from vegetable oil has a better lubricating quality and can help solve engine wear problems without increasing acid rain. For this reason, the use of biodiesel is already common in trucking fleets across the country.

Some other interesting facts:
Biodiesel can be readily mixed with diesel fuel in any proportion. Mixtures of biodiesel and diesel fuel are commonly referred to by the percentage of biodiesel in the mix. For example, B100 contains 100% biodiesel, B20 contains 20%.

- Biodiesel can be run in any unmodified diesel engine.
- Biodiesel is less flammable than diesel. It will gel at a higher temperature (typically around 20°F) and thus should be mixed with petroleum fuel in cold weather.

**Teacher Sheet: Making Biodiesel Fuel**

The reaction that converts vegetable oil into biodiesel is known as transesterification, which is similar to saponification, the process for making soap. Vegetable oil is comprised of triglycerides, which are glycerol-based esters of fatty acids. Glycerol is too thick to burn properly in a diesel engine at room temperatures, while esters make an excellent combustible material. The goal when making biodiesel is to convert the triglycerides from glycerol-based esters to methyl esters of fatty acids, thus transesterification. Sodium hydroxide (lye) is necessary to convert the methanol into methoxide ions, which will cleave the fatty acid from the glycerol by replacing the one glycerol with three methoxy groups per each triglyceride.

For every liter of vegetable oil, the reaction uses 220 milliliters (22% by volume) of methanol. New oil requires 4 grams of lye per liter of oil, whereas used oil will require somewhat more. The quantity of lye will vary depending upon the quality of our vegetable oil, and will need to be determined by chemical analysis. Students will first practice making fuel from new vegetable oil, which requires a known amount of lye for the reaction. In the second step, students will determine the quantity of lye needed for different used vegetable oils, and then test their analyses by making fuel from those oils.

**SAFETY NOTES:** Methanol and lye are dangerous substances and should be handled with caution! Methanol is poisonous to skin, and its fumes are highly flammable. Lye is a strong skin irritant and can cause blindness! Always wear gloves and goggles when working with these chemicals, and keep any sparks or flames away from methanol containers. Work under a chemical hood or other well ventilated space.

**Other cautions:** Biodiesel fuel made in a school lab is experimental in nature, and should be burned in diesel engines at the users own risk. While well made fuel will not harm a diesel engine, interested teachers & students are advised to read further on the subject before actually testing biodiesel in an engine. Students should not remove biodiesel fuel from the laboratory classroom without instructor permission.
Materials:
Chemical resistant gloves and goggles for each student
New vegetable oil (500 ml per group)
3 one-quart mason jars per group, or HDPE plastic bottles with tight fitting lids
Sodium Hydroxide (lye)
Methanol (400 ml per group)
Graduated cylinders: 1000 ml, 100 ml, and 10 ml
Pipettes graduated to measure 0.1 ml
Scale accurate to 0.1 grams
Hot plates with stirring rods
Large beakers for heating oil
Plastic scoops or ladles for transferring warmed oil to graduated cylinders
Celsius thermometers
Isopropyl alcohol (91% or 99%)
Packet of pH strips accurate in the 8-9 ranges
Phenol red indicator solution is an option if pH strips are not available.
Phenylalanine is also effective.
A stock solution made from 1000.0 ml distilled water and 1.00 grams of sodium hydroxide (a 0.1% solution, 1 liter should accommodate the whole class, and stores well if uncontaminated.) The accuracy of this solution is important to the whole exercise.
A 100 ml beaker for each group for decanting stock NaOH solution
Several small beakers for titration (about 4 per group)
Labeling tape and permanent markers

Alternate:
Two samples of waste vegetable oil (about 600 ml or more of each per group)

Procedure: Making fuel from new vegetable oil
Note to Instructor: The instructor may choose to give students a basic refresher in chemistry techniques, such as reading a meniscus in a graduated cylinder. If time permits it may help to demonstrate the reaction technique prior to the students engaging in the activity, or to prepare a well-settled sample of biodiesel ahead of time.

1. Put on your gloves and goggles. Everyone must wear protective gear while handling chemicals!
Check point 1 - No group may progress beyond this point without this step being signed off by the instructor.
2. Measure out 500 ml or more of new vegetable oil and pour it into a large beaker.
3. Heat 500 ml of new vegetable oil to 50 °C on a hotplate using a stirrer. One person in your group should watch the temperature closely so the oil does not overheat.
Note to instructor*: If hotplates are in short supply, one large beaker can be used to heat oil for several groups. This beaker should be located near a sink for easy transfer by scooping to graduated cylinders.
Perform the following two steps under the chemical hood or other well ventilated space.
Check point 2 - No group may progress beyond this point without this step being signed off by the instructor.
4. Measure 110 ml of methanol in a graduated cylinder and pour into your mixing bottle. Cap the methanol bottle and your mixing bottle tightly.
5. Weigh out 2.0 grams of sodium hydroxide (lye) and add to the methanol in your mixing bottle.
Cap the bottle and swirl gently for a few minutes until all of the lye dissolves. You now have sodium methoxide in your bottle, a strong base. Be careful!

6. When the lye is dissolved and the oil reaches 50 °C, add 500 ml of warm oil to the methoxide and cap the bottle tightly. Invert the bottle once over a sink to check for leaks. **Caution: Be certain that the oil is not over 60 °C, or the methanol may boil.**

7. Shake the bottle vigorously for a few seconds then, while holding the bottle upright, open the cap to release any pressure. Retighten the cap and shake for at least one minute venting any pressure occasionally. Set the bottle on the bench and allow the layers to separate.

8. Over the next 30-60 minutes, you should see a darker layer (glycerol) forming on the bottom of the bottle, with a lighter layer (biodiesel) floating on top. Complete separation of the reaction mixture will require several hours to overnight. Move on to the next step of the exercise while your biodiesel is separating.

**Questions for your lab book:**

- If the base rate for sodium hydroxide (lye) is 4.0 grams per liter of oil, why did you only use 2.0 grams for this batch?
  
  **Answer: This reaction used only 500 ml (0.5 liters) of oil.**

- How much lye would be used to convert 50 liters of new oil?
  
  **Answer: 50 L x 4.0 g/L = 200 g of lye.**

- For a given quantity of new oil, what variables could be changed to effect the reaction?
  
  **Answer: Mixing time, temperature, amount of lye, amount of methanol.**
Making Biofuel from new vegetable oil

Student Sheet

Background information:

The reaction that converts vegetable oil into biodiesel is known as transesterification, which is similar to saponification, the process for making soap. Vegetable oil is comprised of triglycerides, which are glycerol-based esters of fatty acids. Glycerol is too thick to burn properly in a diesel engine at room temperatures, while esters make an excellent combustible material. The goal when making biodiesel is to convert the triglycerides from glycerol-based esters to methyl esters of fatty acids, thus transesterification. Sodium hydroxide (lye) is necessary to convert the methanol into methoxide ions, which will cleave the fatty acid from the glycerol by replacing the one glycerol with three methoxy groups per each triglyceride.

For every liter of vegetable oil, the reaction uses 220 milliliters (22% by volume) of methanol. New oil requires 4 grams of lye per liter of oil, whereas used oil will require somewhat more. The quantity of lye will vary depending upon the quality of our vegetable oil, and will need to be determined by chemical analysis. Students will first practice making fuel from new vegetable oil, which requires a known amount of lye for the reaction. In the second step, students will determine the quantity of lye needed for different used vegetable oils, and then test their analyses by making fuel from those oils.

SAFETY NOTES:
Methanol and lye are dangerous substances and should be handled with caution! Methanol is poisonous to skin, and its fumes are highly flammable. Lye is a strong skin irritant and can cause blindness! Always wear gloves and goggles when working with these chemicals, and keep any sparks or flames away from methanol containers. Work under a chemical hood or other well ventilated space.

Other cautions: Biodiesel fuel made in a school lab is experimental in nature, and should be burned in diesel engines at the users own risk. While well made fuel will not harm a diesel engine, interested teachers & students are advised to read further on the subject before actually testing biodiesel in an engine. Students should not remove biodiesel fuel from the laboratory classroom without instructor permission.
Materials:
- goggles
- New vegetable oil (500 ml per group)
- one-quart mason jars per group, or HDPE plastic bottles with tight fitting lids
- Sodium Hydroxide (lye)
- Methanol (400 ml per group)
- Graduated cylinders: 1000 ml, 100 ml, and 10 ml
- Pipettes graduated to measure 0.1 ml
- Scale accurate to 0.1 grams
- Hot plates with stirring rods
- Celsius thermometers
- Isopropyl alcohol (91% or 99%)
- Packets of pH strips accurate in the 8-9 ranges
- A 100 ml beaker for each group NaOH solution
- Several small beakers for titration (about 4 per group)
- Labeling tape and permanent markers

Procedure:
1. Put on your gloves (if available) and goggles. Everyone must wear protective gear while handling chemicals!
   
   **Check point 1 - No group may progress beyond this point without this step being signed off by the instructor.**

2. Measure out 500 ml or more of new vegetable oil and pour it into a large beaker.
3. Heat 500 ml of new vegetable oil to 50 °C on a hotplate using a stirrer. One person in your group should watch the temperature closely so the oil does not overheat.

   ***Perform the following two steps under the chemical hood or other well ventilated space.***

   **Check point 2 - No group may progress beyond this point without this step being signed off by the instructor.**

4. Measure 110 ml of methanol in a graduated cylinder and pour into your mixing bottle. Cap the methanol bottle and your mixing bottle tightly.
5. Weigh out 2.0 grams of sodium hydroxide (lye) and add to the methanol in your mixing bottle. Cap the bottle and swirl gently for a few minutes until all of the lye dissolves. You now have sodium methoxide in your bottle, a strong base. Be careful!
6. When the lye is dissolved and the oil reaches 50 °C, add 500 ml of warm oil to the methoxide and cap the bottle tightly. Invert the bottle once over a sink to check for leaks. **Caution: Be certain that the oil is not over 60 °C, or the methanol may boil.**
7. Shake the bottle vigorously for a few seconds then, while holding the bottle upright, open the cap to release any pressure. Retighten the cap and shake for at least one minute venting any pressure occasionally. Set the bottle on the bench and allow the layers to separate.
8. Over the next 30-60 minutes, you should see a darker layer (glycerol) forming on the bottom of the bottle, with a lighter layer (biodiesel) floating on top. Complete separation of the reaction
mixture will require several hours to overnight. Move on to the next step of the exercise while your biodiesel is separating.

Questions:
1. If the base rate for sodium hydroxide (lye) is 4.0 grams per liter of oil, why did you only use 2.0 grams for this batch?

2. How much lye would be used to convert 50 liters of new oil?

3. For a given quantity of new oil, what variables could be changed to effect the reaction?
HOW MUCH ENERGY CAN BE OBTAINED FROM ALTERNATE SUBSTANCES VERSUS BIOFUELS?

Created by Kim Misyak-Chumney (Resource “Research Projects in Renewable Energy” (http://www1.eere.energy.gov/education/lessonplans/)

Previous knowledge: Students should have knowledge of how to use a calorimeter and the basics of thermochemistry. (High school chemistry books should have a section on thermochemistry.) The equation for specific heat is \( q = m \times \Delta T \times c \), where \( q \) is heat absorbed or released, \( \Delta T \) is the change in temperature and \( c \) is the specific heat. Water has a specific heat of 4.184 J/°C g http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/spht.html website has an explanation and an interactive table to calculate specific heat). The substance that transfers more heat provides more energy.

Materials:
Use the setup for the calorimeter as shown, but use an alcohol burner as the source of heat.
Laboratory balance and a calorimeter (see diagram below):

![Diagram of calorimeter](image)

Safety Work in a well-ventilated area. Be extremely careful of burns because a lot of heat energy will be generated.

PROCESS
1. Conduct preliminary tests to determine the best size of material to test (e.g., peanuts, pecans, walnuts, castor beans, sunflowers, corn, wood, coal and milkweed). Or compare the heat energy from burning alcohols (e.g., methanol, ethanol, propanol, rubbing alcohol, etc).
   Caution Alcohols are very flammable. Work in the science laboratory under supervision of your teacher or another adult.
2. Use equal volumes of water in the test tube for each test.
3. Record the beginning and ending temperatures of the water.
4. Measure the weight of alcohol (or substance) before burning and record.
5. Calculate the mass of the water: 100 mL (equals 100 g) of water and record.
6. Burn the substance in the calorimeter.
7. Calculate the amount of joules per gram of substance tested using the specific heat equation. Show your work below.

<table>
<thead>
<tr>
<th>Table of substances</th>
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<tbody>
<tr>
<td>Substance</td>
</tr>
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**Questions**

1. Write the substances in order of highest to lowest amount of heat produced.

2. Which substance produced the most heat?

3. Would it be economically possible to produce this substance in mass amounts to use as an energy source for the U.S.?

4. What are some of the risks of mass producing this substance?

5. What are some possible errors for this experiment?

**Additional experiments:** Collect gasses produced from calorimeter and test amount of carbon dioxide produced.

**Going further:** Have students determine the usable heat energy that could be produced on an acre of land if certain crops were raised. Choose peanuts and sunflowers, for example. This would require one to know the caloric or heat value (cal/g) and the amount of biomass produced per unit area.