U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ENERGY EDUCATION AND WORKFORCE DEVELOPMENT

# The Biofuel Project:

# Creating Biodiesel

**Grades: 9-12**

**Topic: Biomass**

**Authors: Matthew A. Brown and Raymond I. Quintana**

**Owner: National Renewable Energy Laboratory**

This educational material is brought to you by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy.

# The Bio-Fuel Project

**AUTHORS:**
Matthew A. Brown and Raymond I. Quintana

**GRADE LEVEL/SUBJECT:**
10th, 11th, 12th Chemistry & Technology Education


**Relevant Curriculum Standards:**

**From The National Science Education Content Standards**

**Science as Inquiry Standard A:**

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations.

**Physical Science Standard B:**

- Structure and Properties of Matter - The physical properties of compounds reflect the nature of the interactions among its molecules. Carbon atoms can bond to one another…to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

- Chemical Reactions – Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Catalysts, such as metal surfaces, accelerate chemical reactions.
- Transfer of energy – energy is a property of many substances and is associated with heat, light, and electricity. Energy is transferred in many ways.
- Conservation of Energy – Everything tends to become less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels.

**Science and Technology Standard E:**
- Identify a problem.
- Propose designs and choose between alternative solutions.
- Implement a proposed solution.
- Evaluate the solution and its consequences.

From The Standards for Technological Literacy

**Standard 5: Students will develop an understanding of the effects of technology on the Environment:**

L. Decisions regarding the implementation of technologies involve the weighing of trade-offs
between predicted positive and negative effects on the environment.

**Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving:**

L. Many technological problems require a multidisciplinary approach.

**Standard 16. Students will develop an understanding of and be able to select and use energy and power technologies:**

N. Power systems must have a source of energy, a process, and loads.

**Standard 17. Students will develop an understanding of and be able to select and use information and communication technologies:**

Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

**Standard 18. Students will develop an understanding of and be able to select and use transportation technologies:**

K. Intermodalism is the use of different modes of transportation, such as highways, railways, and waterways as part of an interconnected system that can move people and goods easily from one mode to another.
L. Transportation services and methods have led to a population that is regularly on the move.
M. The design of intelligent and non-intelligent transportation systems depends on many processes and innovative techniques.

**TEACHER'S OVERVIEW:**

This exercise introduces students to the concept of alternative fuels and gives them an opportunity to produce their own biodiesel fuel using an analytical approach. The text of the exercise gives students a brief background in the environmental benefits of using biodiesel as a diesel substitute. The lab portion of this exercise demonstrates the basic chemistry involved in making biodiesel from vegetable oils and waste oils.

Many students have heard about biodiesel without realizing that to produce the fuel from waste vegetable oil is a fairly simple process. Seeing the process firsthand and, better yet, going through the steps from oil to fuel, enables the student to grasp the fuel making process. Included in this exercise is some basic oil analysis that is necessary to differentiate between various oils that a biodiesel producer may encounter. This is an easy exercise to set up. It requires primarily basic equipment commonly found in a high school chemistry laboratory. Interest sparked by this exercise may inspire students to become more familiar with the various aspects of renewable energy technologies.

Safety practices for handling the materials involved in producing biodiesel fuel cannot be overemphasized, especially if students attempt to synthesize biodiesel outside of class.

**LEARNING OBJECTIVES:**

Students participating in this activity are expected to learn the following:

- The definition of a renewable fuel
- How the substitution of biodiesel fuel for petroleum diesel benefits the environment
- How biodiesel fuel is made from waste vegetable oil
- How this fuel-making process can be adjusted to utilize waste oils from different sources, and the chemical analyses necessary to determine oil quality
- How to assess the finished products from the biodiesel reaction
- How issues of waste stream management can be addressed in an environmentally responsible way

**TIME ALLOTTED: Two weeks**

**VOCABULARY**

| | | |
|---|---|---|
| Energy | Biodiesel | Titration |
| Transesterification | Triglycerides | Esters |
| Fuel | pH | Glycerol |

**RESOURCES AND MATERIALS:**

**Resources:**
Bio-Fuel design brief handouts, computers for web research of Bio-Diesel processing.

**Materials:**

Chemical resistant gloves, goggles, and lab aprons

New vegetable oil (500 ml)

Two samples of waste vegetable oil (about 600 ml or more of each)

Sodium Hydroxide (lye)

Methanol

Isopropyl alcohol

0.1% sodium hydroxide stock solution for titrations

2 quart mason jars, or HDPE plastic bottles with tight fitting lids

Graduated cylinders: 1000 ml, 100 ml, and 10 ml.

Pipettes, or burets graduated to measure 0.1 ml, graduated eyedroppers, or graduated plastic syringes

Scale accurate to 0.1 grams

Hot plates with stirring rods or suitable substitute

1 L beakers for heating oil

Beaker tongs for transferring warmed oil to graduated cylinders

Celsius thermometers

pH strips accurate in the 8-9 range or phenol red indicator solution

A 250 ml beaker for each group for decanting stock NaOH solution.

Several small beakers for titration (3 or 4 per group).

Labeling tape and permanent markers

**PREREQUISITE KNOWLEDGE:**

- Students should be able to use computers to do Internet research.
- Students should be able to use common laboratory equipment to measure liquid volumes, to measure mass, and to prepare solutions.

## Creating Bio-Diesel

**Teaching and Prep time:**

**Gathering materials:** 2 hours+. This exercise is most effective if there are a variety of waste vegetable oils to work with. These can be accessed from the school cafeteria, the teacher's own kitchen, or restaurants that fry foods in vegetable oil. It is advisable to consider the oil source a few weeks in advance.

**Classroom setup**: 30 minutes

**Teaching time:** The entire exercise can be completed in one 2-3 hr. lab session. An additional follow-up exercise is included.

Introducing the exercise: 20-30 minutes

Step I, making fuel from new vegetable oil: 40 minutes

Step II, chemical analysis of used vegetable oil: 30 minutes

Step III, making experimental fuel from used vegetable oils: 30 minutes

Optional 2$^{nd}$ week analyses: 1 hr+

**Day 1: 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

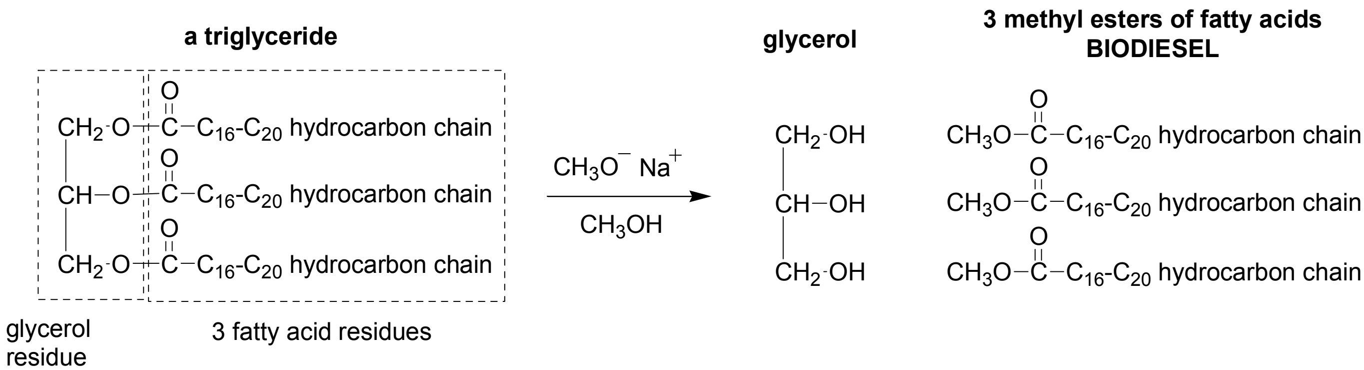
In addition, the use of well-made biodiesel fuel can actually help engines run better. Petroleum diesel fuels previously relied on sulfur compounds in the oil to keep engines lubricated. However, sulfur tailpipe emissions are a significant contributor to the formation of acid rain, so regulators have 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 20F) and thus should be mixed with petroleum fuel in cold weather.

**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 *trans*esterification. 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)

Two samples of waste vegetable oil (about 600 ml or more of each 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, graduated eyedroppers, or graduated plastic syringes

Scale accurate to 0.1 grams

Hot plates with stirring rods or suitable substitute

Large beakers or pots for heating oil

Plastic scoops or ladles for transferring warmed oil to graduated cylinders

Celsius thermometers

Isopropyl alcohol (91% or 99%)

Packets 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

**Procedure:**

**Day 2: 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.*

**Day 3: Testing waste oil by titration to determine the quantity of lye.**

As vegetable oil is used for frying foods, the high heat, water, and food products in the fryer can degrade the oil into various byproducts. One byproduct is the development of free fatty acids in the oil. These acids will act to neutralize some of the lye used in the biodiesel reaction. Since the reaction requires four grams of catalyst for every liter of oil, we will need to add extra lye to make up for that neutralized by the free fatty acids. More heavily used oil will tend to contain more acid, and thus require larger quantities of lye than lightly used oil.

It is important when making biodiesel to use the proper amount of lye for a given oil. Too much lye can result in a solid soap forming in the reaction vessel, and too little lye will result in an incomplete reaction and poor quality fuel.

A process called titration determines the exact amount of extra lye required. To perform the titration, a known solution of lye is added to a sample of used oil in measured amounts, until a desired pH shift is seen. Because it is difficult to measure the pH of oil, the oil will first be dissolved in isopropyl alcohol to make testing easier.

For this exercise, you will determine the quantity of lye needed to make biodiesel from two different oils: one that is heavily used and one that is lightly used.

1. Obtain a sample of used vegetable oil from two different sources. Preferably one will be more heavily used than the other. Label the lightly used oil as sample A, and the heavily used oil as sample B.
2. Using a pipette, syringe, or graduated eyedropper, measure 1.0 ml of oil from one sample into a small mixing beaker. Make a note in your lab book of which oil you are using first: lightly used (A) or heavily used (B).
3. Measure 10 ml of isopropyl alcohol using a graduated cylinder, add this to the oil, and swirl to mix
4. Test the pH of the oil-alcohol solution using a pH strip
5. Using a different pipette, add lye-water (from a stock 1% solution of NaOH in distilled water) to the oil-alcohol solution in 0.5 ml increments. Add the lye-water carefully so that you are sure to only add 0.5 ml at a time.

6. After each 0.5 ml addition of lye-water, recheck the pH with a pH strip. Record the number of 0.5 ml additions you make on a tally sheet!
7. Continue adding lye-water until the pH of the solution reaches approximately 8.5. At this point, count the number of milliliters of lye-water that you added. (For example, if you added 0.5 ml of lye-water three times, you added a total of 1.5 ml of lye-water).
8. Calling the number of ml of lye-water that you added "X", put that number into the following equation:

   X + 4.0 grams = L

   L = the total number of grams of lye needed to make biodiesel from 1 liter of this particular oil. Record this number in your lab book.

9. Repeat steps 1 through 7 using a second batch of oil of different quality, and record the value for L in your lab book. Be sure to keep track of which value for L refers to which oil sample. You may want to repeat the titration for each oil to be sure of your results.

**If using phenol red instead of pH strips, follow these steps:**

1. Add 5 drops of phenol red to the beaker containing 10 ml of isopropyl alcohol and 1 ml of oil to be tested.
2. The solution will appear yellow at an acid pH, and will turn pink when the pH is between 8 and 9. Add lye-water in 0.5 ml increments, counting as you go, until the oil alcohol solution turns pink or purple and stays that way for 30 seconds or more.
3. The number of milliliters of lye-water it took to turn the solution pink is "X". Refer to the equation above.

**Questions:**

- Why is it necessary to perform a titration on used vegetable oil?
- How much lye will be required to convert 1.0 liters of vegetable oil sample A to biodiesel? Sample B?
- How much lye will be required for 0.5 liters of each oil: A? B?
- When biodiesel brewers make large batches of fuel, they typically repeat the titration procedure several times per batch. Why do you think they would do this? *Answer: because the titration uses a very small sample of oil to determine the lye amount for a large volume of oil and thorough mixing is difficult for large batches (try*

*having answers in different color, even just for viewing on the monitor)*

- Which type of oil do you think requires more lye catalyst, lightly used or heavily used? Why? *Answer: Heavily used oil will require more catalyst. As the oil is used it breaks down and forms free fatty acids, which neutralize some of the lye.*
- Can you see any difference in color between the heavily used oil and lightly used oil? *Answer: Heavily used oil is usually darker in color than lightly used oil. This information can be helpful when trying to assess whether or not a titration figure is "in the ballpark".*

**Day 4: Making biodiesel using waste vegetable oils**

In part 3, you will use the value for L that you determined in step 2 to make fuel from waste oil. This is basically a repeat of the procedure from part 1, except that you will be varying the quantity of lye for each batch.

1. Put on your gloves and goggles. Everyone must wear protective gear while handling chemicals!
2. Measure out 500 ml or more of each waste vegetable oil, and pour it into a large beaker. Mark each beaker "A" or "B" depending on the oil you are using. Obtain two mixing bottles and label one "A" and the other "B"
3. Heat 500 ml of each 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.

**Check point 3 - No group may progress beyond this point without this step being signed off by the instructor.**

**Perform this step and the next under the chemical hood**.

4. Measure 110 ml of methanol in a graduated cylinder for each batch and pour into your mixing bottles. Cap the methanol and mixing bottles when you are finished.
5. Weigh out and add the correct amount of lye for each oil to your mixing bottles. Recap the bottles tightly. Gently agitate each bottle until the lye is dissolved.
6. When the oil samples are up to 50 °C, add 500 ml of the proper oil to the each mixing bottle and cap them tightly.

**Be sure that the oil is not over 60 °C to avoid boiling the methanol!**

7. Invert the mixing bottle once over a sink to check for any leaks.
8. 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.
9. Leave the bottles to separate until next week.
10. Clean up your lab space.

**Day 5: Separating and washing your biodiesel**

If your procedure worked correctly, there should be two distinct layers after settling. The darker layer at the bottom is a crude glycerine byproduct, and the lighter layer on top is biodiesel. If you pick up the settling bottle and rock it slightly from side to side, notice how the darker layer is thicker than the fuel floating on top. This higher viscosity of glycerine is one of the reasons that it isn't suitable for use in a diesel engine at room temperatures. By removing the heavier, more viscous part of the oil, the esters pass through the engine's injectors and combust that much easier.

It is common to see a whitish third layer floating between glycerine and the biodiesel. This soap-like material is a result of adding too much lye, or having water in the oil. It should be discarded with the glycerine. Oil can be tested for water content by heating it to the boiling point of water (100 °C) and watching for bubbles.

After settling for a few days (or a week), biodiesel producers will decant the fuel off the top of the glycerine, pass it through a filter, and use it like diesel fuel in any diesel engine. Many fuel producers further refine the fuel by washing with water, which removes any residual glycerol, lye or methanol, before use.

Your bottle now contains biodiesel, glycerin, mono- and di-glycerides, soap, methanol, lye, and possibly a little leftover oil (triglycerides). The glycerides are all oil-soluble, so they'll reside predominantly in the upper, biodiesel layer. The thin layer of glycerin, which is water-soluble, will sink. Depending on the oil and catalyst you used, it might be either liquid or solid. Soap, methanol, and lye, which are also water-soluble, will be mixed throughout both layers – although some of the soap can sometimes form its own thin layer between the bio-diesel and glycerin.

If you see more than two layers, or only one, then something is wrong – possibly excessive soap or monoglyceride formation. These are both emulsifiers, and in sufficient quantities they will prevent separation. In this case, check your scales, measurements, and temperatures. You can reprocess the bio-diesel with more methoxide, or try again with fresher oil (or new oil). If you can, shake the bottle even harder next time. In an engine, glycerin droplets in bio-diesel will clog fuel filters, soap can form ash that will damage injectors, and lye can also abrade fuel injectors. Meanwhile, methanol has toxic and combustible fumes that make bio-diesel dangerous to store. You don't want any of these contaminants in your bio-diesel. If you left your bio-diesel to settle undisturbed for several weeks, these water-soluble impurities would slowly fall out of the bio-diesel (except the methanol). Washing your bio-diesel with water removes the harmful impurities, including the methanol, much faster.

**Days 6 & 7: Additional Testing**

**Cleanup:** Biodiesel can be discarded with other non-halogenated organic chemical waste from the school chemistry lab.

**Making Soap:** Glycerine can be used to make soap, or discarded with other waste products. To make soap from glycerine, heat it to 80 °C for several hours to boil off the methanol. This process must be done under a chemical hood and away from open flame. When the methanol has been removed, the liquid glycerine will stop bubbling, and about 20% or more will reduce the total volume of the fluid. We prefer to wait until the heated glycerine has reached 100 degrees C to be certain the methanol is removed.

For every liter of warm glycerine, add 200 ml of distilled water combined with 30 grams of sodium lye. Add the lye water to the glycerine, stir well, and pour into a plastic mold to cool. The resulting soap should cure for several weeks before use. It is effective at cutting grease on hands. Methanol must be removed from the glycerine before making soap!

**Yield Determination:** Different factors affect the success of a biodiesel reaction, including temperature, mixing time, and the relative amount of each ingredient. A "complete" reaction will result in a glycerine layer approximately equal to the amount of methanol added (in the case of the 500 ml batches, about 110 ml of glycerine.) Reactions that come up short on glycerine have residual byproducts, including mono and di-glycerides in the fuel layer. These compounds result in a poorer quality fuel that is more difficult to refine.

To determine the glycerine yield, the contents of a mixing bottle can be poured into a graduated cylinder, and the relative volume of each layer measured. Comparisons can be made between the results from different batches of oil, or by changing variables between batches of the same oil.

**Wash Test:** Many of the impurities contained in settled biodiesel are soluble in water. A good way to assess your different batches of fuel is to pour a sample into a mixing bottle with an equal amount of water, then shake this vigorously until the two are mixed together. After mixing, allow the fluids to settle and observe what happens. Fuel with a lot of soap in it (too much lye, or fuel made from oil high in free fatty acids) will form an emulsion (like mayonnaise) that is difficult to separate even with time. Well-made fuel will separate into a layer of milky wash water and amber biodiesel after about 10 or 20 minutes. Comparisons can be made between settling/ separation times for different batches of fuel, to assess the level of impurities in each batch.

It is common in large scale biodiesel processing to continue the wash process until the water no longer becomes cloudy. In water washing, water is very gently combined with the fuel to avoid emulsification (adding water via fine mist nozzles is one option, running air bubbles through the water layer beneath a column of fuel is another.)

After the initial wash, saturated water is drained off, and the process is repeated until water runs clear and is relatively neutral in pH. Washed biodiesel should be allowed to settle several days until it becomes completely clear before using. You will notice that washed fuel is typically clear enough to see through.

**Specific Gravity:** The specific gravity of biodiesel should be somewhere between 0 and 0.90. Although this is reported to be an unreliable indicator of fuel quality, it does present an interesting comparison between batches of fuel or between fuel and unprocessed vegetable oil.

**Biodiesel resources:**

Matt Steiman, Wilson College, Chambersburg PA

**Websites:**

Homebrew biodiesel:

www.kitchen-biodiesel.com

http://www.biodieselcommunity.org/

www.journeytoforever.org

www.biodieselamerica.com

Discussion board with great archives:
http://biodiesel.infopop.cc/6/ubb.x?a=cfrm&s=447609751

Industrial biodiesel: www.biodiesel.org

**Books:**

- "From the Fryer to the Fuel Tank" by Joshua Tickell. The original book on biodiesel, including basic information on how to make small batches, build a biodiesel processor, and convert a vehicle to straight vegetable oil. Also contains nice informative sections on biodiesel history and environmental benefits. The website www.biodieselamerica.org sells the book, and lots of other useful information.

- "Biodiesel Homebrewer's Manual", by Maria "Mark" Alovert. This resource guide contains a step-by-step explanation of how to make fuel in small and large batches, as well as an affordable processor design. Answers most of the questions one will have after reading "From the Fryer" and making fuel for a while. Highly recommended! Ms. Alovert sells her book at www.localb100.com, another very useful website!

**Other safety information**

**Methanol Safety:**


**Methanol is poison!** This powerful alcohol causes eye and skin irritation, and can be absorbed through intact skin. This substance has caused adverse reproductive and fetal effects in animals. it is 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.

**Danger! Flammable liquid and vapor.** Keep sparks and flame away. Methanol vapors sink in air.

The MSDS for methanol is available from http://www.kitchen-biodiesel.com/Methanol_MSDS.htm

**Sodium hydroxide (lye)**


**Poison! Danger! Corrosive!** May be **fatal** if swallowed, and harmful if inhaled. This compound causes burns to any area of contact. Reacts with water, acids and other materials.

The MSDS for Sodium Hydroxide (lye) is available from http://www.kitchen-biodiesel.com/NaOH_MSDS.htm

**Materials Sources:**

- Most materials and equipment for this procedure can be obtained through normal school lab supply companies.
- Sodium hydroxide (lye) can be obtained from the school chemical supplier. Red Devil Lye may also be found in the cleaning section of hardware and grocery stores. Sodium Hydroxide can also be ordered online.

- Methanol can also be ordered from the school chemical supplier. Race fuel shops also carry methanol, and the yellow bottle of Heet gas line deicer (from auto parts stores) is 99% methanol.
- Small plastic syringes for titration can be found affordably at many pharmacy stores.
- Phenol red can be found at many swimming pool supply stores.
- A cheap and effective indicator solution can be made from Turmeric (an Indian spice available in grocery stores) using the following recipe: Add 6 grams (1 tbsp) turmeric to 100 ml of isopropyl (rubbing) alcohol. Place turmeric and alcohol in a jar and shake, allow to settle overnight, and decant the liquid. 5 drops makes an effective indicator that changes to red at pH 8.5.

# Making Bio-Diesel


***Technology Education***

**Statement of the Problem**

To create a fuel to be used in a diesel engine from a renewable feedstock and use as many by-products of the process for other end use products

**IDEAS * DEVELOPING * BUILDING * TESTING**
**EVALUATING * REDESIGN/REBUILD/RETEST**
**to**
**SUCCESS**

ME:______________________________________________
TE STARTED:__________________________ DATE DUE:__________________________

**OVERALL ACTIVITY GRADE:__________**

## Requirements

**1. This activity will be completed in______________.**
**2. You will work in teams of two and create 1 quart of Biodiesel.**
**3. Your completed brief is due on _________________.**
**4. Answer the Research Questions on page 3 prior to beginning biodiesel process.**
**5. You must fully complete part five by recording all data.**
**6. Complete all the work asked for and answer all questions in this brief booklet.**
**7. Names of all group members must be on the front page and assessment rubric.**
**8. Review the Assessment Rubric to know all grade requirements were satisfied.**
**9. Present all findings in a 2 page report and PowerPoint presentation to the class.**

## Objectives

1. Definition of a renewable fuel.

2. How the substitution of biodiesel fuel for petroleum diesel benefits the environment.

3. How biodiesel fuel is made from waste vegetable oil.

4. How the process can be adjustedto utilize waste oils from different sources, and the chemical analyses necessary to determin oil quality.

5. How to assess the finished product.

## Research Paper and PowerPoint Presentation

**Requirements:**

Each group will prepare a 5 page paper outlining the following (all members **must** participate):

1. An abstract
2. Introduction
3. An overveiw of the entire process
4. Data, findings, and calculations
5. Difficulties and solutions
6. Conclusion

Each group will prepare a ten minute PowerPoint presentation and present to the class.

1. This presentation should be a snapshot of your paper and design brief.
2. All students **must** participate in the presentation (changing slides doesn't count)
3. Students should be professionally dressed.

## PART ONE : Research Questions

Describe the process used to produce diesel fuel. Be specific.

Besides the type of fuels used what is the major difference between gasoline and diesel engines? (how do they work)

List and describe 5 major advantages and 5 major disadvantages to fossil fuels

What is the process called that we will be using to produce fuel from vegetable oil? (describe)

List and describe 5 major advantages and 5 major disadvantages to renewable fuels?

What is the key difference between WVO and bio-diesel? ( what does one have that the other doesn't?)

## Part Two: 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 to the world running on peanut oil 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

In addition, 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, use of Biodiesel is already common in trucking fleets across the country.

Some other interesting facts:

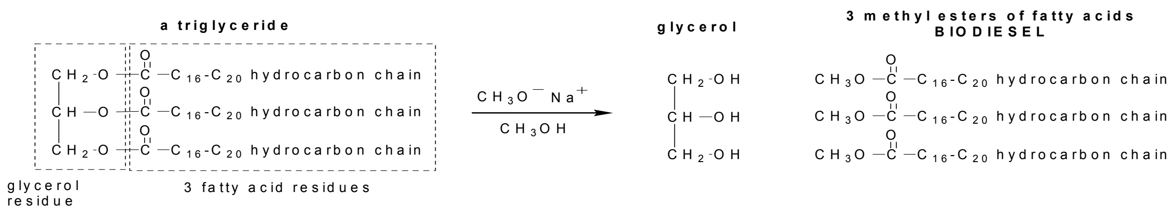
- Biodiesel can be readily mixed with diesel fuel in any proportion. Mixtures of biodiesel
- Biodiesel can be run in any unmodified diesel engine.
- Biodiesel is less flammable than diesel. It will gel at a higher temperature (typically

| **Part Two cont.: Materials List:** |
|---|
| Chemical resistant gloves and goggles |
| Two samples of waste vegetable oil (about 600 ml or more of each) |
| Sodium Hydroxide (lye) |
| Graduated cylinders: 1000 ml, 100 ml, and 10 ml. |
| Pipettes graduated to measure 0.1 ml, graduated eyedroppers, or graduated plastic syringes |
| Hot plates with stirring rods or suitable substitute |
| Large beakers or pots for heating oil |
| Packets of pH strips accurate in the 8-9 range. Phenol red indicator solution is an option if pH strips are not available. |
| A stock solution of lye in distilled water (0.1%) |
| New vegetable oil (500 ml) |
| Labeling tape and permanent markers |
| A 100 ml beaker for each group for decanting stock NaOH solution |
| Several small beakers for titration (3 or 4 per group). |
| Isopropyl alcohol |
| Celsius thermometer |
| 3 quart mason jars, or HDPE plastic bottles with tight fitting lids |
| Methanol |
| Scale accurate to 0.1 grams |
| Plastic scoops or ladles for transferring warmed oil to graduated cylinders |


5

## PART TWO cont'd: Making Biodiesel Fuel & Safety

The process of converting vegetable oil into biodiesel is known as transesterification, which is similar to saponification, the process for making soap. Vegetable oil molecules are triglycerides: they are made up of a heavy glycerol molecule, and three lighter fatty acid chains called esters. Glycerol is too thick to burn properly in a diesel engine at room temperatures, while esters make an excellent combustible material. Thus, the goal is to separate the esters from the glycerol. In this reaction, the vegetable oil molecules are cleaved apart with the catalyst Sodium Hydroxide (Lye), which is a strong base. Then the esters are combined with methanol to become methyl esters, otherwise known as biodiesel.




For every liter of vegetable oil, the reaction uses 220 milliliters (22% by volume) of methanol, a powerful alcohol. 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, then test our 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 flame 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 students are advised to read further on the subject before actually testing biodiesel in an engine. Do not remove biodiesel fuel from the laboratory classroom.

6

## PART THREE : Procedure Steps

### Part 1: Making fuel from new vegetable oil

1. Put on your gloves and goggles. Everyone must wear protective gear while handling chemicals!
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 2 steps under a chemical hood or other well ventilated space.***

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 is up to 50C, 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 degrees C, or the methanol may boil.***
7. Shake the bottle vigorously for at least one minute, then allow your reaction to settle.
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 settling of the reaction will require several hours to overnight. Move on to the next step of the exercise while your biodiesel is settling.

**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?
·How much lye would be used to convert 50 liters of new oil?
·For a given quantity of new oil, what variables could be changed to effect the reaction?

### Part 2: Testing waste oil by titration to determine the quantity of lye.

As vegetable oil is used for frying foods, the high heat, water, and food products in the fryer can degrade the oil into various byproducts. One byproduct is the development of free fatty acids in the oil. These acids will act to neutralize some of the lye used in the biodiesel reaction. Since the reaction requires 4 grams of catalyst for every liter of oil, we will need to add extra lye to make up for that neutralized by the free fatty acids. More heavily used oil will tend to be more acid, and thus require larger quantities of lye than lightly used oil.
It is important when making biodiesel to use the proper amount of lye for a given oil. Too much lye can result in a solid soap forming in the reaction vessel, and too little lye will result in an incomplete reaction and poor quality fuel.
The exact amount of extra lye required is determined by a process called titration. To perform the titration, a known solution of lye is added to a sample of used oil in measured amounts, until a desired pH shift is seen. Because it is difficult to measure the pH of an oil, the oil will first be dissolved in isopropyl alcohol to make testing easier.
For this exercise, you will determine the quantity of lye needed to make biodiesel from two different oils: one that is heavily used and one that is lightly used.

| PART THREE con't : Procedure Steps |
|---|
| 1. Obtain a sample of used vegetable oil from two different sources. Preferably one will be more heavily used than the other. Label the lightly used oil as sample A, and the heavily used oil as sample B. |
| 2. Using a pipette, syringe, or graduated eyedropper, measure 1.0 ml of oil from one sample into a small mixing beaker. Make a note in your lab book of which oil you are using first: lightly used (A)or heavily used (B). |
| 3. Measure 10 ml of isopropyl alcohol using a graduated cylinder, add this to the oil, and swirl to mix |
| 4. Test the pH of the oil-alcohol solution using a pH strip |
| 5. Using a different pipette, add lye-water (from a stock 1% solution of NaOH in distilled water) to the oil-alcohol solution in 0.5ml increments. Add the lye-water carefully so that you are sure to only add 0.5 ml at a time. |
| 6. After each 0.5ml addition of lye-water, recheck the pH with a pH strip. Record the number of 0.5ml additions you make on a tally sheet! |
| 7. Continue adding lye-water until the pH of the solution reaches approximately 8.5. At this point, count the number of ml of lye-water that you added. (For example, if you added ½ ml of lye-water three times, you added a total of 1.5 ml of lye-water). |
| 8. Calling the number of ml of lye-water that you added "X", put that number into the following equation: |
| **X + 4.0 grams = L** |
| ***L = the total number of grams of lye needed to make biodiesel from 1 liter of this particular oil. Record this number in your lab book.*** |
| |
| 9. Repeat steps 1 through 7 using a second batch of oil of different quality, and record the value for L in your lab book. Be sure to keep track of which value for L refers to which oil sample. You may want to repeat the titration for each oil to be sure of your results. |
| |
| **If using phenol red instead of pH strips, follow these steps:** |
| 1. Add 5 drops of phenol red to the beaker containing 10 ml of isopropyl alcohol and 1 ml of oil to be tested. |
| 2. The solution will appear yellow at an acid pH, and will turn pink when the pH is between 8 and 9. Add lye-water in 0.5 ml increments, counting as you go, until the oil alcohol solution turns pink or purple and stays that way for 30 seconds or more. |
| 3. The number of ml of lye-water it took to turn the solution pink is "X". Refer to the equation above. |
| |
| **Questions:** |
| ·Why is it necessary to perform a titration on used vegetable oil? |
| ·How much lye will be required to convert 1.0 liters of vegetable oil sample A to biodiesel? Sample B? |
| ·How much lye will be required for 0.5 liters of each oil: A? B? |
| ·When biodiesel brewers make large batches of fuel, they typically repeat the titration procedure several times per batch. Why do you think they would do this? |
| ·Which type of oil do you think requires more lye catalyst, lightly used or heavily used? Why? |
| ·Can you see any difference in color between the heavily used oil and lightly used oil? |
| 8 |

**PART THREE con't : Procedure Steps**

**Part 3. Making biodiesel using waste vegetable oils**

In part 3, you will use the value for L that you determined in step 2 to make fuel from waste oil. This is basically a repeat of the procedure from part 1, except that you will be varying the quantity of lye for each batch.

1. Put on your gloves and goggles. Everyone must wear protective gear while handling chemicals!

2. Measure out 500 ml or more of each waste vegetable oil, and pour it into a large beaker. Mark each beaker "A" or "B" depending on the oil you are using. Obtain two mixing bottles and label one "A" and the other "B"

3. Heat 500 ml of each 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.

4. Measure 110 ml of methanol in a graduated cylinder for each batch and pour into your mixing bottles. ***Perform this step and the next under the chemical hood.*** Cap the methanol and mixing bottles when you are finished.

5. Weigh out and add the correct amount of lye for each oil to your mixing bottles. Recap the bottles tightly. Gently agitate each bottle until the lye is dissolved.

6. When the oil samples are up to 50 degrees C, add 500 ml of the proper oil to the each mixing bottle and cap them tightly.

***Be sure that the oil is not over 60 degrees C to avoid boiling the methanol!***

7. Invert the mixing bottle once over a sink to check for any leaks.

8. Shake the bottles vigorously for at least one minute, then allow your reactions to settle.

9. Leave the bottles to settle until next week.

10. Clean up your lab space.

**Assessing your biodiesel (Week 2)**

If your procedure worked correctly, there should be two distinct layers after settling. The darker layer at the bottom is a crude glycerine byproduct, and the lighter layer on top is biodiesel. If you pick up the settling bottle and rock it slightly from side to side, notice how the darker layer is thicker than the fuel floating on top. This higher viscosity of glycerine is one of the reasons that it isn't suitable for use in a diesel engine at room temperatures. By removing the heavier, more viscous part of the oil, the esters pass through the engine's injectors and combust that much easier.

It is common to see a whitish third layer floating between glycerine and the biodiesel. This soaplike material is a result of adding too much lye, or having water in the oil. It should be discarded with the glycerine. Oil can be tested for water content by heating it to the boiling point of water (100C) and watching for bubbles.

After settling for a few days (or a week), biodiesel producers will decant the fuel off the top of the glycerine, pass it through a filter, and use it like diesel fuel in any diesel engine. Many fuel producers further refine the fuel by washing with water before use.

**Cleanup:** Biodiesel can be discarded with other chemical wastes from the school chemistry lab.

## PART THREE con't : Procedure Steps

**Washing the Bio-Diesel**

Your bottle now contains biodiesel, glycerin, mono-and di-glycerides, soap, methanol, lye, and possibly a little leftover oil (triglycerides). The glycerides are all oil-soluble, so they'll reside predominantly in the upper, biodiesel layer. The thin layer of glycerin, which is water-soluble, will sink. Depending on the oil and catalyst you used, it might be either liquid or solid. Soap, methanol, and lye, which are also water-soluble, will be mixed throughout both layers – although some of the soap can sometimes form its own thin layer between the bio-diesel and glycerin.

If you see more than two layers, or only one, then something is wrong – possibly excessive soap or monoglyceride formation. These are both emulsifiers, and in sufficient quantities they will prevent separation. In this case, check your scales, measurements, and temperatures. You can reprocess the bio-diesel with more methoxide, or try again with fresher oil (or new oil). If you can, shake the bottle even harder next time. In an engine, glycerin droplets in bio-diesel will clog fuel filters, soap can form ash that will damage injectors, and lye can also abrade fuel injectors. Meanwhile, methanol has toxic and combustible fumes that make bio-diesel dangerous to store. You don't want any of these contaminants in your bio-diesel. If you left your bio-diesel to settle undisturbed for several weeks, these water-soluble impurities would slowly fall out of the bio-diesel (except the methanol). Washing your bio-diesel with water removes the harmful impurities, including the methanol, much faster.

Unfortunately, washing will not remove the invisible, oil-soluble mono- and di-glycerides. These are a problem in rare instances when large amounts of certain types of monoglycerides crystallize. This can clog fuel filters and injectors, and cause hard starts, especially in cold weather. High quality commercial bio-diesel has very low levels of mono- and di-glycerides, which in the ideal fir bio-diesel homebrewing. You can roughly test for the presence of mono- and di-glycerides in your own batch by processing it a second time, as if it were vegetable oil. If more glycerin drops out, then your first reaction left some unfinished business behind.

Washing the Bio-Diesel

1. Once you have poured off any glycerin off you are ready to wash the remaining bio-diesel.
2. Gently add some warm distilled water to the bio-diesel.
3. Rotate the bottle end over end until the water starts to take on a little bit of soapiness, which may take a few minutes. Do not shake the bottle! You will want to bring the water and bio-diesel into contact without mixing it too vigorously. The bio-diesel contains soap and if you overdo the agitation the soap, bio-diesel, and water will make a stable emulsion that won't separate.
4. Turn the bottle upside-down crack the cap and drain away the soapy water. If you're using a soft drink bottle with a narrow neck, you can plug the opening with your thumb.
5. Add more warm water and keep repeating the sloshing and draining process. Each time there will be less soap and you can mix a little more vigorously. If you go too far and get a pale-colored emulsion layer between the bio-diesel and white, soapy water, don't drain it away; it's mostly bio-diesel. Just keep washing and diluting until the water becomes clear and separates out quickly. It takes a lot of water. But if the emulsification layer persists, try applying heat, adding salt, and adding vinegar, in that order.
6. After draining the last wash water away, let the bio-diesel sit to dry in open air until it's perfectly clear, which may take up to a couple of days. In general, the better your washing, the faster the fuel will clear. If you're in a hurry, you can dry the fuel faster by heating it at a low temperature. As with the evaporation method, the fuel is done when it clears. If you can read a newspaper through the bio-diesel, it's dry and ready to pour into a vehicle.

## PART THREE con't : Procedure Steps

**Optional Fuel Analyses:**

**Yield test:** Different factors affect the success of a biodiesel reaction, including temperature, mixing time, and the relative amount of each ingredients. A "complete" reaction will result in a glycerine layer approximately equal to the amount of methanol added (in the case of the 500 ml batches, about 110 ml of glycerine.) Reactions that come up short on glycerine have residual byproducts, including mono and diglycerides in the fuel layer. These compounds result in a poorer quality fuel that is more difficult to refine.

To test for glycerine yield, the contents of a mixing bottle can be poured into a graduated cylinder, and the relative volume of each layer measured. Comparisons can be made between the results from different batches of oil, or by changing variables between batches of the same oil.

**Wash Test:** Many of the impurities contained in settled biodiesel are soluble in water. A good way to assess your different batches of fuel is to pour a sample into a mixing bottle with an equal amount of water, then shake this violently until the two are mixed together. After mixing, allow the fluids to settle and observe what happens. Fuel with a lot of soap in it (too much lye, or fuel made from oil high in free fatty acids) will form an emulsion (like mayonnaise) that is difficult to separate even with time. Well made fuel will separate into a layer of milky wash water and amber biodiesel after about 10 or 20 minutes. Comparisons can be made between settling/ separation times for different batches of fuel, to assess the level of impurities in each batch.

It is common in large scale biodiesel processing to continue the wash process until the water no longer becomes cloudy. In water washing, water is very gently combined with the fuel to avoid emulsification (adding water via fine mist nozzles is one option, running air bubbles through the water layer beneath a column of fuel is another.)

After the initial wash, saturated water is drained off, and the process is repeated until water runs clear and is relatively neutral in pH. Washed biodiesel should be allowed to settle several days until it becomes completely clear before using. You will notice that washed fuel is typically clear enough to see through.

**Specific Gravity:** The specific gravity of biodiesel should be somewhere between .88 and .90. Although this is reported to be an unreliable indicator of fuel quality, it does present an interesting comparison between batches of fuel or between fuel and unprocessed vegetable oil.

### Minimizing the Waste

Glycerine can be used to make soap, or discarded with other waste products. To make soap from glycerine, heat it to 80 °C for several hours to boil off the methanol. This process must be done under a chemical hood and away from open flame. When the methanol has been removed, the liquid glycerine will stop bubbling, and the total volume of the fluid will be reduced by about 20% or more. We prefer to wait until the heated glycerine has reached 100 degrees C to be certain the methanol is removed.

For every liter of warm glycerine, add 200 mL of distilled water combined with 30 grams of sodium lye. Add the lye water to the glycerine, stir well, and pour into a plastic mold to cool. The resulting soap should cure for several weeks before use. It is effective at cutting grease on hands. Methanol must be removed from the glycerine before making soap!

## PART FOUR : RESOURCE USAGE

*These are the* ***SEVEN RESOURCES of TECHNOLOGY*** *. How have you used these resources to complete your Biofuels Project?*

### *PEOPLE*

| Name | Briefly describe how each helped you. |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

### *TOOLS & MACHINES*

| Tools used | Briefly explain how each extended your abilities. |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

### *INFORMATION*

*Where did you find and/or how did you acquire information needed to reach your goals?*

| Place/Event | Briefly describe the information you acquired. |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

## ***ENERGY***

| *The energy form* | *Application - What did the energy source affect?* |
|---|---|
| Mechanical | |
| (potential, kinetic) | |
| Thermal | |
| | |
| Radiant (Solar) | |
| | |
| Electrical | |
| | |
| Chemical | |
| | |
| Nuclear | |

## ***MATERIALS and CAPITAL($)***

*List any materials that you used to complete this activity, then calculate the total cost.*

| *Materials Used* | *Quantity* | *Unit Price* | *Total $* Amount |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Total $ Spent:

## ***THE TIME RESOURCE***

*Describe when and how you used your time to complete this activity.*

| **Date** | **TIME SPENT** | **NATURE OF ACTIVITY** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

13

## PART FIVE : Design Data Collection Log

*In the boxes below, describe the results for each batch of biodiesel. Be sure to record the amount of each chemical added, the results of titration, separation time, etc. Record each washing, the amount of time and the clarity of the bio-diesel on a scale of 1-5 (1=clearest) will lead you to your goal more quickly.*

| #1 Record All Measurements Here | Washing | Time | Clarity (1-5) |
|---|---|---|---|
| | | | |
| | Dry Time | | |

| #2 Record All Measurements Here | Washing | Time | Clarity (1-5) |
|---|---|---|---|
| | | | |
| | Dry Time | | |

| #3 Record All Measurements Here | Washing | Time | Clarity (1-5) |
|---|---|---|---|
| | | | |
| | Dry Time | | |

| #4 Record All Measurements Here | Washing | Time | Clarity (1-5) |
|---|---|---|---|
| | | | |
| | Dry Time | | |

## PART SIX : Activity & Student Assessment

*Describe two problems/difficulties that you had to solve/overcome during this project.*

*Roughly, what was the ratio of bio-diesel to glycerin? List 3 products we can we use the glycerin for?*

*Explain the purpose of titrating the WVO. What should pH of the finished bio-diesel be?*

*What is the purpose of shaking the bottle after you add the methoxide to the vegetable oil?*

*Why is it important to add water to your biodiesel after the glycerine has been drained off?*

*Discuss two things that you learned from the other group presentations.*

## PART SIX cont'd: Student Assessment

*Did you understand what you had to do? Yes - No - With Help (Circle one). Explain how:*

*Which of these describes the research you did? Sufficient - Not Enough - Enough to Get By (Circle one) Explain your answer:*

*Did the design brief guide you to do a better job? Yes - No - To some degree (Circle one) Explain your answer:*

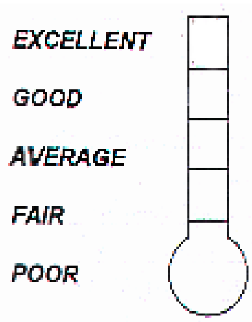
*Was the activity challenging? OK - Very Hard - Too Easy (Circle one) Explain in what way:*

*Was the activity interesting? Yes - No - Could be Better (Circle one) Explain why:*

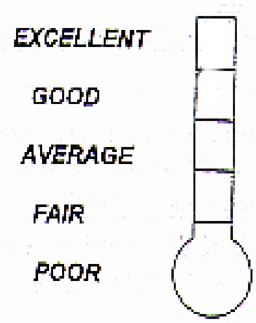
*Was this activity relevant to the course? Yes - No - OK (Circle one) Explain why or why not:*

*Rate your effort on the following graphs*

**Research**




**The Design Brief**




*Describe something new that you learned from this activity beyond building of an insulated container.*
***The more information you can provide the better - be specific!***

*What is the grade you expect to get for the work you did?_____ forever optimistic*

16

## Creating Bio-Diesel Assessment Rubric

***Student:*________________________________________________ *Period:*______**

**Assessment Scale:**

*6 = Exceptional - Your work shows brilliance and extreme high quality.*
*5 = Mastery - your work demonstrates excellence in this portion of the activity.*
*4 = Accomplished - Your work fulfills all of the objectives of this portion of the activity.*
*3 = Acceptable - Your work is minimally acceptable or needs minor revisions.*
*2 = Minimum - Your work is either incomplete or requires major revisions.*
*1 = Not Addressed - Your work did not address or include what was asked for in the ru*
*0 = Not Turned In - Some portion of the activity was not turned in leaving nothing to s*

*Points are awarded to each of the sub-categories (left margin), then their average is put as the total of the main category (right margin). The average of all the main categories will become the overall grade for the activity.*

**Safety -**

________ Safety precautions were taken throught the entire process
________ Safety equipement was used when necessary
________ Safety precautions were documented for using hand tools and machines

**Research Paper -**

________ Overall work performed showed neatness and quality
________ Work was logically organized and met all requirements
________ Students demonstrated understanding
________ Students could make connections between their work and the real world
________ Student used proper formatting and citations

**Presentation -**

________ All group members demonstrated understanding
________ All group members could make connections between their work and the real world
________ Student presentation was professional and well rehearsed
________ Presentation met the time requirement
________ All students participated equally in the presentation

**Design Brief -**

________ Part One: Extent of research performed (people & information utilized)
________ Part Three: Procedures were reviewed and precisely followed
________ Part Four: Resource pages were clear, detailed and accurate - particularly the time resou
________ Part Five: The data Collection log was clear, accurate and complete
________ Part Six: Activity & Student Assessment: Neat, complete and insightful

**Team Work -**

________ Acted as a responsible member of the team during work and testing
________ Acted efficiently during work and testing sessions (time)

**18 Criteria Activity Total Average___________**

***Grade Legend***

| | | | |
|---|---|---|---|
| A+ = Above 5 | B+ = 4 to 4.4 | C+ = 3 to 3.4 | D = 1.5 tc |
| A = 4.5 to 5 | B = 3.5 to 3.9 | C = 2.5 to2.9 | F = 0 to 1 |

**Instructor Comments: On reverse side** 1