Biodiesel


16
SOYBEAN POWERED
This Bus Runs On Soybean Bio-Diesel
NEBRASKA SOYBEAN
PROGRAM

What is Biodiesel?

- Biodiesel consists of alkyl-esters derived from a biological source
- Biodiesel can be used as a fuel in compression ignition engines (i.e. diesels)
- Can be blended with petroleum diesel in any ratio (e.g. B2, B20, B100)

What is Biodiesel?

- Vegetable oils (soy, canola, palm) are the most commonly used oils for biodiesel production.

- All common oils can be converted
  (i.e. plant oils, animal fats, waste cooking oil)

Why Biodiesel?

IT'S RENEWABLE!

Why Biodiesel?

- **Non-toxic**
  - LD50 of 17.4 g/kg
    - ten times less toxic than table salt
  - Less skin irritation than a 4% soap solution
    - very mild irritation
  - Insignificant aquatic toxicity
    - 1000mg/L is lethal to bluegill

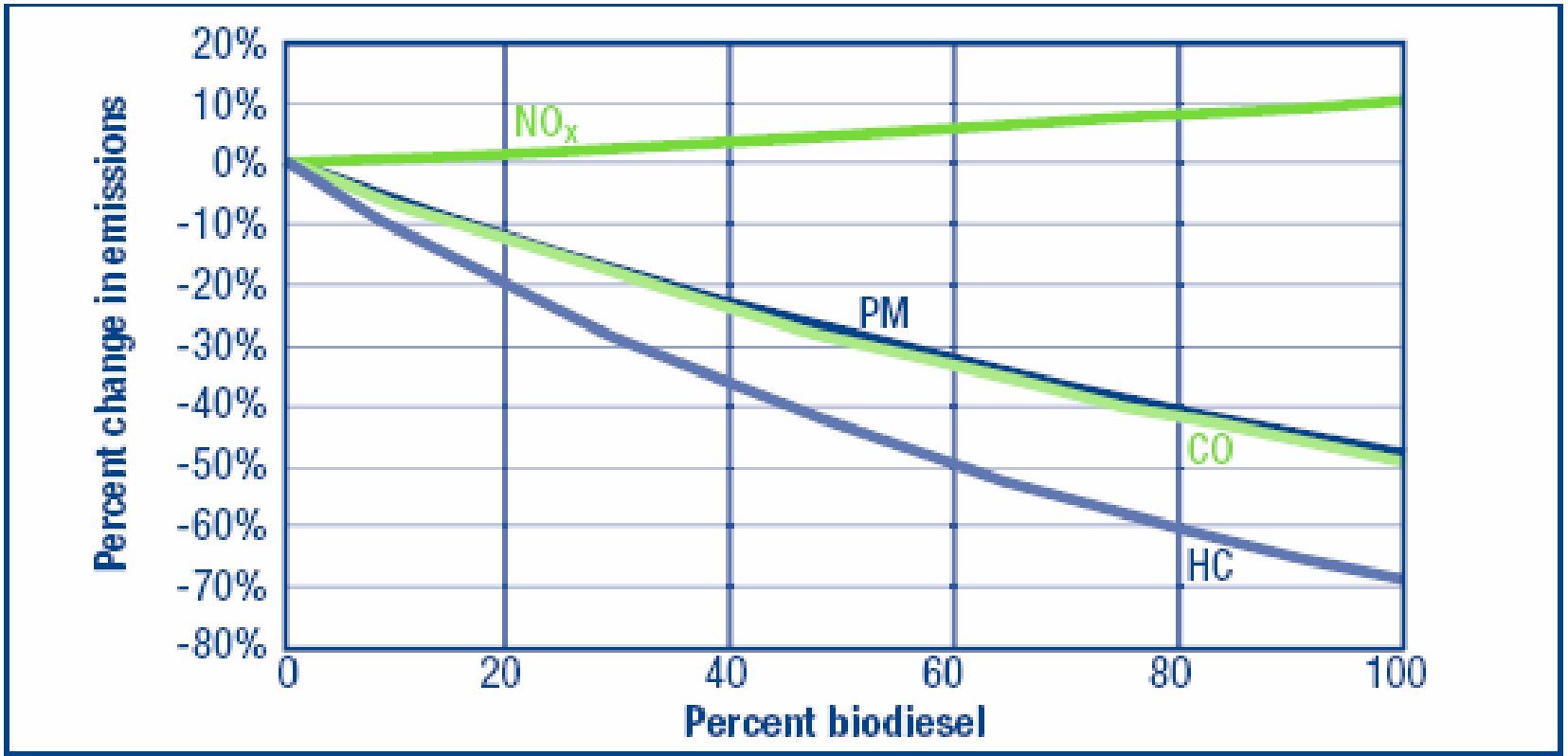
Why Biodiesel?

- **Reduced air pollution**
  - Sulfur emissions are greatly reduced
    - Equivalent to ultra low sulfur diesel now required by EPA
  - EPA Criteria pollutants are reduced
    - unburned hydrocarbons
    - carbon monoxide
    - particulate matter

Effects on Air Quality

- **Reduced air pollution**
  - Reduces health risks associated with petroleum diesel:
    - 75-85% reduction of polycyclic aromatic hydrocarbons (PAH)
    - 90% reduction of nitrated polycyclic aromatic hydrocarbons (nPAH).
  - These have been identified as carcinogens

Biodiesel vs. Petrodiesel



Basic Emission Correlation. Average emission impacts of biodiesel for heavy-duty highway engines. Source: U.S. EPA[2].

2: EPA Emissions Evaluation for the National Biodiesel Board

AVERAGE BIODIESEL EMISSIONS COMPARED TO CONVENTIONAL DIESEL, ACCORDING TO EPA

Emission Type	B100	B20
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
Nox	+10%	+2% to -2%
Non-Regulated		
Sulfates	-100%	-20%*
PAH (Polycyclic Aromatic Hydrocarbons)**	-80%	-13%
nPAH (nitrated PAH's)**	-90%	-50%***
Ozone potential of speciated HC	-50%	-10%

*** Estimated from B100 result**
**** Average reduction across all compounds measured**
***** 2-nitroflourine results were within test method variability**

Source: EPA Emissions Evaluation for the National Biodiesel Board

Environmental Benefits

- **Homegrown**
  - Can be grown from local oil crops
  - Reduce long distance transport of fuels
- **Biodegradable**
  - Biodiesel degrades at ~the same rate as dextrose
    - Environmentally positive (no oil spill disasters)

Some other important considerations

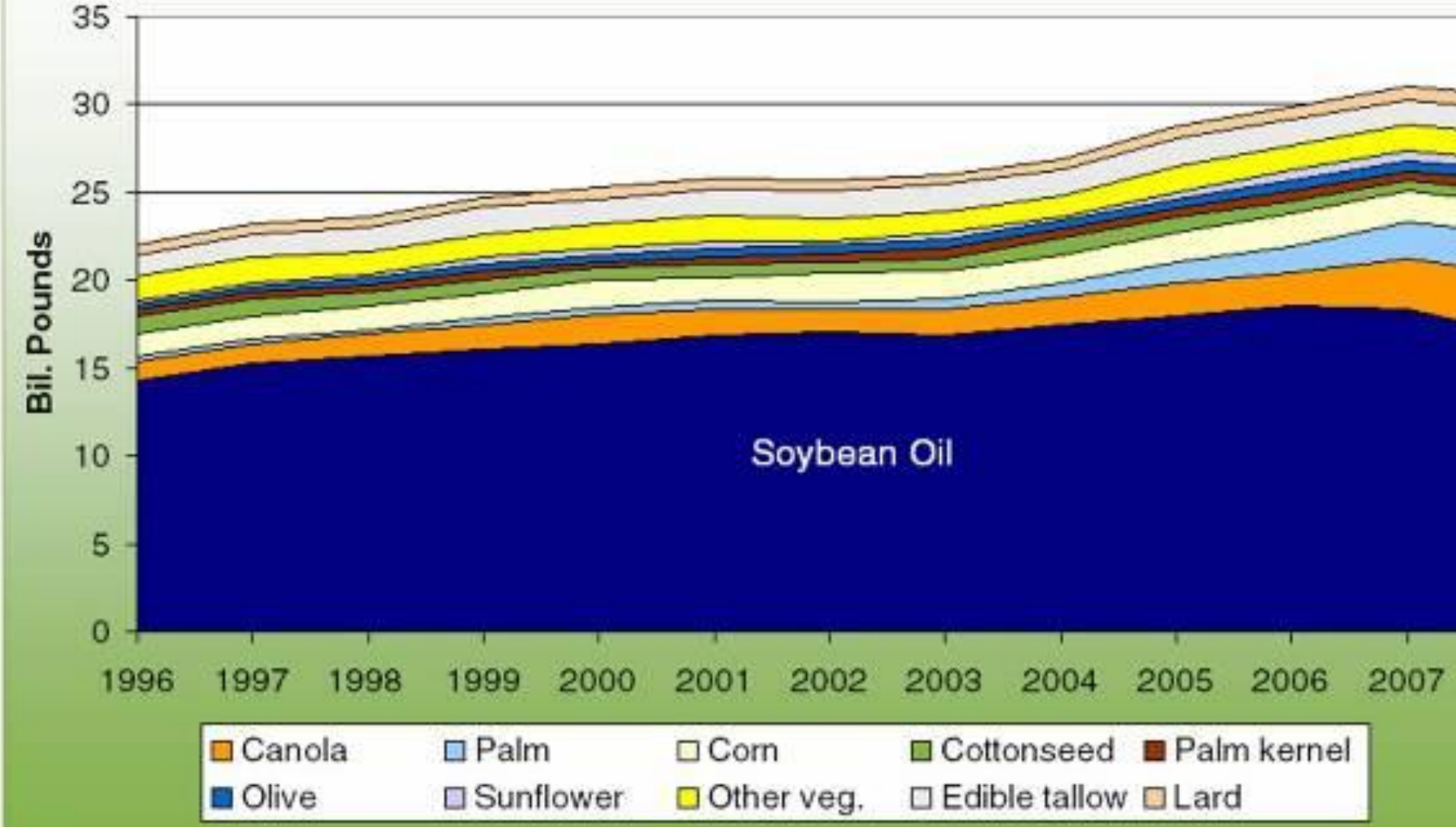
- Fits existing fuel infrastructure
  - Runs in current diesel engines
  - Can be stored at existing petrol stations
  - Can be transported like petroleum diesel
- Higher flashpoint than petroleum diesel
  - Classified as non-flammable by OSHA (150 ˚C)
  - Safer to handle and transport, safer in accidents
- Provides lubricating properties
  - Reduces engine wear
  - Extends engine life

What’s the Catch?

Feedstock Supply

There simply isn’t enough oil to turn into biodiesel!

Figure 1. U.S. Domestic Vegetable Oils and Animal Fat Usage



Data source: USDA, ERS

Feedstock Supply

- Devoting all 2005 U.S. soybean production to biodiesel would have offset 6.0% of U.S. diesel demand.

Source: Hill et al. 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proceedings of the National Academy of Sciences, 103:30 11206-11210

Feedstock Supply

- However, because of the fossil energy required to produce biodiesel, this change would provide a net energy gain equivalent to just 2.9%.

Source: Hill et al. 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proceedings of the National Academy of Sciences, 103:30 11206-11210

Feedstock Supply Solutions

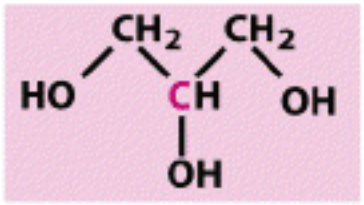
1. Use less fuel by increasing **efficien**
2. Recycle waste cooking oil
3. Get creative in oil crops!
   - Tremendous botanical potential
     - ✓ Sesame (*Sesamum indicum)*
     - ✓ Camelina (*Camelina sativa*)
     - ✓ Jatropha (*Jatropha curcus*)
     - ✓ Castor (*Ricinus communis*)
     - ✓ Tallow (*Sapium sebifera*)
     - ✓ Algae (~40,000 species)

THE CHEMISTRY OF BIODIESEL

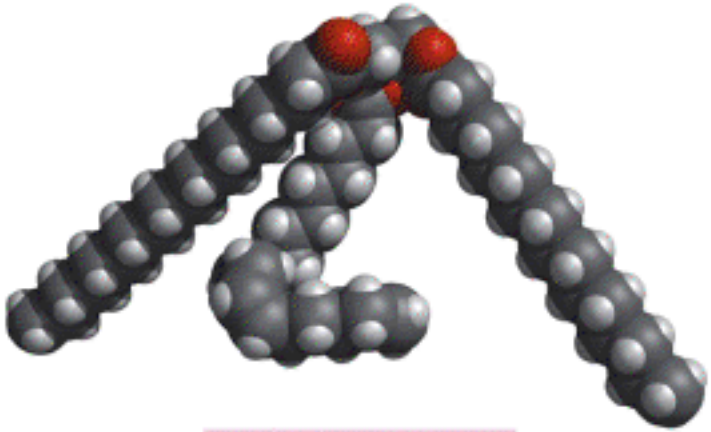
Important Families of Organic Compounds in Relation to Biodiesel

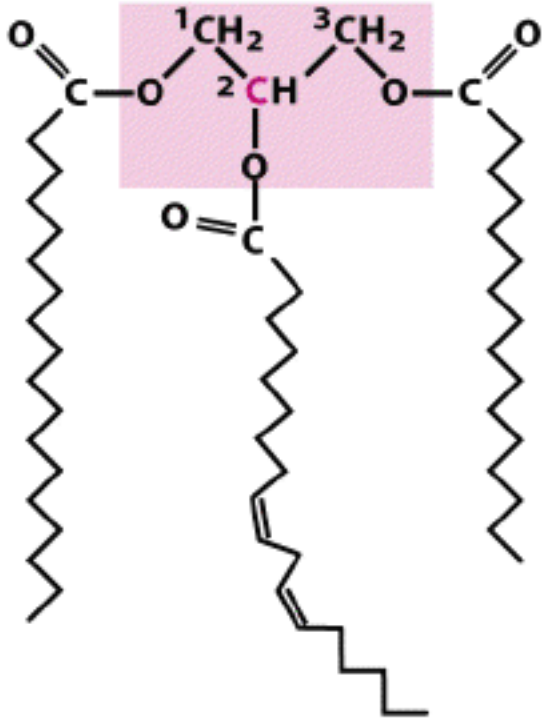
- Alcohols
  - Methanol
  - Ethanol
- Carboxylic acids
  - Free fatty acids
- Lipids
  - Triacylglycerols (oils)
  - Phospholipids
  - Waxes
- Esters
  - Methyl esters
  - Ethyl esters

Triacylglycerol



Glycerol

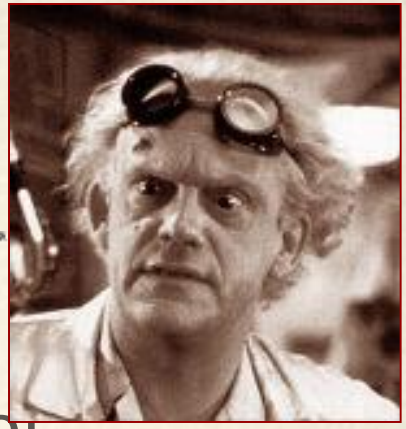




1-Stearoyl, 2-linoleoyl, 3-palmitoyl glycerol,
a mixed triacylglycerol

Figure 10-3
Lehninger Principles of Biochemistry, Fifth Edition

How is Biodiesel Made?



- A **TRANSESTERIFICATION** reaction of vegetable (or animal) lipids with a low molecular weight alcohol (methanol) produces 'biodiesel'

- This reaction is catalyzed by a base, typically: Sodium Hydroxide (NaOH) or Potassium Hydroxide (KOH)

Transcendental Transesterification

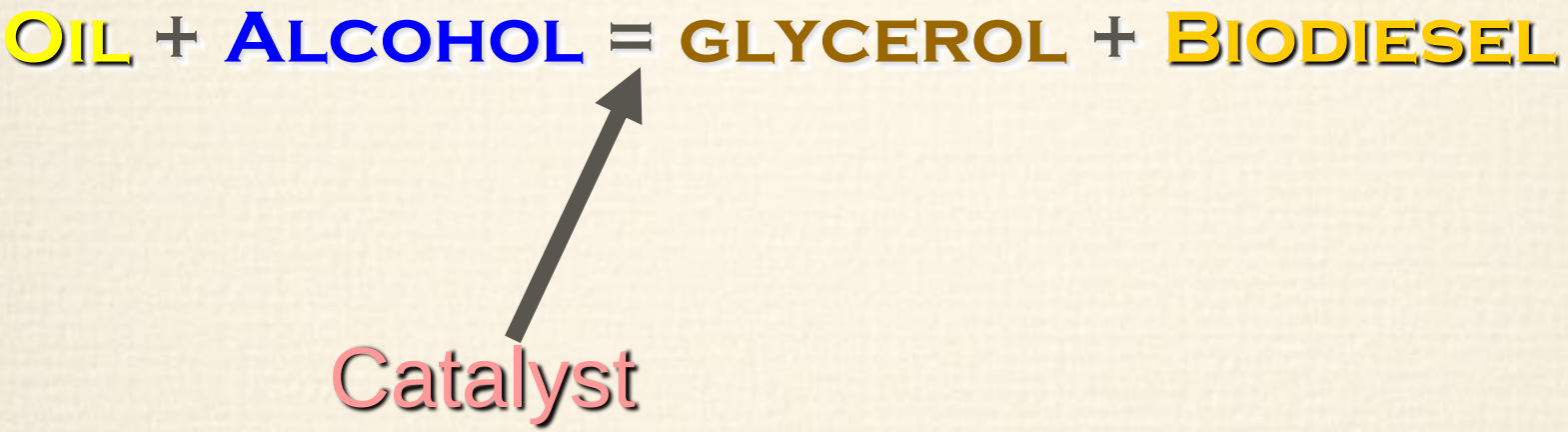
- Trans= change
- esterification= creating an ester
- Oil + Alcohol = glycerol + Alkyl esters (Biodiesel)

A base and heat are reaction catalysts

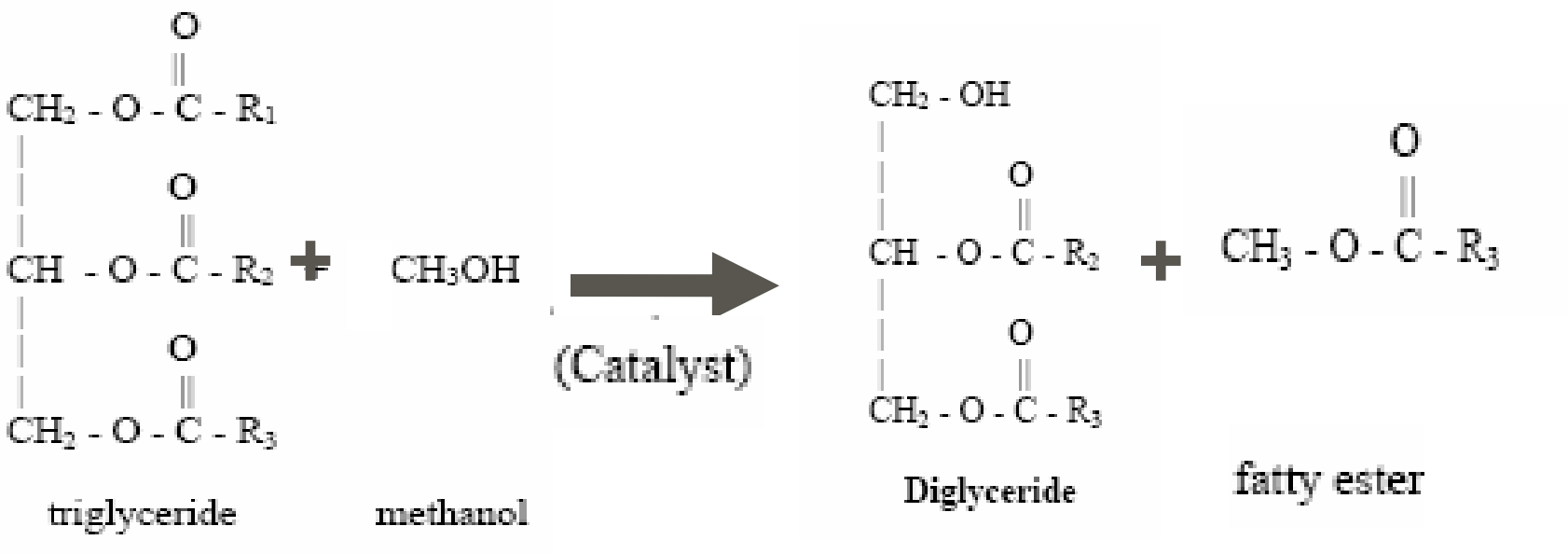
- In the context of biodiesel transesterification is:
  - the **replacment of the glycerol portion of the oil with methanol or ethanol**

TRANSESTERIFICATION

a step-by-step visual guide

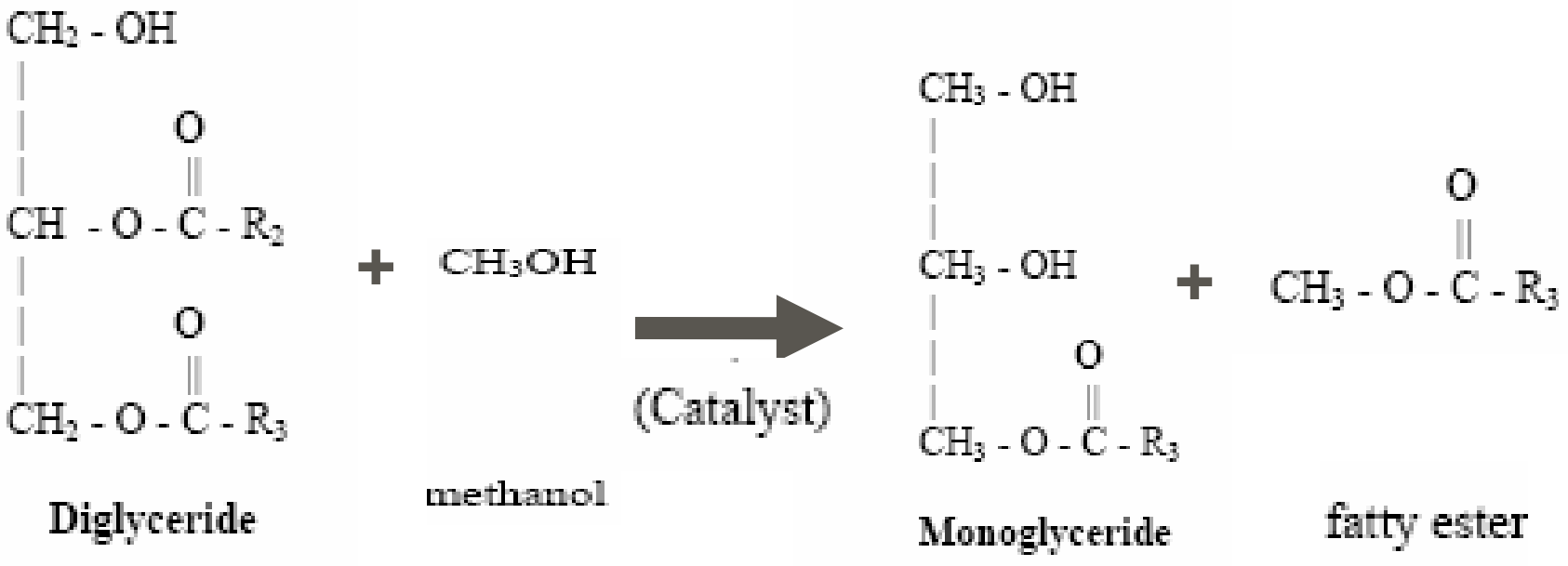


Step 1



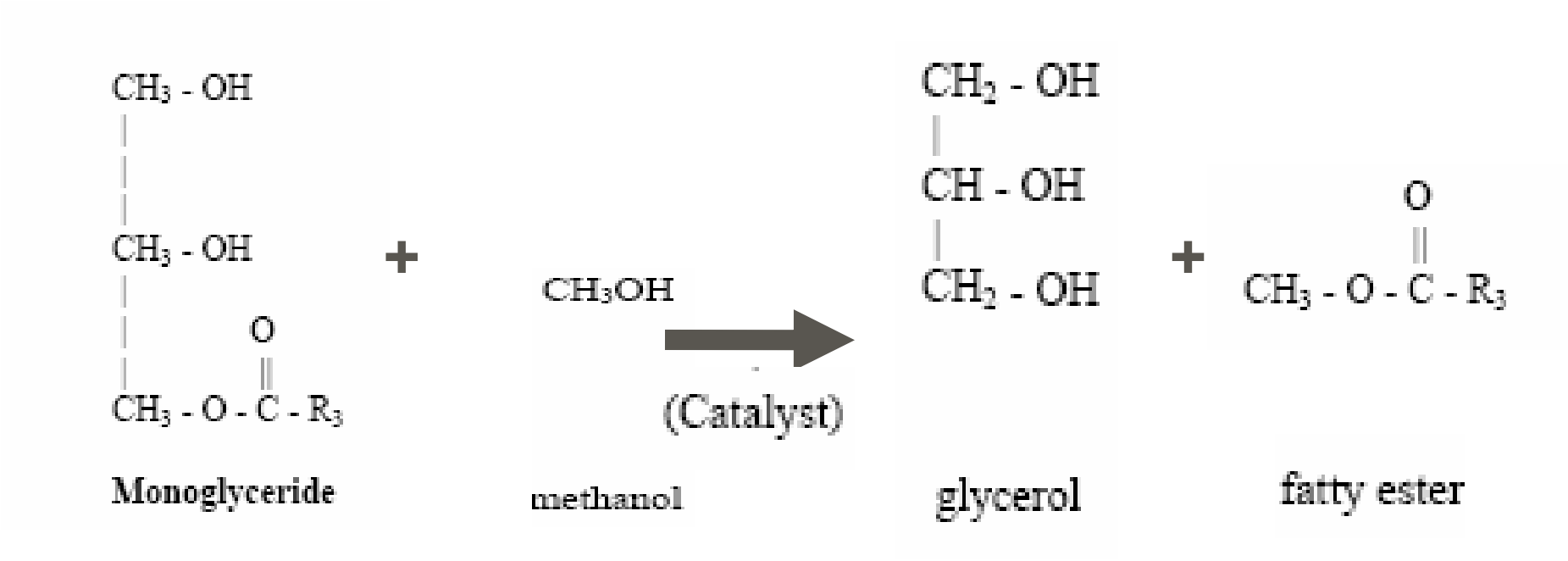
LIPID ALCOHOL LIPID BIODIESEL

Step 2:



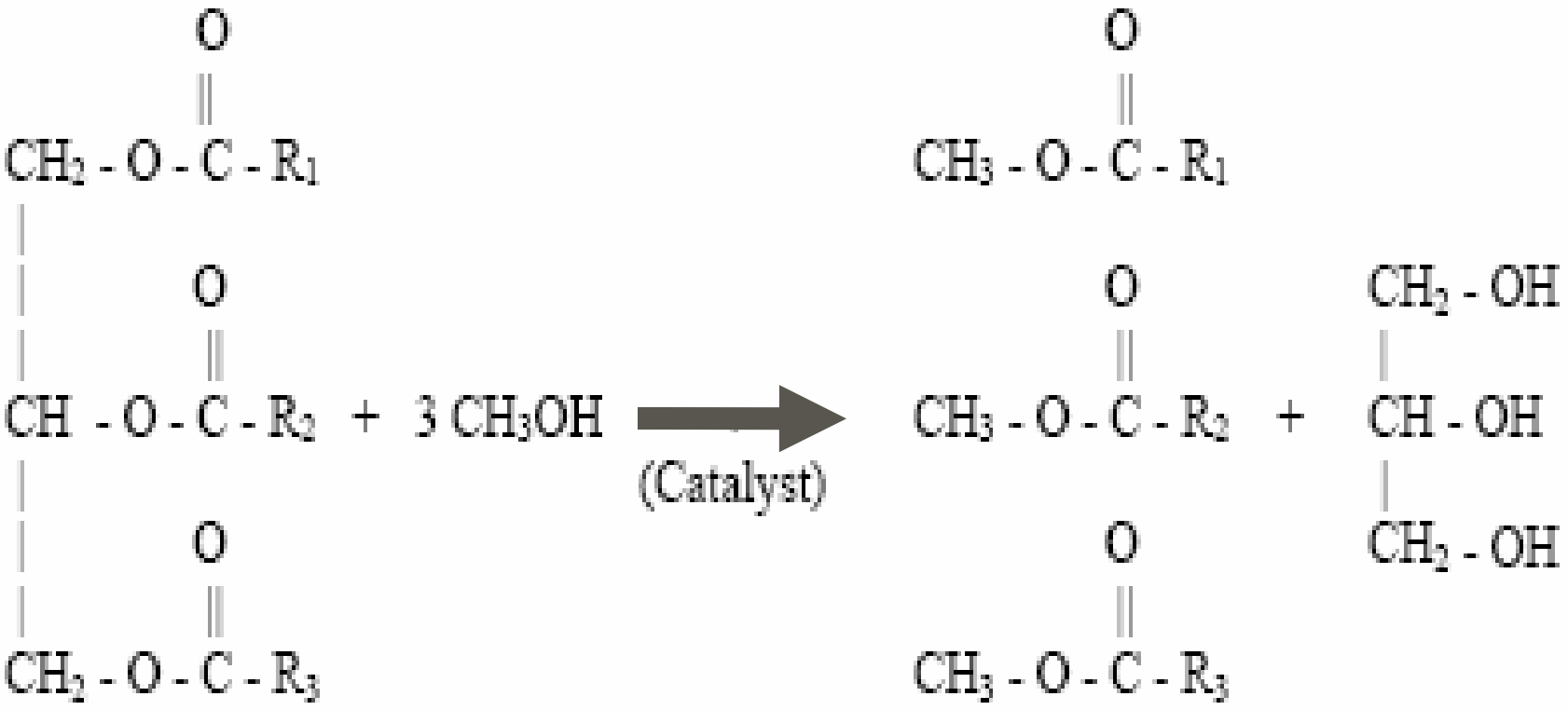
LIPID ALCOHOL LIPID BIODIESEL

Step 3



LIPID ALCOHOL GLYCEROL BIODIESEL

Combined Reaction



triglyceride methanol mixture of fatty esters glycerol

LIPID ALCOHOL BIODIESEL GLYCEROL

The Biodiesel Production Process

THE REACTION TANK

- Location of the transesterification
- The reaction tank is a closed vessel
- The tank must be made of solvent resistant materials: polyethylene or stainless steel

The “Appleseed Reactor”

Heating the Oil

- Heat acts as a catalyst to drive the transesterification reaction
- The oil can either be heated in the reaction tank or heated prior to adding to the tank
- Oil in the reaction tank is at a temperature of ~55˚C
- Temperature is critical as methanol boils at 64.7˚C

Transesterification of the Oil

- An alcohol, usually methanol, is combined with a strong base, potassium hydroxide (KOH) or sodium hydroxide (NaOH)
- This creates methoxide, which is then added to the reaction tank with the oil to initiate the transesterification reaction
- Methanol is added at 20% by volume of oil, only 10% needed in reaction.

Glycerol Settling

- During the transesterification reaction two products are created:
  - Alkyl esters and Glycerol
- Glycerol settles to the bottom of the reaction vessel and the Alkyl esters float on top
- The glycerol is drained from the bottom of the reaction vessel
- Glycerol typically constitutes 10% of total oil volume

Washing the Biodiesel

- The remaining alkyl esters contain small amounts of the **base catalyst**, free **glycerol**, and saponified **fatty acids**
- These are all **water soluble** and can be washed out of the biodiesel
- 1:1 ratio of water used per biodiesel made
- Wash water is drained off the bottom of a washing tank

Drying Biodiesel

- Water, however, is undesirable within a diesel engine
- All residual wash water must be removed from the washed biodiesel
- Either through intensive heating (100°C), passive evaporation, settling, or centrifugation

Ready to use Fuel!

- Raw **vegetable** (or **animal**) **oil** has now been transesterified into **alkyl esters**
- These **alkyl esters** have been **washed** to increase the purity level
- And dried to remove all water
- The fuel is ready to run in any diesel engine

Producing 100 liters of biodiesel also:

- Consumes at least 350g base catalyst
- Consumes 20 liters methanol
- Produces 10 liters glycerol
- Produces 100 liters wash water

A Note on Safety

- An alcohol is required in the production of Biodiesel
  - methanol is used in our biodiesel lab

- Methanol is a **flammable neurotoxin**

  - However, so is gasoline (a quite common fuel)

-Safety precautions must be used when handling, transporting, or producing methanol:

- no sparks
- no smoking
- proper ventilation
- proper safety equipment: gloves, goggles, lab coats, etc.