

Fall 10-2018

Biodiesel for the Classroom

Blaine M. Heisner

Southern Illinois University Carbondale, bheisner@siu.edu

Follow this and additional works at: https://opensiuc.lib.siu.edu/auto_pres

Presentation slides from ICAIA Fall 2018 conference

Recommended Citation

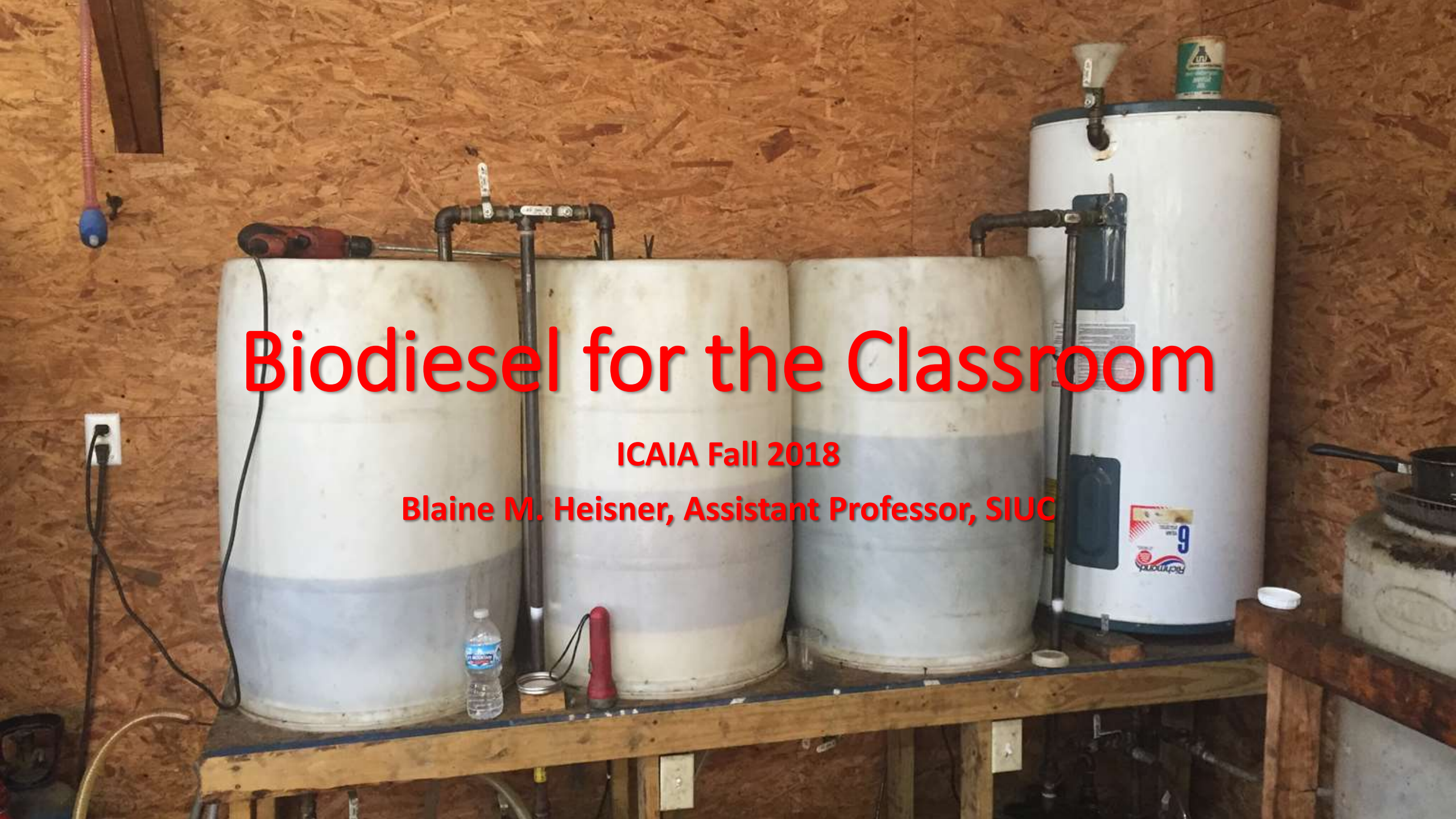
Heisner, Blaine M. "Biodiesel for the Classroom." (Fall 2018).

This Article is brought to you for free and open access by the Department of Automotive Technology at OpenSIUC. It has been accepted for inclusion in Presentations by an authorized administrator of OpenSIUC. For more information, please contact opensiuc@lib.siu.edu.

Biodiesel for the Classroom

ICAIA Fall 2018

Blaine M. Heisner, Assistant Professor, SIUC



Fun Fact

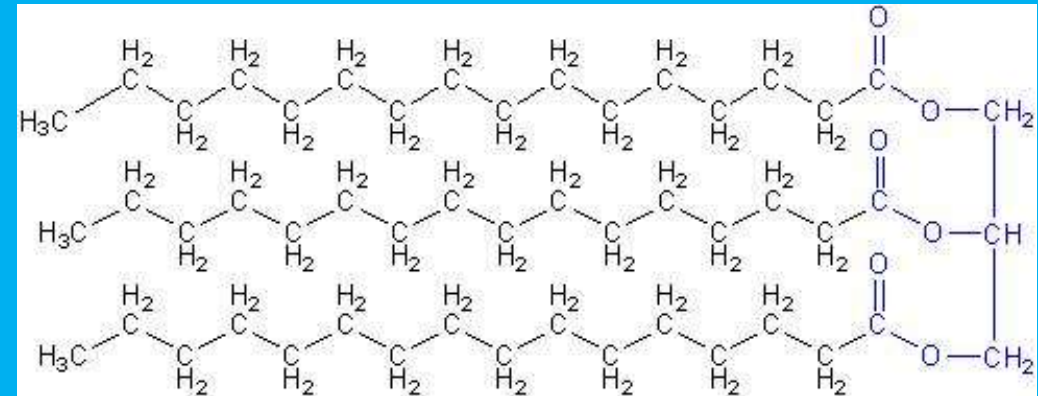
- We've all heard the Diesel engine was build to run on vegetable oil.
- Rudolph Diesel's engine was NOT designed to run on vegetable oil.
- "But it is not yet generally known that it is possible to use animal and vegetable oils in Diesel engines. In 1900 a small Diesel engine was exhibited at the Paris exhibition by the Otto Company which, on the suggestion of the French Government, was run on Arachide (Peanut) oil, and operated so well that very few people were aware of the fact. *The motor was built for ordinary oils*, and without any modification, was run on vegetable oil." R. Diesel, December, 1911

Biodiesel Basics

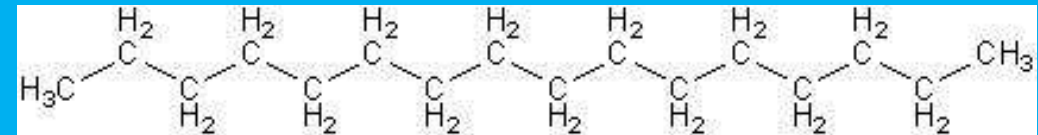
- A fuel suitable for use in a compression ignition (diesel) engine
- Manufactured from, but not, a triglyceride
- Manufactured through the process of *transesterification*
- Alkyl Esters, Methyl Esters, Ethyl Esters, etc...
- Blends include B5, B11, B100

Chemical Structures of Diesel Fuels

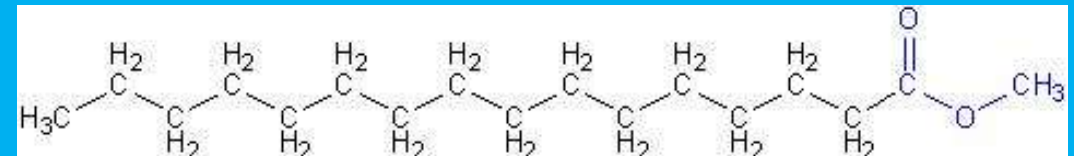
Vegetable oil (triglyceride)



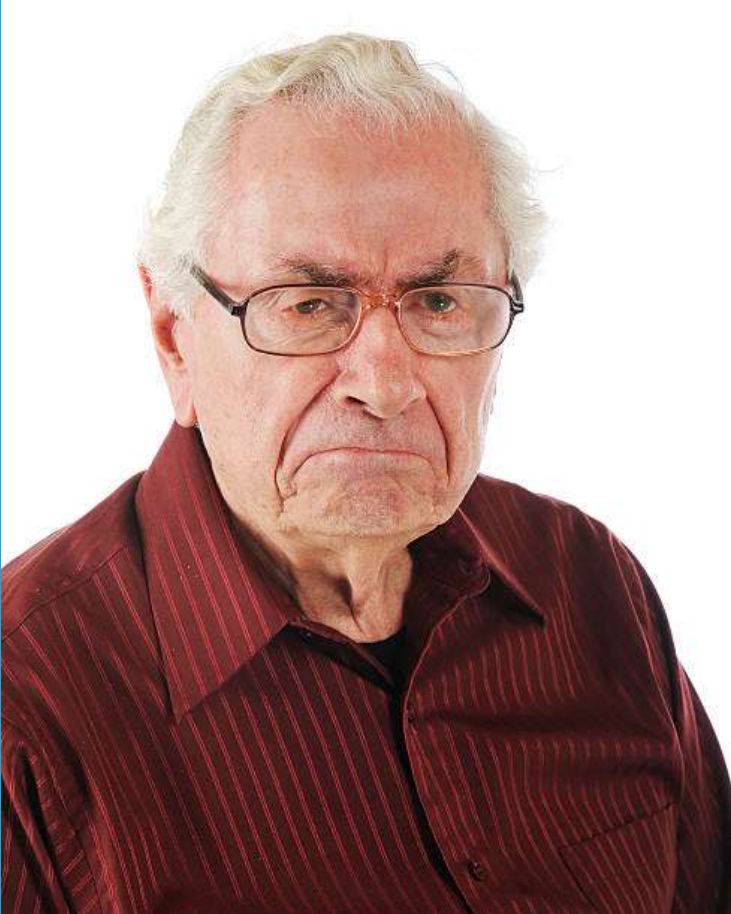
Petrodiesel Fuel



Biodiesel (Alkyl Esters)



Why teach/use Biodiesel?



- Biodiesel clogs fuel filters!
- Biodiesel grows algae!
- Biodiesel damages injection pumps!
- Biodiesel doesn't store well!
- Biodiesel is subsidized by the gubment!
- You don't have to like it, but it's here

Another Fun Fact

- “Already in the year 1899 I employed in my motor the by-products from the distillation of coal, and the manufacture of coke-tar or creosote oil-with the same success as with natural liquid fuel. The quality of these oils was however generally unsatisfactory for use in Diesel motors and subject to continual variations. “

R. Diesel, December, 1911

- People have been complaining about the quality of diesel fuel for a very long time.

Why teach/use Biodiesel?

- Biodiesel is currently in use
- Domestic
- Nontoxic
- Renewable
- Biodegradable
- Reduces carbon footprint
- Higher cetane rating
- Higher lubricity
- Fun to make
- Cheap to use
- EPAAct fuel
 - Non-petroleum
 - Energy security benefits
 - Environmental benefits
- Motivates students
- Gain knowledge/research
- Feel good about usage
- Be responsible
- Be safe in lab
- Not the same old stuff
- Grants/Funding

Renewable Fuel Standard (EPA)

- Renewable Fuel Standard Policy (Energy Policy Act of 2005)
 - Requires usage of renewable fuel in USA
 - Target of 2.1 billion gallon of *Biomass-Based Diesel* (2018)
 - Increasing target to 2.43 billion gallon in 2020
 - Likely to continue to increase?
- *Biomass-Based Diesel*
 - Must achieve a 50% GHG emissions reduction
 - Includes both Biodiesel and Renewable Diesel fuels

Biodiesel vs Renewable Diesel

- Feedstock only lipids
 - Vegetable oils, greases, fats, etc
 - Manufactured through process of transesterification only
 - Base or acid catalyzed
 - Chemically different than Petrodiesel
 - Uses ASTM spec D6751
 - Different than Petrodiesel
 - Not a *drop-in* fuel
- Feedstock includes lipids and...
 - Biomass, crop residues, pulp, etc
 - Manufactured by various processes including hydrotreating, gasification, and pyrolysis
 - Similar to petrochemical industry
 - Chemically similar to Petrodiesel
 - Uses ASTM spec D975
 - Same spec as Petrodiesel
 - Drop-in replacement for Petrodiesel

McDonalds Biodiesel Program



- Europe

- 80% of all WVO manufactured into B100
- 28% of all logistic vehicle fleet fuel comes from biodiesel
- Average participating restaurant recycles approximately 1500 gallon WVO annually

- UAE Program

- Started in 2011
- Collects and manufactures 100% of all WVO into B100
- All MCD fleet vehicles in UAE run B100
- Over 8500 Ton reduction in CO2 emissions
- Over 10,000,000 Km on B100

- United States

- Partnered with RTI
- Over 8600 locations
- All WVO transesterified

Manufacturing Biodiesel at Home or at School

Getting Started

- Obtaining a supply of oil
- Collecting oil
- Building a processor
- Experimenting with processing
- Cleaning up
- Utilizing the Biodiesel



Obtaining a Supply of Oil

- Used/Waste vegetable oil
 - Easiest feedstock to obtain
 - Set up a storage facility
 - Contact mom & pop restaurants
 - Contact banquet halls, VFW's, American Legions, etc...
- New or Virgin Vegetable Oils
 - Most biodiesel sold in US from new soybean oil
 - Requires extra processes (pressing, degumming)
 - Typically more expensive
- Animal Fats
 - Higher gelling point

Collecting Oil

- Dip off the Top, Don't suck off the Bottom
- Secure storage area
- Cubies-35 lb., 4.6 gal
- Open top barrels
- 55 gallon barrels
- 275 gallon IBC totes







Collecting Oil

- Vacuum/Pressure collection tank “AKA”-[Super Sucker](#)



Building a Processor

- Ultra small- [Dr. Pepper](#)
- “Appleseed” Processors
 - Small- Single tank
 - Medium- [My home processor](#)
- Large- Commercial [Bio Pro](#) Unit



Appleseed Processor Component List

Main Components

- Hot water heater
 - Prefer new-no rust
 - Remove upper element, dip tube, sacrificial anode
- Circulation pump(s)
 - Iron-ton ½ horsepower centrifugal pump
 - Proven very reliable
 - 1" inlet/outlet
- Holding/Mixing Tanks
 - 55 gallon plastic drums
 - “complete drain” cone bottom plastic tanks



Appleseed Processor Component List

Other parts

- Iron pipe/sealer
- “Full port” ball valves
- Brass check valve
- Romex
- Electrical switches
- Barb fittings
- Hose clamps
- Braided PVC tubing
- Funnels
- Filters
- Buckets
- Electric Drill
- Paint stirrer
- Alcohol/Biodiesel compatible containers (5 Gal)
- Platform materials
- Beakers/jars
- Gram scale
- Filter adapters
- A little left in the budget

Building the processor



Finishing the processor

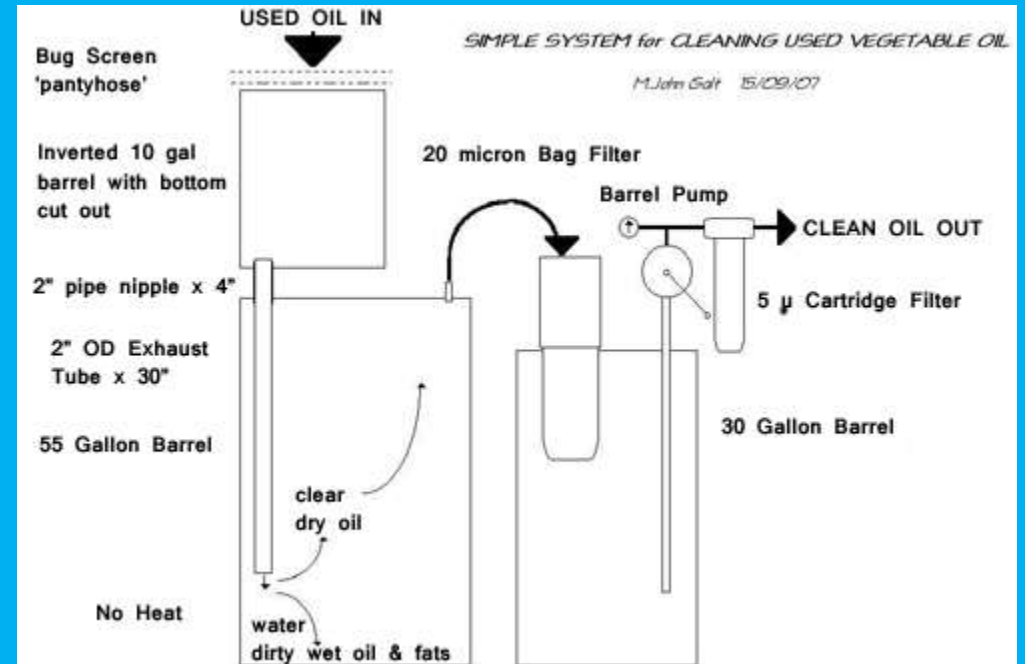


Experimenting with Processing

- Filtering and settling the oil
- Titrating the oil
- Mixing methoxide
- Transesterification
- Washing
- Drying

Filtering and settling the oil

- Inspect the oil
 - Opacity, standing water
 - Shortening, food, bugs, leaves, etc...
- Let the oil sit/settle
 - Use last years oil on a rotation if possible
 - Gravity and time are cheap
- “Cold-upflow” tank method
 - Best oil floats
- Filters
 - Screens, bag filters, canister/cartridge filters
- Heated Dewatering
- Centrifuge cleaning



Titrating the Oil

- Measuring the oil for acidity
- Need to be *basic* to complete reaction, need additional lye to neutralize oil
- Determine correct amount of lye to use
 - Not enough=incomplete reaction
 - Too much=more soap/extra cost
- Isopropyl Alcohol (IsoHeet/Thermo-Aid)
- Indicator solution (phenol red, phenolphthalein, or turmeric)
- Titrating solution every semester (0.1% catalyst)
 - Make a new batch each semester

Titrating the Oil

- Put 10 mL isopropyl alcohol, 5 drops indicator solution into a clean beaker; swirl to dissolve
- Add titrating solution, one drop at a time while swirling, until color of solution just changes (yellow to red in video)
- Add 1mL oil sample to beaker and swirl, color will change back to yellow
- Add titrating solution to beaker while swirling until color changes back to red
- Each mL of titrating solution used to change color back is an additional gram of lye needed per liter of oil

Mixing the Methoxide Solution

- Safety Note:
 - Sodium/Potassium Methoxide is dangerous! Use PPE as needed.
- Need Methyl Alcohol (methanol)
 - I use 99.9% methanol race fuel
 - Make sure no fuel additives in methanol
- Need lye (sodium or potassium base)
 - I use Roto Brand Drain Cleaner (sodium hydroxide)
 - Potassium Hydroxide lye works also
 - Use what you can find
 - I have to provide DL and signature to buy lye



Transesterification

- “Making” biodiesel with a chemical reaction
- Base transesterification, acid esterification, Acid/base, base/base (80/20)
- Triglycerides have 3 esters attached to glycerol/glycerine molecule
- Transesterification detaches esters from glycerine and attaches an alcohol (methyl esters)
- Heat speeds everything up
 - I try for around 130°F, over 150°F and methanol evaporates/boils fast



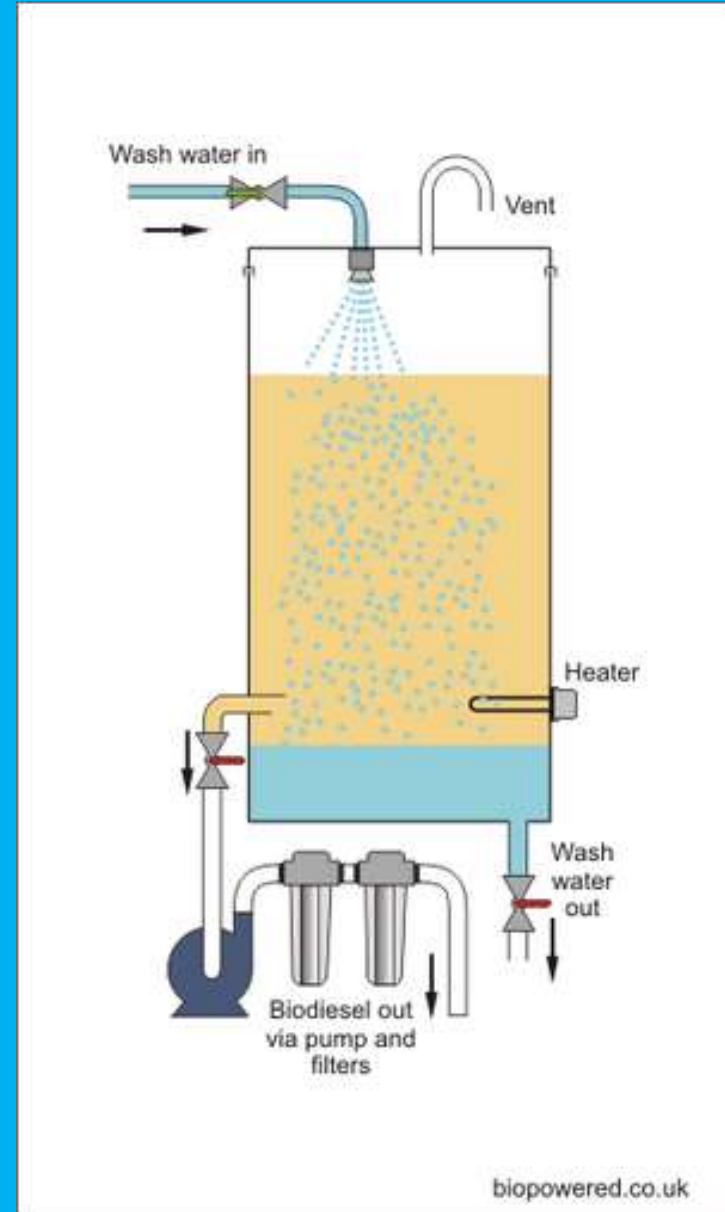
Transesterification

- Load the processor
- Circulate the oil
- Take a sample
- Turn on the heat
- Titrate the oil
- Turn off the heat
- Induct the methoxide
- Wait 1 hour
- Perform completion test
 - ([3/27 test](#))
- Continue processing?
- Perform 5% prewash?
- Transfer to settling tank
- Relax for 24 hours!
- Separate raw biodiesel from glycerine

Washing Biodiesel

- Raw biodiesel
 - Excessive amounts of methanol, lye, soap, glycerin, unreacted glycerides, dust, etc...
- Dry washing
 - Filtering raw biodiesel through media, no water
 - Magnesol, Eco2Pure, etc...
 - Does not remove methanol
 - Needs methanol removal first
 - I do not use this method
- Water washing
 - Batch washing
 - Pump mixing
 - Stir mixing
 - Spray washing
 - Continuous washing
 - Mist washing
 - Bubble washing
 - Requires disposal of wash water
 - [EPA says municipal sewers OK](#)
 - Not in storm drains or septic
 - Requires drying of biodiesel

Washing biodiesel



Water washing process

- Verify glycerin has settled
 - Reprocess if necessary
- Longer settling time for raw biodiesel
 - Methanol evaporates, soaps drop out
 - Extreme settling times dramatically reduce wash/dry requirement
- Batch wash
 - 8-10 gal in 25 gal (35%)
 - 4-5 wash cycles
- Can mix with pumps, stir, or drizzle water in through ports
- Be gentle with 1st wash cycle
 - High soap % can cause emulsion
 - Break emulsion with salt water, heat, or in emergencies-mild acidic water
 - Subsequent washes can be more aggressive
- Wash water will progressively clear up, can be tested with PH meter
- When wash water approaches PH of tap water, the end is near
- Test for soaps
 - Titration
 - 50/50 shake test

Drying biodiesel

- Water removal after water washing
- Settle first
 - Longer settling times can dry fully
- Evaporative drying
 - Spray biodiesel in a thin spray
 - Blow dry air across fuel
- Heat drying
 - Use heaters to boil/evaporate
 - Costly
- Biodiesel will darken and clear up as it dries



Cleaning up

- Spills are inevitable
- Line area with newspapers
- Disposable gloves
- Scrape concrete periodically
- Mop concrete
 - Strong lye
 - Muriatic acid
- Isopropyl on a rag to wipe barrels
- Veg/biodiesel are biodegradable
- Glycerin disposal
 - 5 gal glycerin for each 25 gal batch
 - Lye, methanol, soap, glycerin
 - [Make soap](#)
 - Possibly landfill (get permission)
 - Degreasing agent
 - I compost glycerin
 - Wood chips
 - Straw
- Alcohols can evaporate outside
- Fans to clear air around processor

Utilizing the Biodiesel

- How do I “convert” my vehicle to burn biodiesel?
- Can I burn biodiesel straight?
- What vehicles can use biodiesel?
- Can I mix biodiesel with regular diesel?
- What problems does biodiesel have?
- Is it legal to burn biodiesel?
- How much does it cost to make?

How do I “convert” my vehicle to burn biodiesel?

- You don't convert a vehicle to use biodiesel
- You may perform small adjustments to optimize for biodiesel
- Fuel hoses, pump seals, filters
- I put fresh fuel filters, fuel hoses, no seals, replace filters yearly
- [Blue Ridge Biofuels recommendations on biodiesel usage](#)

What vehicles can use biodiesel (B100)?

- Any diesel engine with a mechanical injection pump
 - Mercedes OM616, OM617, OM605, OM606, etc...
 - Volkswagen 1.9L, 2.0L, etc...
 - GM 5.7L, Detroit 6.2L, 6.5L (General Motors)
 - Cummins 5.9L (Dodge)
 - 6.9L, 7.3L International IDI (Ford)
 - Untold numbers of tractors, bulldozers, heavy equipment, etc...
 - 2011-2012 Duramax (9th injector...grain of salt)
- Unit injection engines
 - 6.0L, 7.3L Power Stroke
 - Volkswagen Pumpe Düse (1.9L, 2.0L)
 - Detroit 53, 71, 92 Series?
- I currently use B100 in 1983 Mercedes 300D (II)
- I previously fueled 1985 MB 300TD, 2004 VW Passat TDI, 1983 MB 300D (I)

What vehicles can use biodiesel (<B20)?

- Blended down, lots more engines can use B20 and under
- Ford 6.7L, Duramax 6.6L, Dodge 6.7L,
- Higher viscosity can create overwhelming fuel pressures in high pressure common rail applications
- Diesel aftertreatment systems may cause slight oil dilution during regeneration/post-injection (if using in-cylinder injectors)
- Check owners manual/warranty guides for conservative guidelines
- I would be cautious with HPCR vehicles and vehicles with exhaust aftertreatment systems

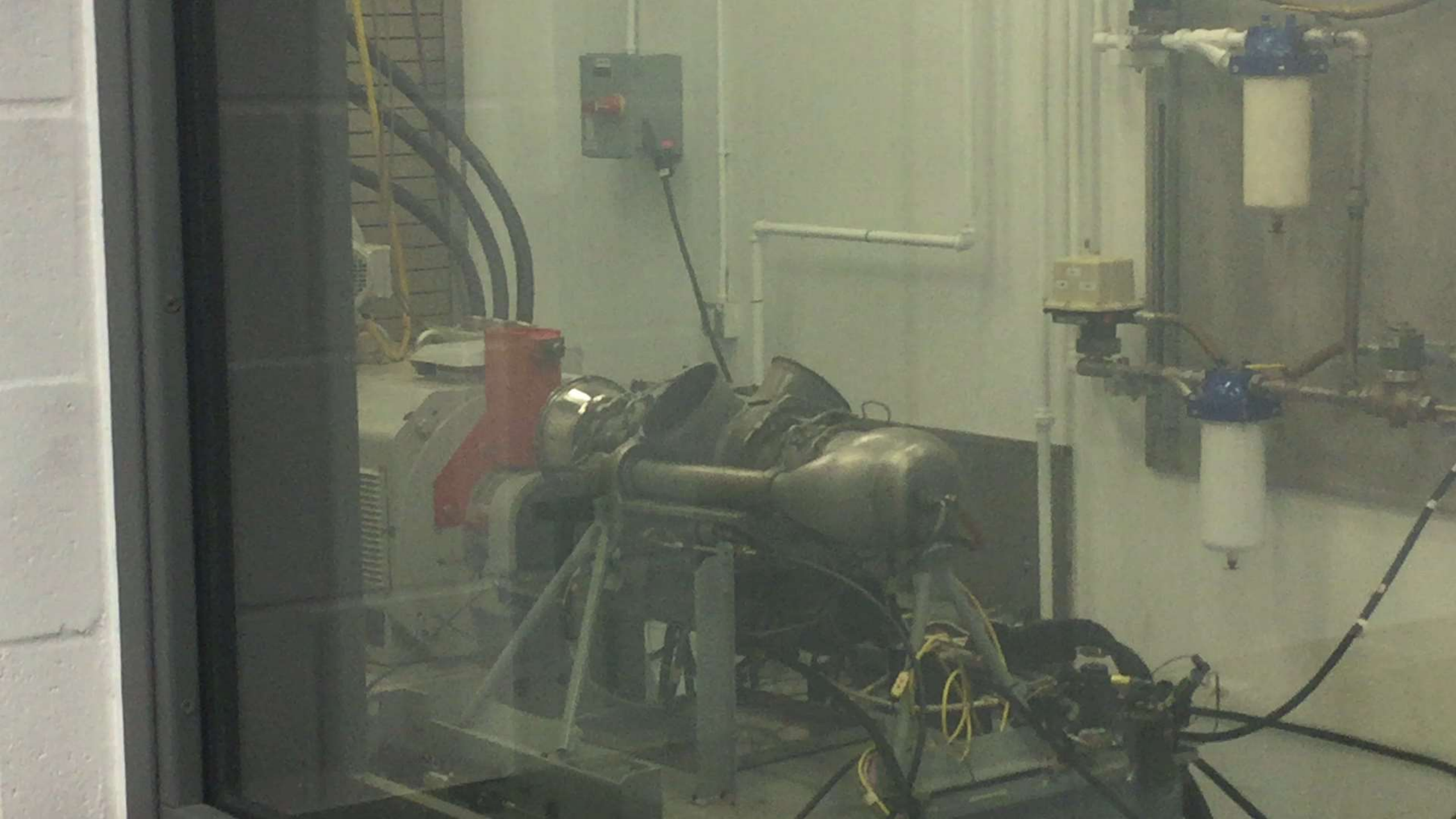








Rolls Royce Allison 250-C20 turboshaft engine
[research paper](#)



Problems with B100

- Gelling in the cold weather
- Incompatibility with certain materials
- Solvent properties cleaning residue from tank and lines
 - Requiring more frequent fuel filter replacements
- Engine oil dilution
- Oxidation from long term storage

Biodiesel Gelling

- My bio gels at about 30°F
- Can add winterizer/additive
- Can blend with diesel fuel
- Block heaters
- Fuel heaters
- Keep tank as full as possible





Biodiesel Compatible Components

- Biodiesel can soften typical fuel system hoses/seals
 - Fuel hose with spec SAE 30R9 is rated for biodiesel
 - Teflon, Viton, Nylon should resist biodiesel damage
 - All fuel hoses/seals degrade over time
 - Watch/inspect for leaks regularly
- Fuel storage materials
 - Do use-aluminum, steel, fluorinated polyethylene, fluorinated polypropylene, Teflon, and most fiberglass
 - Avoid-Brass, bronze, copper, lead, tin, and zinc



Biodiesel solvent properties (cleaning)

- Studies have shown biodiesel (alkyl esters) is known to have high solvent properties
- Petroleum residues in diesel vehicle fuel systems will be dissolved and carried into fuel filters
- Expect multiple frequent fuel filter replacements when switching from Petrodiesel to biodiesel usage
- Methyl soyate, a biodiesel made from soybean feedstock, is currently being marketed as a “green” alternative to petrochemicals
- Products using methyl soyate include engine degreasers, graffiti removers, laundry stain pre-treaters, parts washer solvents, and adhesive removers.

Engine oil dilution

- Fuel will dilute engine oil
- Biodiesel does show up in UOA
- Reduction in viscosity
- Increase in lubricity
- Change oil at proper intervals

Storage Issues

- Biodiesel may be more susceptible to oxidation than Petrodiesel
- Biodiesel may be more susceptible to biological growth than Petrodiesel
- Long term storage anti-oxidant additives are suggested
- I personally make fuel as needed

Can I burn biodiesel straight?

Can I mix biodiesel with regular diesel?

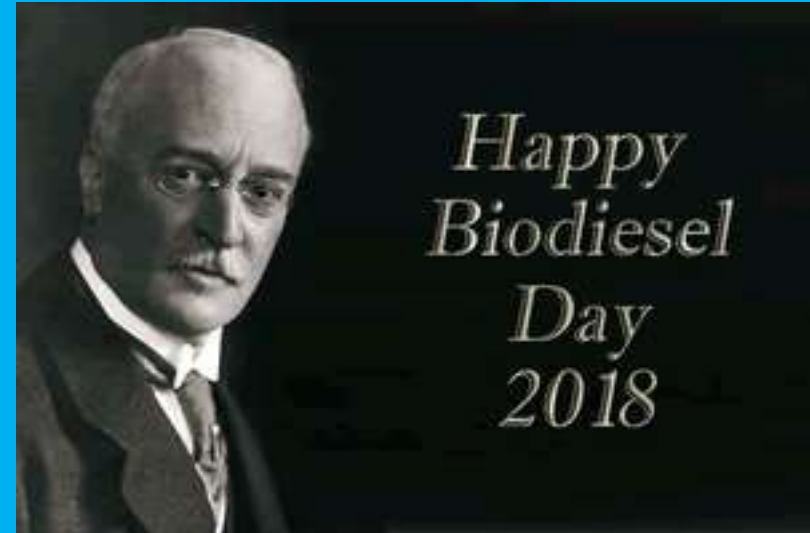
- Biodiesel can be mixed with Petrodiesel as desired
- Blends of biodiesel up to B20 are commonly found at the pump
- B100 can be used in certain engine designs (mechanical injection pumps)
- Winter temperatures may be better at a lower biodiesel %



How much does it cost?

- 25 gallon veg oil= \$0-\$25
- 5 gallon methanol=\$15-\$25
- 1-2 lbs lye= \$5-\$10
- Electricity, isopropyl, indicator, etc...= \$1
- Total cost=\$21-\$61
- Tax=\$0.244 per gal
- Estimated cost per gallon=\$0.84-\$2.684

- Repurposing waste products into viable fuel in an environmentally and sustainably conscious manner...priceless!



- Be safe!

Reference Materials

- Diesel, R., Chalkley, A.P. (1912), *Diesel engines for land and marine work* (2nd ed.), New York, New York, USA: D. Van Nostrand.
- https://www.afdc.energy.gov/uploads/publication/biodiesel_handling_use_guide.pdf
- <https://www.goshen.edu/academics/chemistry/biodiesel/chemistry-of/>
- https://www.afdc.energy.gov/fuels/emerging_hydrocarbon.html
- <https://www.fb.org/market-intel/epa-proposes-new-renewable-fuel-and-biomass-based-diesel-volume-standards>
- <http://www.biofuelsdigest.com/bdigest/2018/06/27/mcdonalds-uae-clocks-10-million-kilometers-on-biodiesel-blend/>
- https://corporate.mcdonalds.com/mcd/sustainability-old/library/policies_programs/environmental_responsibility/biodiesel_and_recycling_cooking_oil.html
- <https://unitedsoybean.org/media-center/issue-briefs/biodiesel/>
- <https://www.utahbiodieselsupply.com/biodieseltutorial/index.php>
- <http://www.make-biodiesel.org/>
- <https://archive.epa.gov/region07/biofuels/web/html/water.html>
- <https://www.youtube.com/watch?v=qPzV4iwDlrw>
- http://www.biopowered.co.uk/wiki/Water_washing
- https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwiw35HAXpzdAhVPJt8KHftzChMQFjAAegQIChAC&url=http%3A%2F%2Fbiod101.com%2Fman_040213.pdf&usg=AOvVaw1eb88NjUvsPbs6CiupC8_U