

SANTA FE COMMUNITY COLLEGE

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Biofuel Center for Excellence

TEACHER'S MANUAL  
Introduction to Biodiesel Biofuel:  
Training & Methods

BIOFUEL CENTER FOR EXCELLENCE

# **Introduction to Biodiesel Biofuel: Training & Methods**

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# Class 1

## Introduction to Biodiesel Production

### Friday/Day One

- 9-10 Introduction
- 10-11 Background of Biodiesel (What is it/History/Applications)
- 11-12 How is Biodiesel Made/Transesterification (Lab 1 Intro)
- 12-1 *Lunch Break*
- 1--2 Introduction to Lab Procedures: Lab rules, notebooks, reports
- 2--3 Lab Procedure 1: Titrations
- 3--4 Questions/Conclusions

### Equipment, Supplies and Materials for each lecture/lab:

|                            |                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Class I: Lecture and Lab 1 | Lecture:<br>Introduction                                                                                                                                                     | Student /Teacher Manual<br>PowerPoint Slides                                                                                                                                                                                                                                                                                                                      |
|                            | Lecture:<br>Background of Biodiesel<br>(What is it/History/Applications)                                                                                                     | Student /Teacher Manual<br>PowerPoint Slides                                                                                                                                                                                                                                                                                                                      |
|                            | Lecture:<br>How is Biodiesel Made/ Transesterification<br>(Introduction to Lab Procedure 1)                                                                                  | Student /Teacher Manual<br>PowerPoint Slides                                                                                                                                                                                                                                                                                                                      |
|                            | Lecture:<br>Introduction to Lab Procedures (Exercise 1): Lab<br>Etiquette and Safety<br>Exercise 2): How to set up a Lab notebook<br>(Exercise 3): How to write a Lab report | Lab notebook<br>Student /Teacher Manual                                                                                                                                                                                                                                                                                                                           |
|                            | Lab Procedure 1: Titrations (2-3 types of oil)                                                                                                                               | Lab notebook<br>Student /Teacher Manual<br>1 Liter of distilled water in a HDPE bottle<br>Scale<br>Foil paper cup<br>1gram KOH<br>Magnetic stirrer<br>Isopropyl Alcohol<br>100mL Used vegetable oil (2-3 types)<br>10mL pipettes<br>Phenolphthalein solution * see safety info<br>10mL syringes<br>Potassium Hydroxide (KOH).<br>Safety gloves and safety glasses |

## BCX Biodiesel Module Equipment and Materials Requirements & Hazard/Safety Overview:

Proper Disposal of lab Materials for BCX Biodiesel Module: The following list of lab materials that need proper disposal is based on 20 students per class.

### Lab 1 Titrations

Less than 1 Liter of distilled water mixed with 1 gram of KOH Mixture:

- 600mL isopropyl alcohol
- 60mL of vegetable oil
- 300 drops of phenolphthalein solution combined with
- Up to 200mL of distilled water/KOH mixture

### Safety Specific Lab 1:

- Potassium Hydroxide (KOH) is **corrosive**.
- Safety gloves and safety glasses should be used when handling KOH or KOH solutions to prevent contact with skin and eyes.

# **Background of Biodiesel Its History and Applications**

## **Introduction/Overview:**

- What is Biodiesel?
- Advantages of Biodiesel
- History of Biodiesel
- How Biodiesel is Made
- How Biodiesel is Used

## **Key Terminology**

- Biodiesel
- Mono Alkyl Esters
- Fatty Acids
- Diesel
- Renewable

## **Supplemental Materials**

- PowerPoint slides 22-33
- Writing Utensil/Notebook

## **Activities**

- Discussion of basic biodiesel properties
- Brainstorm of biodiesel applications
- View and smell sample of biodiesel

## **PowerPoint Presentation Slides:**

### **What is Biodiesel?**

**Biodiesel** is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats which conform to ASTM D6751 specifications for use in diesel engines.

### **Advantages of Biodiesel**

- Can be used in compression-ignition (diesel) engines with little or no modifications
- Biodegradable, nontoxic, and essentially free of sulfur and aromatics
- Can be used as a pure fuel or blended with petroleum in any percentage
- Produced from domestic, renewable resources
- Registered as a fuel and fuel additive (legal)
- Reduces net CO<sup>2</sup> emissions by 78 percent compared to petroleum diesel
- Positive Net energy Ratio of 5.54 to 1
- Provides increased lubricity necessary in ULSD

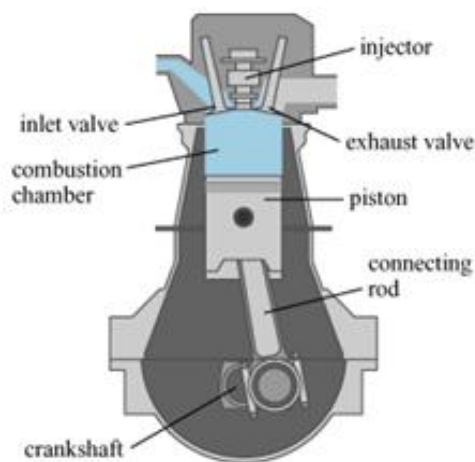
### **Applications for Biodiesel**

- Military
- School Buses/Trains/Transit
- Trucks/Fleets
- Commuters
- Marine
- Electrical Generation
- Heating
- Mining
- Farming

## Diesel Engine History

- In 1893 Rudolf Diesel invented the diesel engine
- The original diesel engine used peanut oil for fuel
- Diesel engines use thermal compression for ignition, not spark ignition
- Diesel engines are 40% more efficient than gasoline engines
- First public demonstration of vegetable oil based diesel fuel was at the 1893 World's Fair
- Cheap petroleum became widely available, and the diesel engine was optimized to use the resource
- WWII, the oil crisis in the 1970's, and continuing pressure of fuel prices peaked greater interest in finding an alternative for petroleum
- 1980s -- 1990s Pioneer fuel producers in Europe and South Africa began using the chemical process of transesterification, first discovered in 1837, to lower the viscosity of vegetable oils so they could be used in modern diesel engines

## Diesel Engine



# How is Biodiesel Made?

## Transesterification

### (Introduction to Lab 1)

#### Overview:

- Chemical processes
- Transesterification/Acid esterification
- Conversion of fatty acids into methyl esters
- Lab Introduction

#### Key Terminology

- Transesterification
- Base
- Catalyst
- Triglycerides
- Alcohol (methanol/ethanol)
- Potassium Hydroxide/Sodium Hydroxide
- Acid esterification

#### Supplemental Materials

- Student Manual Slides 34-41
- Chemical Element Chart (optional)
- Writing Utensil/Notebook

#### Activities

- Definition and explanation of chemical processes
- Review of acids/bases/catalysts
- Explanation of all lesson terminology
- Balancing of chemical equations

## PowerPoint Presentation Slides:

|          |          |           |           |           |           |           |           |           |          |          |          |          |          |          |          |          |          |
|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| H<br>1   |          |           |           |           |           |           |           |           |          |          |          |          |          |          |          |          | He<br>2  |
| Li<br>3  | Be<br>4  |           |           |           |           |           |           |           |          |          |          | B<br>5   | C<br>6   | N<br>7   | O<br>8   | F<br>9   | Ne<br>10 |
| Na<br>11 | Mg<br>12 |           |           |           |           |           |           |           |          |          |          | Al<br>13 | Si<br>14 | P<br>15  | S<br>16  | Cl<br>17 | Ar<br>18 |
| K<br>19  | Ca<br>20 | Sc<br>21  | Ti<br>22  | V<br>23   | Cr<br>24  | Mn<br>25  | Fe<br>26  | Co<br>27  | Ni<br>28 | Cu<br>29 | Zn<br>30 | Ga<br>31 | Ge<br>32 | As<br>33 | Se<br>34 | Br<br>35 | Kr<br>36 |
| Rb<br>37 | Sr<br>38 | Y<br>39   | Zr<br>40  | Nb<br>41  | Mo<br>42  | Tc<br>43  | Ru<br>44  | Rh<br>45  | Pd<br>46 | Ag<br>47 | Cd<br>48 | In<br>49 | Sn<br>50 | Sb<br>51 | Te<br>52 | I<br>53  | Xe<br>54 |
| Cs<br>55 | Ba<br>56 | Lu<br>71  | Hf<br>72  | Ta<br>73  | W<br>74   | Re<br>75  | Os<br>76  | Ir<br>77  | Pt<br>78 | Au<br>79 | Hg<br>80 | Tl<br>81 | Pb<br>82 | Bi<br>83 | Po<br>84 | At<br>85 | Rn<br>86 |
| Fr<br>87 | Ra<br>88 | Lr<br>103 | Db<br>104 | Jl<br>105 | Rf<br>106 | Bh<br>107 | Hn<br>108 | Mt<br>109 |          |          |          |          |          |          |          |          |          |

|          |          |          |          |          |          |          |          |          |          |          |           |           |           |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|
| La<br>57 | Ce<br>58 | Pr<br>59 | Nd<br>60 | Pm<br>61 | Sm<br>62 | Eu<br>63 | Gd<br>64 | Tb<br>65 | Dy<br>66 | Ho<br>67 | Er<br>68  | Tm<br>69  | Yb<br>70  |
| Ac<br>89 | Th<br>90 | Pa<br>91 | U<br>92  | Np<br>93 | Pu<br>94 | Am<br>95 | Cm<br>96 | Bk<br>97 | Cf<br>98 | Es<br>99 | Fm<br>100 | Md<br>101 | No<br>102 |

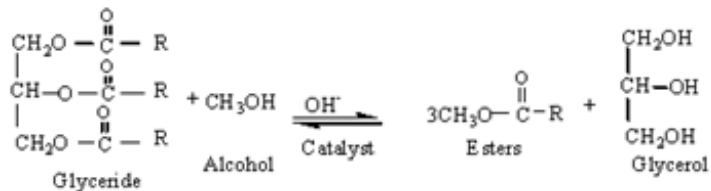
Chemical Element Chart

## How is Biodiesel Made?

### The Chemical Process of Transesterification

- Base Transesterification

The chemical reaction of a triglyceride with an alcohol to form methyl esters and glycerol by way of a base catalyst. ie. Sodium or Potassium Hydroxide



## Transesterification

- The base catalyst (KOH, NaOH, or Sodium Methyate) acts as a bridge enabling the fatty acids from the glyceri core to be bonded with methanol resulting in methyl esters (biodiesel) and a glycerol by-product.

## Transesterification

- Base catalyst (KOH, NaOH, Sodium Methyate)  
+ Fatty Acids (from glycerin core)  
+ Methanol = **Methyl Esters (i.e BIODIESEL)**  
*and*  
**Glycerol (by-product)**

# Transesterification

## Triglycerides (oil/fat)

Triglycerides are an ester composed of three fatty acids bonded to a glycerol core.



# Transesterification

## Acid Esterification

Often there are high levels of Free Fatty Acids found in used vegetable and animal oils.

Unconverted FFAs can lead to the formation of soap when reacted with Sodium Hydroxide.

Acid esterification resolves this problem by directly catalyzing the FFAs to esters.

The acid esterification uses sulfuric acid compounded with methanol as a preliminary step before base esterification.

Methanol= 8% by volume

Sulfuric Acid= 1mL per Litre.

# Introduction to Lab Procedures:

## Introduction/Overview:

Etiquette and Safety

Fire Safety Procedures

LHA: Lab Hazard Assessment

Standard Lab Procedures

    Maintenance of a Lab Notebook

    Writing of Lab Reports

## Key Terminology

- flammable
- corrosive
- ignition
- LHA: Lab Hazard Assessment

## Supplemental Materials

- Student Manual PowerPoint slides 42-57
- Writing Utensil/Notebook
- LHA: Lab Hazard Assessment
- Lab Notebook

## Activities

- Discussion of basic safety and hazard issues as pertains to biodiesel production
- Laboratory Tour
- LHA report

# Introduction to Lab Procedures

## Exercise 1: Etiquette and Safety

### Basic Lab Etiquette

- Listen to and read through ALL lab instructions first
- Review relevant safety precautions
- Review locations of first aid/fire extinguishers
- Review locations of Material Safety Data Sheets
- Review locations of Equipment Manuals
- Wait until given directed to begin any lab activity
- When in doubt, ALWAYS ASK
- Ensure plenty of time to clean up the lab thoroughly
- Never use the lab alone or unsupervised

### Hazards

- The hazards in these labs include:
  - Use of heated oils
  - Use of flammable materials
  - Use of corrosive chemicals

### Basic Safety Specifics

- **Safety goggles, PVC gloves and aprons** should be worn when handling chemicals to prevent contact with skin and clothes.
- **Heat resistant gloves and beaker tongs** should be used when transferring the heated oil from the microwave to bench.
- Mixing of chemicals should be done **under a hood or in a room with sufficient ventilation** to prevent inhalation of reaction byproducts which may cause respiratory problems. *(If insufficient ventilation is present, wear a chemical cartridge respirator with organic/corrosive cartridges when transferring or mixing chemicals.)*
- **Label** all containers with content and hazards.
- **Keep containers closed** when not in use.

## Fire Safety Procedures

- Control or eliminate all potential ignition sources when handling flammable chemicals (methanol/methoxide solution).
- All containers should be covered/ capped when not in use.

### Identify Fire Hazards

- Check for sources of ignition.
- Check for flammable liquids.
- Move flammable debris away from hazardous areas when possible.
- Keep oily rags in a metal, airtight, closed container.
- Make certain that there is no open flames or exposed heating elements nearby when pouring highly volatile liquids.

#### *Control Sources of Ignition*

- Leave all cell phones on classroom tables
- Smoke only in designated areas
- Never leave an open flame or heating element unattended while in use
- Ensure that there are **no open flames** or hot heating elements are in the area where volatile liquids are being poured

#### *Control Sources of Ignition*

- Discard organic products only in authorized containers, never in sinks or drains.
- Always allow hot liquids to cool before discarding them into drains or containers.
- Ensure chemicals that react with each other are stored in separate areas.

### Fire Safety Responses

- **Do not use water for extinguishing oil fires**  
because it will spread the fire.
- **Do not use water on electrical fires**  
because water is a conductor of electricity.
- Know location of fire extinguishers.

# LHA

Lab Hazard Analysis

Activity: OSHA Safety

## Exercise 2: LAB NOTEBOOK

Maintenance of a Lab Notebook

Writing of Lab Reports

### LAB NOTEBOOK

Format

- BOUND (glued), not spiral or a loose-leaf binder
- Pages consecutively numbered
- No pages removed under any circumstances
- All work directly entered with blue or black ink (not re-written later, typed and glued in, etc.)
- Use only right hand pages (backs=scratch paper\_
- Legible and organized
- Accurate

### LAB NOTEBOOK

Content

- Page 1: Name, Class and Contact Information
- Pages 2-3: Table of Contents
- Following pages: Title of Experiment at top, page number, date of last entry on page, and your signature at the bottom (track in Table of Contents)
- EACH LAB WILL REQUIRE SEVERAL PAGES OF YOUR NOTEBOOK AND INCLUDE THE FOLLOWING SECTIONS IN THE FOLLOWING ORDER~Please title each section neatly in your notebook.
- Title: Experiment's title, your name, the name(s) of your lab partner(s), and the date the experiment was begun
- Statement of Purpose: 2-3 sentence description (concise) of the purpose of the experiment, including the general method that will be used and anticipated results

- Background: More information and extra notes on the goals of the experiment, the methods used and the procedures to be followed
- Procedural Outline: Brief but complete description IN YOUR OWN WORDS of the steps taken to carry out the experiment
- Results: A listing of the reduced data (e. g., tables), all graphs, spreadsheet results, and spectra.
- Calculations: An example of each calculation performed to reach the final reported answers should be shown with the units clearly shown at each step
- Discussion of Conclusions and Error Analysis: Summarize your results paralleling what you set forth in the Statement of Purpose, compare them to the expected results and try to place them in context (either in the larger field of biofuels or from class).
- Summary of Results: Final thoughts, observations and data.

### Exercise 3: Lab Reports

- Individual Assignment
- End of Lab
- Written (Usually Typed) Document with 5 Sections
  - Introduction
  - Methods and materials
  - Results
  - Discussion and conclusion
  - Citation

# Lab Procedure 1:

## Titration (2-3 types of oil)

### INTRODUCTION

- Titration determines the levels of FFAs in oils and fats.
- This indicates the **amount** of catalyst needed for a complete base reaction.
- Initial amount of 5g of NaOH or 7g of KOH per liter is necessary when converting virgin oil.

### Purpose:

The goal of the titration test is to determine how much catalyst (KOH) is needed to complete the reaction between methanol and vegetable oil to produce mono Alkyl esters (biodiesel).

### Lab Vocabulary

- Titration
- Catalyst
- Acid
- Base
- Corrosive
- Phenolphthalein

### Equipment List

- 1 Liter of distilled water in a HDPE bottle
- Scale
- Foil paper cup
- 1gram KOH
- Magnetic stirrer
- Isopropyl Alcohol
- 100mL Used vegetable oil (2-3 types)
- 10mL pipettes
- Phenolphthalein solution

- 10mL syringes

### Safety Specific to this Lab:

- Potassium Hydroxide (KOH) is **corrosive**.
- Safety gloves and safety glasses should be used when handling KOH or KOH solutions to prevent contact with skin and eyes.

### Titration Procedure: 3 Step Overview

1. Put on Safety Gear and Review Locations of...
  - a. Fire Extinguishers
  - b. First Aid/Eye Wash Station
  - c. MSDS
  - d. Equipment Manuals
2. Make Test Solution (next slide)
3. Introduce Test Solution to Oil (following)

# Titration

## Making the test solution

- Measure 1 liter of distilled water into a HDPE Bottle .
- Place foil paper cup container for KOH on scale and tare.  
(Do not return dispensed materials to stock bottles.)
- Measure 1 gram of KOH on a scale.
- Add weighed KOH into distilled water and stir with glass rod until thoroughly dissolved.

## Titration Procedure

- Place the graduated poly beaker on the magnetic stirrer.
- Insert the magnet.
- Using a pipette measure 10 mL of isopropyl alcohol into the poly beaker.
- Add 1 ml of used vegetable oil into the container with the IPA. Stir thoroughly to dissolve the vegetable oil/IPA solution.
- Add 5 drops of Phenolphthalein solution to the mixture.
- With a 10mL graduated syringe, put a 1 mL drop of the KOH/water mix into the oil/alcohol mix. Continue adding 1 mL aliquots until the solution stays pink for 30 seconds.
- Titration Readings
- The amount of KOH/water mixture added to the solution is the titration number.
- Perform the test 3 times to get an average reading.

## Calculation/Data Analysis

- Add the average titration number + 7 (KOH base)
- Multiply the resulting number times the number of liters of oil to be reacted to determine the grams of catalyst needed.
- (1 Liter = .0264 Gallons; 1 Gallon = 3.785 Liters)
- Calculate Average

## CLEAN-UP

- Empty remaining test solution \_\_\_\_\_
- Empty untested oil \_\_\_\_\_
- Empty tested oil \_\_\_\_\_
- Wash all equipment with \_\_\_\_\_
- Return all equipment to where you found it
- Put all safety gear away

## Questions and Conclusions

- What have you learned?
- What do want to know?
- LHA
- Lab notebook and reports
- Review of
  - Key Terminology (slides 4, 23, 35, 59)
  - Class Overviews/Themes (slides 3, 22 34, Lab Info)
  - Classroom Activities

# Class 2

## Biodiesel Production Methods

### Saturday/Day Two

|            |                                           |
|------------|-------------------------------------------|
| 9-9:45     | Lab 2 Introduction: How to Make Biodiesel |
| 9:45-11:15 | Lab 2: Biodiesel Mini-Batch               |
| 11:15-12   | Lab 3: 3/27 Quality Test                  |
| 12-1       | <i>Lunch Break</i>                        |
| 1-1:30     | Introduction to Bio-Pro 190               |
| 1:30- 2:30 | BioLyle Bio-Pro 190 Video                 |
| 2:30-4     | Lab 4: Bio-Pro 190 Usage                  |

### Equipment, Supplies and Materials for each lecture/lab:

|                               |                                                       |                                                                                                                                                                                                                                                                                                                                                                    |
|-------------------------------|-------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Class II Lecture and Labs 2-4 | Lecture: Introduction to Lab 2: How to Make Biodiesel | Student Manual<br>Teacher's Manual<br>PowerPoint Slides                                                                                                                                                                                                                                                                                                            |
|                               | Lab 2: Biodiesel Mini-Batch                           | Lab notebook<br>Student /Teacher Manual<br>500mL graduated beaker<br>500mL or larger Pyrex glass<br>350 mL virgin vegetable oil<br>Microwave<br>Thermometer<br>Beaker Tongs<br>Hot Pad<br>2 300mL + graduated beakers<br>KOH* see safety information<br>Methanol* see safety information<br>Extra dish for draining glycerol<br>Timer<br>(ppe: goggles and gloves) |
|                               | Lab 4: 3/27 Quality Test                              | Lab notebook<br>Student /Teacher Manual<br>PowerPoint Slides<br>2 graduated 100mL poly cone beakers<br>2 graduated syringes<br>Methanol sample* see safety information<br>Raw Biodiesel sample* see safety information<br>Timer<br>Tightly covered container you can shake vigorously<br>PREPARE TO REPEAT 3 TIMES<br>(ppe: goggles and gloves)                    |

|  |                                                          |                                                                                                                                                                                                                                                                                                                                                                   |
|--|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Introduction to Bio-Pro 190<br>BioLyle Bio-Pro 190 Video | Lab notebook<br>Student /Teacher Manual<br>PowerPoint Slides (34)<br>DVD - "BioLyle's Biodiesel Workshop"<br>Lyle Rudensey                                                                                                                                                                                                                                        |
|  | Lab 4: Bio-Pro 190 Usage                                 | Lab notebook<br>Student /Teacher Manual<br>PowerPoint Slides<br>Bio Pro 190* see safety information<br>50 gallons of Vegetable Oil<br>2350g KOH* see safety information<br>10 gallons of methanol* see safety information<br>190mL Sulfuric Acid* see safety information<br>*instructional manuals and personal protective<br>equipment (ppe: goggles and gloves) |

## BCX Biodiesel Module Equipment and Materials Requirements & Hazard/Safety Overview:

Proper Disposal of lab Materials for BCX Biodiesel Module: The following list of lab materials that need proper disposal is based on 20 students per class.

### Lab 2 Biodiesel Mini Batch

20 count 1 Liter HDPE bottles (the bottles will contain a combination of methyl esters (biodiesel) and glycerin and the chemicals)

- 350ml of vegetable oil
- 3 grams of KOH
- 70 mL of methanol.

### Lab 3 3/27 Test

20 count closed 100mL beaker containing

- 27mL of Methanol
- 3mL of methyl esters (biodiesel)

40 syringes

- 20 used for methanol transfer
- 20 used for methyl ester (biodiesel) transfer

Less than 1 litre of methanol in HDPE container

Less than 1 litre of methyl esters (biodiesel) in HDPE container

### Lab 4 BIO PRO

50 gallons of methyl esters (biodiesel)

10 gallons of glycerin containing methanol and soaps

# Introduction to Lab Procedure 2: How to Make Biodiesel

## Introduction/Overview:

- Mini-batch biodiesel production lab
- Intro to Quality Control Testing

## Key Terminology

- Methanol/Methoxide
- Glycerin/Glycerol
- KOH
- Transesterification
- Phase Separation

## Supplemental Materials

- Powerpoint slides 70-92
- Lab Equipment/Materials (provided)
- Lab Notebook

## Activities

- Discussion of biodiesel manufacturing
- Mini-batch biodiesel lab
- 3/27 quality control testing

# Lab Procedure 2:

## Transesterification

### Biodiesel Mini-Batch

#### INTRODUCTION

We will be using pre-measured virgin vegetable oil, KOH and methanol to do a mini batch conversion.

#### Purpose:

This lab demonstrates the process of transesterification.

#### Lab Vocabulary

- Virgin Vegetable Oil
- KOH
- Methanol
- Methoxide
- Glycerol
- Raw Biodiesel

#### Equipment List

- 500mL graduated beaker
- 500mL or larger Pyrex glass
- 350 mL virgin vegetable oil
- Microwave
- Thermometer
- Beaker Tongs
- Hot Pad
- 2 300mL + graduated beakers
- KOH\* see safety information
- Methanol\* see safety information
- Extra dish for draining glycerol
- Timer

### Safety Specific to this Lab:

\*Potassium Hydroxide (KOH) is corrosive\*

Safety gloves and safety glasses should be used when handling KOH or KOH solutions.

Prevent contact with skin and eyes.

\*Methanol is a flammable organic chemical\*

Sufficient ventilation must be present to use.

Control or eliminate all potential ignition.

All containers should be covered when not in use.

Label all containers with content and hazards.

## Procedure: Transesterification- Biodiesel Mini Batch

- Heat 350mL of new vegetable oil in microwave to 130 degrees F in a Pyrex glass. Use beaker tongs to transfer container to hot pad on bench.
- Add the premeasured catalyst (KOH) to the premeasured methanol and shake vigorously.
- Add “methoxide” solution to oil.
- Shake the oil/ “methoxide” solution for 5 minutes.
- Let settle for 24 hours.
- After the settling period, glycerin will phase to the bottom of the bottle and the raw biodiesel will be floating above. The glycerin will be a dark layer below a golden layer of biodiesel.

### Making Biodiesel

- Now we have raw biodiesel floating on top of a glycerol layer through phase separation.
- The glycerol layer can now be drained off, sent to methanol recovery, be purified and used in one of hundreds of applications as a valuable co-product from the process.

### Calculation/Data Analysis

- Observe the different properties of glycerol and biodiesel
- Discuss variances in % glycerol vs. biodiesel
- Discuss subsequent quality control tests

### CLEAN-UP

- Empty remaining glycerol \_\_\_\_\_
- Empty remaining biodiesel \_\_\_\_\_
- Wash all equipment with \_\_\_\_\_
- Cap all containers
- Return all equipment to where you found it

## Questions and Conclusions

- What have you learned?
- What do want to know?
- LHA
- Lab notebook and reports

# Lab Procedure 3: 3/27 Test

## INTRODUCTION

Biodiesel must undergo rigorous testing before it sold on the market. The first, most basic quality test we will perform is the **“3/27 test.”**

## Lab Vocabulary

- Virgin Vegetable Oil
- KOH
- Methanol
- Methoxide
- Glycerol
- Raw Biodiesel
- Jan Warnqvist
- Conversion
- Glycerides
- Triglycerides

## Purpose

Simple quality control of biodiesel conversion.

- determines if there are glycerides present
- determines how completely the oil was converted into biodiesel.

## Equipment List

- 2 graduated 100mL poly cone beakers
- 2 graduated syringes
- Methanol sample
- Raw Biodiesel sample
- Timer
- Tightly covered container you can shake vigorously
- PREPARE TO REPEAT 3 TIMES

### Safety Specific to this Lab:

- \*Methanol is a **flammable** organic chemical\*
  - Sufficient ventilation must be present to use.
  - Control or eliminate all potential ignitions.
- All containers should be covered when not in use.
- Label all containers with content and hazards.

### 3/27 Basic Procedure: Overview

- Vigorously mix 3mL of raw biodiesel with 27mL of methanol.
- Biodiesel will dissolve in methanol.
- Any remaining triglycerides will fall to the bottom and appear as oil droplets.
- *Note that this test only serves as an indicator and is not sufficient in determining any part of ASTM 6751 specifications.*

### Procedure : 3/27 Test

- Ensure the graduated 100mL poly cone beaker is clean and dry.
- With a syringe place 27ml of room temperature methanol into the beaker.
- Use a separate syringe to put **exactly 3ml** of the room temperature biodiesel into the methanol.
- Put rubber top on beaker.
- Shake beaker hard for 5 seconds and let settle.

### 3/27 Calculation/Analysis

- If the biodiesel completely dissolves into the methanol and no oil settles out on the bottom of the beaker you have very high conversion (pure) biodiesel.

### CLEAN-UP

- Empty tested biodiesel \_\_\_\_\_
- Wash all equipment with \_\_\_\_\_
- Cap all containers
- Return all equipment to where you found it
- Put all safety gear away

### Questions and Conclusions

- What have you learned?
- What do want to know?
- LHA
- Lab notebook and reports

# Introduction to Bio-Pro 190

## Overview: BioPro Usage

- Familiarize with Bio Pro 190
- Learn specifics of how it functions
- Learn how to properly load and utilize Bio Pro 190
- Practice using the Bio Pro 190

## Key Terminology

- Bio Pro 190
- Phase Separation

## Supplemental Materials

- Student Manual Slides 93-107
- Writing Utensil/Notebook
- Bio Pro 190 and lab supplies (provided)
- BioLyle Video (shown in class)

## Activities

- Introduction to manufacturing equipment
- Watching BioLyle's instructional video
- Using the Bio Pro 190

# BioLyle: Bio-Pro 190 (DVD)

BioPro 190 can make a 50 gallon batch of biodiesel in as little as 13 hours.

Completely Automated

Just add filtered vegetable oil and pre-measured chemicals.

BioPro 190

## PHASE ONE

- Start reaction.
- Let BioPro190 do the work.
- Wait until glycerol has phase-separated and settled.

## PHASE TWO

- Drain glycerol
- Perform 3/27 test (slides 82-91)
- If passes 3/27, begin wash/dry sequence.

Now that we've watched Bio Lyle successfully make biodiesel with the BioPro 190, we will attempt to do the same in Lab Procedure 4.

# Lab Procedure 4:

## Bio-Pro 190 Usage

### Introduction

- Using the Bio-Pro 190 allows us to manufacture larger batches of biodiesel with less effort.

### Purpose

- Quantity production of biodiesel
- Lower hands-on workload

### Lab Vocabulary

- Bio Pro 190
- Phase Separation
- Wash/Dry

### Equipment List

- Bio Pro 190
- 50 gallons of Vegetable Oil
- 2350g KOH
- 10 gallons of methanol
- 190mL Sulfuric Acid

## Safety Specific to this Lab:

- Read and review all instructional materials and potential hazards of the Bio Pro 190 including Methanol and KOH safety
- Review precautions for chemical additives
  - Wear safety goggles and gloves
  - Ensure proper ventilation
  - Control/Eliminate possible ignition sources

\*Potassium Hydroxide (KOH) is corrosive\*

Safety gloves and safety glasses should be used when handling KOH or KOH solutions.

Prevent contact with skin and eyes.

\*Methanol is a flammable organic chemical\*

Sufficient ventilation must be present to use.

Control or eliminate all potential ignition.

All containers should be covered when not in use.

Label all containers with content and hazards.

## Procedure: Bio-Pro 190

- Fill Processor with Feedstock
- Add base catalyst to methoxide tank
- Add 4 gallons of methanol to methanol tank
- Add 6 gallons of methanol to methoxide tank
- Plug in Machine and push Reaction Start button
- Add 190mL Sulfuric acid
- Drain of Glycerin (after 24 hrs)

## Calculation/Data Analysis

- The success of this batch in the bio-pro 190 will be measured in subsequent quality control testing labs.

## CLEAN-UP

- Empty biodiesel \_\_\_\_\_
- (Next Day) Drain glycerol \_\_\_\_\_
- Wash all equipment with \_\_\_\_\_
- Cap all containers
- Return all equipment to where you found it
- Put all safety gear away

## Wash/Dry Sequence

- WHAT: Washing with water or using resin towers to dry-wash the biodiesel
- WHY: Ensure we have stopped the reaction from continuing and removed all remaining soaps and particulate matter that wasn't removed with the glycerol.
- **(Note: If we only use the dry wash system, our fuel will still contain a substantial amount of methanol and we will not meet ASTM 6751 specifications.)**

## Questions and Conclusions

- What have you learned?
- What do want to know?
- LHA
- Lab notebook and reports

# Class 3

## Biodiesel Quality Testing, Economics and Business

### Introduction/Overview:

Drain glycerin from Bio-Pro 190

9:30-12 Lab 5: Soap and Flashpoint Quality Testing

12-1 *Lunch*

1-1:30 ASTM Standards

1:30-2 Feedstocks

2-2:30 Regulations

2:30-3 Biodiesel Economics

3-4 Evaluation/Certification

### Equipment, Supplies and Materials for each lecture/lab:

|                                                          |                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Class III Lecture and Labs<br>4 cont and 5<br>Evaluation | Lab 4: Bio-Pro 190 Usage (cont.)<br>Drain glycerin from Bio-Pro 190 | Lab notebook<br>Student /Teacher Manual<br>PowerPoint Slides<br>Bio Pro 190* see safety information<br>50 gallons of Vegetable Oil<br>2350g KOH* see safety information<br>10 gallons of methanol* see safety information<br>190mL Sulfuric Acid* see safety information<br>*instructional manuals and personal protective equipment (ppe: goggles and gloves)                                                                                                        |
|                                                          | Lab 5: Quality Testing<br>Soap Test                                 | Lab notebook<br>Student /Teacher Manual<br>PowerPoint Slides<br>Biodiesel sample* see safety information<br>Hydrochloric acid (0.01N solution, as a reagent)<br>* see safety information<br>Bromophenol blue* see safety information<br>0.4% aqueous, as a pH indicator,<br>100ml isopropyl alcohol as a solvent<br>200 mL + beaker<br>10 mL graduated cylinder<br>Pipettes and/or Syringes<br>Calculator (optional)<br>*instructional manual/ ppe goggles and gloves |
|                                                          | Lab 5: Quality Testing<br>Flash Point Testing                       | Lab notebook<br>Student /Teacher Manual<br>PowerPoint Slides<br>Closed cup flash point tester with stirrer, heater,<br>and flame source. * see safety information<br>Biodiesel sample* see safety information<br>Electric thermostat (on flash pt tester)<br>Thermometer<br>Goggles and gloves should be used during this<br>test.<br>*instructional manual/ ppe goggles and gloves                                                                                   |

|  |                                                                                |                                                                                           |
|--|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
|  | Lecture:<br>ASTM Standards<br>Feedstocks<br>Regulations<br>Biodiesel Economics | Lab notebook<br>Student /Teacher Manual<br>PowerPoint Slides                              |
|  | Evaluation                                                                     | Lab notebook<br>Student /Teacher Manual<br>LHA<br>BCX Biodiesel Module Certification Test |

## BCX Biodiesel Module Equipment and Materials Requirements & Hazard/Safety Overview:

Proper Disposal of lab Materials for BCX Biodiesel Module: The following list of lab materials that need proper disposal is based on 20 students per class.

### Lab 4 BIO PRO

50 gallons of methyl esters (biodiesel)

10 gallons of glycerin containing methanol and soaps

### Lab 5 Soap Test

20 count mixture:

- 100mL isopropyl alcohol
- 20 drops bromophenol blue
- 10mL methyl esters
- up to 100mL of hydrochloric acid

### Lab 6 Flash Point

Up to 1 Liter of spent methyl esters (biodiesel)

# Lab Procedure 4 (continued):

## Drain glycerin from Bio-Pro 190

Reminder: Safety Specific to this Lab:

\*Potassium Hydroxide (KOH) is corrosive\*

Safety gloves and safety glasses should be used when handling  
KOH or KOH solutions.

Prevent contact with skin and eyes.

\*Methanol is a flammable organic chemical\*

Sufficient ventilation must be present to use.  
Control or eliminate all potential ignition.

All containers should be covered when not in use.

Label all containers with content and hazards.

- Drain of Glycerin (after 24 hrs)

### Calculation/Data Analysis

- The success of this batch in the bio-pro 190 will be measured in subsequent quality control testing labs.

### CLEAN-UP

- Empty biodiesel \_\_\_\_\_
- (Next Day) Drain glycerol \_\_\_\_\_
- Wash all equipment with \_\_\_\_\_
- Cap all containers
- Return all equipment to where you found it
- Put all safety gear away

## Wash/Dry Sequence

- WHAT: Washing with water or using resin towers to dry-wash the biodiesel
- WHY: Ensure we have stopped the reaction from continuing and removed all remaining soaps and particulate matter that wasn't removed with the glycerol.
- **(Note: If we only use the dry wash system, our fuel will still contain a substantial amount of methanol and we will not meet ASTM 6751 specifications.)**

## Questions and Conclusions

- What have you learned?
- What do want to know?
- LHA
- Lab notebook and reports

# Lab 5: Quality Control Tests

## Soap and Flashpoint Quality Testing

### Introduction

These tests indicate the completion of the chemical conversion and ensure the biodiesel holds the appropriate properties for usage in a diesel engine

### Quality Control

- 3/27 (most basic)
- Wash/dry sequence
- Soap Test
- Flashpoint Test

### Safety Specific to this Lab:

Review precautions for all chemicals

- Wear safety goggles and gloves
- Ensure proper ventilation
- Control/Eliminate possible ignition sources

Review the properties of these liquids and the necessary lab precautions.

\*Potassium Hydroxide (KOH) is corrosive\*

Safety gloves and safety glasses should be used when handling KOH or KOH solutions.

Prevent contact with skin and eyes.

\*Methanol is a flammable organic chemical\*

Sufficient ventilation must be present to use.

Control or eliminate all potential ignition.

All containers should be covered when not in use.

Label all containers with content and hazards.

# Lab Procedure 5

## Exercise 1: Soap Test

### Introduction

Our biodiesel must be sufficiently free of residual soaps to fall within the specifications of ASTM 6751.

The soap test titration uses hydrochloric acid, 0.01N solution, as a reagent, bromophenol blue, 0.4% aqueous, as a pH indicator, and 100ml isopropyl alcohol as a solvent

### Purpose

#### Soap Test Theory

- Bromophenol blue turns yellow at about 4.5.
- The yellow endpoint is the point at which all the soap in a test sample has been neutralized by the hydrochloric acid titrate.
- By knowing the volume of .01N HCl used in the soap test titration, it is possible to calculate the amount of soap in the biodiesel test sample.

### Lab Vocabulary

- Solvent
- Reagent
- pH indicator

### Equipment List

- Hydrochloric acid
- 0.01N solution, as a reagent
- Bromophenol blue
- 0.4% aqueous, as a pH indicator,
- 100ml isopropyl alcohol as a solvent
- 200 mL + beaker
- 10 mL graduated cylinder
- Pipettes and/or Syringes
- Calculator (optional)

## Safety Specific to this Lab:

- Read and review all instructional materials and potential hazards of the Bio Pro 190 including Methanol and KOH safety
- Review precautions for chemical additives
  - Wear safety goggles and gloves
  - Ensure proper ventilation
  - Control/Eliminate possible ignition sources

## Soap Test Procedure: Overview

- Add 100mL of isopropyl alcohol to beaker.
- Add a few drops of bromophenol blue to test acidity of alcohol.
- Add 10mL of biodiesel to be tested.
- Add 15 drops of bromophenol blue.
- Use 10mL pipette to add hydrochloric acid until sample turns light yellow.
- Multiply the amount of hydrochloric acid x 320 for soap content in ppm.

## Calculation/Data Analysis

- Compare your results in ppm to the class average and to the ASTM allowable amount

## CLEAN-UP

- Empty tested solution \_\_\_\_\_
- Wash all equipment with \_\_\_\_\_
- Cap all containers
- Return all equipment to where you found it
- Put all safety gear away

## Questions and Conclusions

- What have you learned?
- What do want to know?
- LHA
- Lab notebook and reports

# Lab Procedure 5

## Exercise 2: Flash Point Test

### Introduction

Flash Point: the lowest temperature at which vapors from a test sample of biodiesel combine with air to give a flammable mixture and “flash” when an ignition source is applied.

### Purpose:

Determining and understanding the quality of the biodiesel produced by comparing the flash point to the ASTM allowable range.

### Lab Vocabulary

- Flashpoint
- Closed-cup flashpoint tester

### Equipment List

- Closed cup flash point tester with stirrer, heater, and flame source.
- Biodiesel sample
- Electric thermostat (on flash pt tester)
- Thermometer

### Safety Specific to this Lab:

- Goggles and gloves should be used during this test.
- Review all fire safety procedures.
- Review location of fire extinguishers.

## Procedure: Flash Point Test

- Use a closed cup flash point tester that has a stirrer, heater, and flame source.
- Place a sample of the biodiesel in the brass cup until we reach the fill line.
- Turn on the electric thermostat.
- Put thermometer into place.
- Every 10 degree increment, stir the sample via the switch and introduce the flame to the sample.
- When we see a quick “flash” of ignition, we have reached the sample’s flash point.

## Calculation/Data Analysis

- Compare your temperature results to the class average and to the ASTM allowable range
- ASTM 6751 defines that biodiesel must not have a flash point below 93c or 200f.

## CLEAN-UP

- Turn off/unplug closed-cup flashpoint tester
- Empty tested solution \_\_\_\_\_
- Wash all equipment with \_\_\_\_\_
- Cap all containers
- Return all equipment to where you found it
- Put all safety gear away

## Questions and Conclusions

- What have you learned?
- What do want to know?
- LHA
- Lab notebook and reports

# ASTM Standards

## Lesson Overview

- Introduce scope and specifics of ASTM standards

## Key Terminology

- ASTM
- Acid Number
- Sulfated Ash
- Flashpoint
- Water and Sediment
- Cloud Point
- Total and Free Glycerin
- Cold Soak Filtration

## Supplemental Materials

- Student Manual Slides 126-138
- Writing Utensil/Notebook

## Activities

- Discussion of ASTM
- Introduction to each test category
- Explanation of WHY each category is important

## **PowerPoint Presentation Slides:**

### **ASTM D-6751**

- American Society for Testing and Materials
- An international standards organization that develops and publishes technical standards for a variety of materials and procedures.
- \*ensures uniformity in quality for biodiesel production

### **Scope of ASTM D-6751**

- Acid Number
- Sulfated Ash
- Flashpoint
- Water and Sediment
- Cloud Point
- Total and Free Glycerin
- Cold Soak Filtration

## Scope of ASTM D 6751

- **Acid Number (ASTM D664)**
- The acid number is used to determine the level of free fatty acids that may be present in biodiesel.
- WHY? Biodiesel with a high acid number may increase fueling system deposits and may increase the likelihood of corrosion.

## ASTM D 6751

- **Sulfated Ash (ASTM D482)**
- Ash-forming materials may be present in biodiesel in two forms:
  - - abrasive solids
  - - soluble metallic soaps.
- WHY? Abrasive solids contribute to injector, fuel pump, piston and ring wear, and also to engine deposits. Soluble metallic soaps have little effect on wear but can contribute to engine deposits.

## ASTM D 6751

- **Flash Point (D93)**

- The minimum Flash Point for B100 is 93c (200f).
- WHY? The results are not directly related to engine performance but rather to ensure safe handling and storage guidelines.

## ASTM D 6751

- **Water and Sediment (D 2709)**

- Determines how much water and residual sediments are found in the fuel.
- .05% by volume is the specification.
- WHY? Water in fuel is considered a serious contaminant and may lead to engine failure.

## ASTM D 6751

- **Cloud Point (D 2500)**
- Cloud point determines at what temperature the fuel begins to haze.
  - WHY? Biodiesel has a higher cloud point than petroleum diesel and efforts must be taken to ensure proper flow of the fuel through the fueling system. Blending biodiesel with petroleum diesel or kerosene lowers the overall cloud point.

## ASTM D 6751

- **Cold Soak Filtration (D 7501)**
- Ensures cold weather operability of the fuel. Biodiesel is chilled to 40f for 16 hours. It is then brought back up to room temperature and the test determines how many seconds it takes for the sample to pass through filters.
  - WHY? To ensure proper flow of fuel through filters.

# Feedstock

## Lesson Overview

- The raw materials of biodiesel...
  - Currently viable
  - In research
  - Economics

## Key Terminology

- SME
- FAME
- Rendering

## Supplemental Materials

- Student Manual Slides 139-149
- Writing Utensil/Notebook

## Activities

- Discussion of initial class feedstock brainstorm
- Introduction to current dominant feedstock
- Feedstock Economics discussion

## **PowerPoint Presentation Slides:**

### **Feedstocks**

As we have discussed, a wide range of oils and fats can be used as feedstocks for biodiesel production.

In the U.S. , soy bean oil is the primary feedstock.

In Europe, rapeseed is the primary feedstock.

### **Feedstocks**

#### **Waste Vegetable Oil (yellow grease)**

Yellow grease can be a combination of used cooking oils and partial animal fats.

Standards for biodiesel production dictate FFA levels of less than 15% and water content less than 2%.

## Feedstocks

Typically, feedstock, whether virgin oil or yellow grease or tallow are delivered to biodiesel plants in truck loads or by rail car in volumes around 6000 gallons.

Fuel made from virgin soy oil is referred to as SME biodiesel or Soy Methyl Ester.

Fuel made from recycled oils and fats are referred to as FAME or Fatty Acid Methyl Esters.

## Feedstocks

Current prices for feedstocks. (2012)

Virgin Soy oil- \$.55 per lb. or \$4.29 per gallon

Yellow Grease- \$.38 per lb. or \$2.96 per gallon

### **B100 Biodiesel Selling Price**

B100 SME- \$4.80 per gallon

B100 FAME- \$ 4.50 per gallon

## Feedstocks

Virgin oils will have lower FFA levels and less water content and will potentially require less chemical inputs to produce into biodiesel, however they are more expensive.

Recycled oils have higher FFA levels and water content which require additional chemical inputs and dewatering components in their production into biodiesel, however they are less expensive.

## Feedstocks

### **Rendering**

The process of recycling animal byproducts and restaurant waste into usable forms of protein, minerals and fats.

Before the biodiesel industry, the products made from rendering facilities were primarily used in the animal feed industry.

# Feedstocks

## **Collection by Rendering Company**

Rendering companies place grease containers capable of holding 50-300 gallons of spent grease outside of restaurants.

Depending on the container used, they either swap out 55 gallon barrels or dump the larger containers into a truck using hydraulic lifts very similar to a garbage truck.

# Regulations

## Regulations:

### Lesson Overview

- Environmental Protection Agency
- National Board of Biodiesel
- Other Government Organizations
- RFS/RINS

### Key Terminology

- Emissions
- Carcinogenicity
- Mutagenicity
- Teratogenicity
- Reproductive Toxicity
- Noncompliance
- RFS
- RIN

### Supplemental Materials

- Student Manual Slides 150-165
- Writing Utensil/Notebook

### Activities

- Definition of EPA and regulations
- Discussion of enforceability and relevance
- The economics of regulations for small businesses
- Debate: Do subsidies help or hurt this industry?

## **PowerPoint Presentation Slides:**

# Regulations

### **EPA Registration**

All producers of fuels and fuel additives for motor vehicles must be registered with the EPA.

The EPA requires manufacturers to complete and submit testing results for environmental affects of use of fuels and fuel additives.

# Regulations

### **EPA Tiers**

#### Tier 1

- Literature Search
- Characterization of emissions
- Exposure Analysis

# Regulations

## **EPA Tiers**

### Tier 2

Laboratory rats are exposed to exhaust from engines to determine-

- Carcinogenicity (cancer causing)
- Mutagenicity (genetic mutations)
- Teratogenicity (fetal abnormalities)
- Reproductive Toxicity (inability to reproduce)
- Neurotoxicity (nervous system damage)

# Regulations

## **National Biodiesel Board (NBB)**

Conducted Tier 1 and Tier 2 testing at a cost over 2 million dollars.

Producers can become members of the NBB in lieu of submitting their own individual EPA testing requirements.

Non members must pay excess of \$100,000 and volume fees to have access to the health effects data.

## Regulations

### **NBB Membership**

Minimum annual dues = \$5,000/yr but is dependent on volume

Small Producer annual dues= \$2,500/yr

## Regulations

### **NBB Volume Dues**

|                          |                 |
|--------------------------|-----------------|
| 0 to 1,000,000           | \$0.01/gallon   |
| 1,000,001 to 5,000,000   | \$0.0075/gallon |
| 5,000,001 to 10,000,000  | \$0.005/gallon  |
| 10,000,001 to 15,000,000 | \$0.0025/gallon |
| Over 15,000,000          | \$0.001/gallon  |

## Regulations

### **EPA Noncompliance**

EPA imposes civil penalties where there is failure of compliance with the requirements and regulations.

Each day of noncompliance is fined \$25,000 plus the amount of any economic savings from failing to comply.

## Regulations

### **Other Governance**

Any biodiesel producer must also be registered with the DOE, the IRS, and the State Tax Board.

Permitting is required by state and local municipalities, fire departments, and solid waste.

## RFS and Rins

### Renewable Fuel Standard

The RFS program was created under the Energy Policy Act (EPA) of 2005, and established the first renewable fuel volume mandate in the United States.

- **Biomass-Based Diesel: 1 Bgal by 2012 and beyond**

Biodiesel, “renewable diesel” if fats and oils not co-processed with petroleum

Must meet a 50% lifecycle GHG threshold

## RFS and RINS

“The RFS program being finalized today requires refiners, importers, and blenders (other than oxygenate blenders) to show that a required volume of renewable fuel is used in gasoline. The required volume is determined by multiplying their annual gasoline production by a percentage standard specified by EPA. Compliance is demonstrated through the acquisition of unique Renewable Identification Numbers (RINs) assigned by the producer or importer to every batch of renewable fuel produced or imported. The RIN shows that a certain volume of renewable fuel was produced or imported. Each year, the refiners, blenders and importers obligated to meet the renewable volume requirement (referred to as “obligated parties”) must acquire sufficient RINs to demonstrate compliance with their volume obligation. RINs can be traded, thereby functioning as the credits envisioned in the Act. A system of recordkeeping and electronic reporting for all parties that have RINs ensures the integrity of the RIN pool.” (EPA 2007)

## RFS and RINS

RINS are bought, sold, and traded on the open market and have different categories.

Biodiesel is categorized as a D4 RIN and has an equivalence value of 1.5.

2011 RIN's were and are trading for \$1.24-\$1.27 per gallon.

2012 RIN'S are trading for \$1.42-\$1.46 per gallon.

This means that today's D4 RINS are \$2.19/gallon

# Biodiesel Economics

## PowerPoint Presentation Slides:

### Biodiesel Economics

A \$1.00 tax credit per gallon of biodiesel blended expired at the end of 2011.

RINS are the only current instrument to offset the cost of producing renewable biodiesel.

### Biodiesel Economics

A million gallon a year biodiesel plant typically has operating costs of \$.90 per gallon.

|                   |                          |
|-------------------|--------------------------|
| Feedstocks costs= | \$2.96-\$4.29 per gallon |
| Total Costs=      | \$3.86-\$5.19 per gallon |
| 2012 RIN Value =  | \$2.19 per gallon        |
| 2012 B100 Price = | \$4.50-\$4.80 per gallon |
| Profit=           | \$1.80-\$1.83 per gallon |

# Evaluation & Certification

LHA Forms:

Test:

*This workforce solution was funded by a grant awarded by the U.S. Department of Labor's Employment and Training Administration. The solution was created by the grantee and does not necessarily reflect the official position of the U.S. Department of Labor. The Department of Labor makes no guarantees, warranties, or assurances of any kind, express or implied, with respect to such information, including any information on linked sites and including, but not limited to, accuracy of the information or its completeness, timeliness, usefulness, adequacy, continued availability, or ownership. This solution is copyrighted by the institution that created it. Internal use by an organization and/or personal use by an individual for non-commercial purposes is permissible. All other uses require the prior authorization of the copyright owner.*