Biodiesel From Field to Fuel
Welcoming Remarks

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On behalf of the College of Engineering and the University of Idaho I wish to welcome you to this workshop "Biodiesel From Field To Fuel". The purpose of the workshop is to provide an overview of the technology of biodiesel. We are covering the topic from feedstock to production technology to standards and fuel quality to economics. It will be a fast moving program with lots of information. Probably more than you will absorb in one setting. We invite you to look for additional opportunities to learn more about this exciting new alternative fuel by visiting our website www.biodieseleducation.org, attending other conferences that we will be sponsoring, and through the wealth of other information that has become available in the last few years.

The technical definition of Biodiesel as defined by the American Society for Testing and Materials is -- *Biodiesel consists of the alkyl monoesters of fatty acids derived from vegetable oils or animal fats.*

Biodiesel is vegetable oil or animal fat converted through a chemical reaction called transesterification (although from time to time other processes are proposed) wherein an alcohol (methanol or ethanol) in the presence of an alkaline catalyst, such as sodium hydroxide or potassium hydroxide, is used to chemically cleave the raw vegetable oil molecule into methyl or ethyl esters and glycerin.

Example: 100 lb Canola oil + 10 lb methanol yields 100 lb biodiesel + 10 lb glycerin
The process requires a catalyst (such as sodium hydroxide or potassium hydroxide)

Biodiesel What it is not:

•Unprocessed vegetable oil.
    Vegetable oil can be used in some diesel engines (especially if heated) but tends to cause performance to deteriorate over time.
•Mixtures or emulsions of alcohol with diesel fuel (E-diesel).
    Major advances have been made in alleviating concerns about cetane number and lubricity. Flash point is still the primary obstacle.

University of Idaho Personnel are pioneers in Biodiesel Production:

- University of Idaho Personnel have been involved in using vegetable oils as fuels since 1979
- The primary feedstocks have been winter rapeseed, canola, yellow mustard oils and used oils from deli's and processing plants
- Much of the process used for producing biodiesel was pioneered at the University of Idaho by the Department of Biological and Agricultural Engineering in conjunction with faculty in Plant Sciences and Chemical Engineering
- Since 1992, over 35,000 gallons have been produced

Some of the University of Idaho Firsts Include:

- First in the US to use rapeseed, canola and yellow mustard for biodiesel production
- First to use ethanol instead of methanol in the biodiesel process
- First to drive a vehicle both directions coast-to-coast on 100% biodiesel – 1994
- First to drive a vehicle 100,000 miles on 100% biodiesel
- First to drive a large truck 200,000 miles on a 50% blend of biodiesel
- First to involve engine manufacturer's in major emissions tests and engine evaluation for durability
- First to power a TDI Volkswagen on 100% biodiesel
- First to introduce biodiesel into our National Park System to exploit the environmental benefits of biodiesel.
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The principle advantages of Biodiesel are:

- Renewable - Carbon Dioxide is recycled thus reducing the potential for adding to the global warming effect
- Requires little if any engine modifications (except replacing some fuel lines on pre-1993 engines).
- Can be blended in any proportion with petroleum diesel fuel.
- High cetane number and excellent lubricity.
- It is safer because it has a very high flashpoint (>300°F)
- Emissions contain much less black smoke and are cleaner exhaust emissions, especially in terms of HC, CO and PM. NOx is said to be increased.

Potential difficulties with Biodiesel:

- NOx tends to be higher
- Reduced fuel filter change intervals
- Biodiesel may cause problems with loosening of varnish deposits in fuel tanks and lines, degradation of fuel lines because some elastomers are not compatible with biodiesel (such as BUNA rubbers)
- Potentially damaging to paint.
- Paving and concrete can be degraded if it is subjected to chronic exposure to biodiesel.

- Soybean oil-based biodiesel will start to crystallize at around 0°C. Blending with diesel fuel or with additives can mitigate this.
- Biodiesel is less oxidatively stable than petroleum diesel fuel. Old fuel can become acidic and form sediments and varnish. Additives can prevent this.
- Biodiesel has been more expensive than petroleum diesel fuel.

Blends up to B5 should not cause problems, provided the B100 meets ASTM D 6751
Neat biodiesel and higher blends of biodiesel can cause a variety of performance problems -- filter plugging, injector coking, piston ring sticking and breaking, elastomer swelling

Engine manufacturers warrant the parts and assembly of their engines. They do not warrant their engines on specific fuels. If a customer has a problem caused by the fuel, the engine manufacturer will direct them to the fuel supplier.

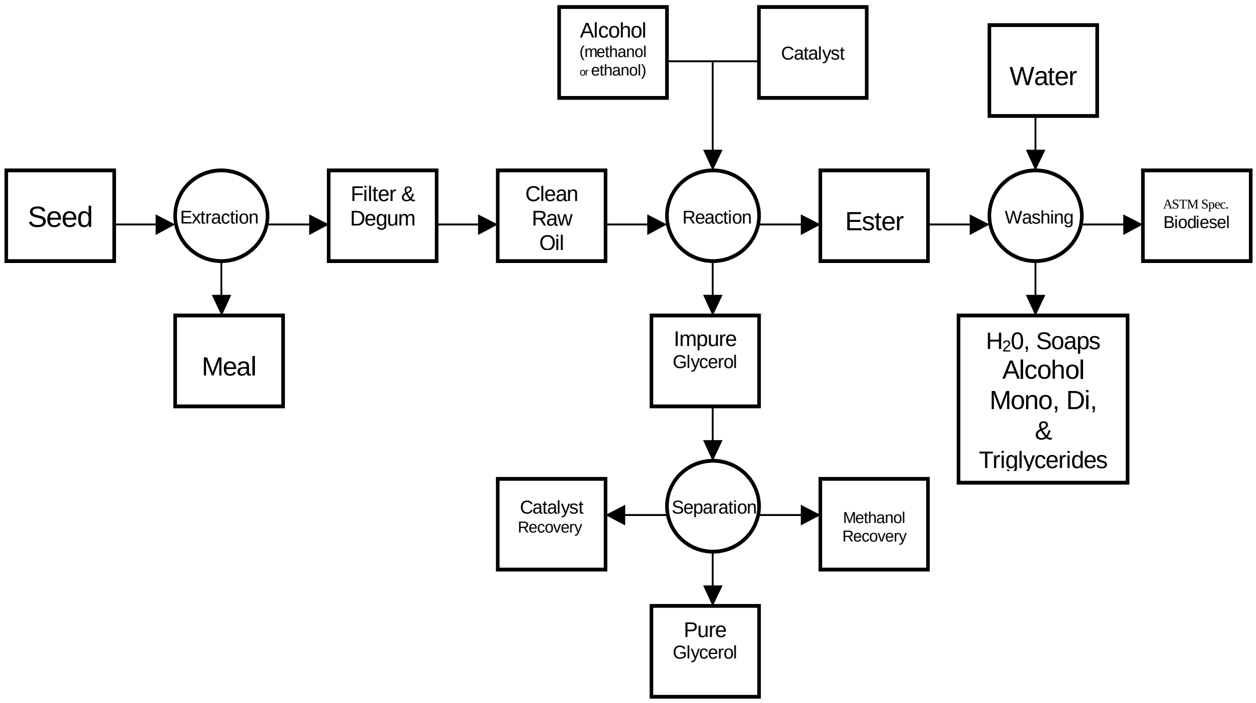
From Caterpillars statement on biodiesel:
"Caterpillar neither approves nor prohibits use of biodiesel fuels….The use of biodiesel fuel does not affect Caterpillar's materials and workmanship warranty. Failures resulting from the use of any fuel are not Caterpillar factory defects and therefore the cost of repair would NOT be covered by Caterpillar's warranty."

The Engine Manufacturers Association (EMA) says that B5 is not a problem.
Most engine companies indicate that use up to B20 is O.K. Above that, they are trying to gain more experience. Caterpillar says B100 is O.K. for non-Perkins engines. Chrysler is putting B5 into the Jeep Liberty as the factory fill. Deere is using B2 as their factory fill.

Infrastructure Issues with Biodiesel

- When switching old fuel tanks or vehicles to biodiesel, there may be some loosening of deposits – plan to change fuel filters once or twice after fuel changes.
- Biodiesel will dissolve concrete – stop drips.
- Avoid contact between biodiesel and bronze, zinc, and similar materials.

The Biodiesel Process:



Five questions to answer when considering a commercial biodiesel business.

1. What is the motivation?
2. What is the source of feedstock?
3. What are your markets?
4. What are you going to do with your by-products?
5. What is your plan to meet the ASTM Specification for Quality Biodiesel?
6. Do you have a business plan that incorporates each of these?

1. What is the motivation?: Assessing ones motivation helps set goals and aids in long term planning. The usual motivation is profit. If so then having a well thought out business plan and careful consideration of the next five questions is essential. Other motivations are to help economic development in the local community, to provide a market for agricultural crops, to reduce dependence on foreign oil, to aid the environment, and/or to be energy self sufficient in one's business or personal enterprise. The author has been told that being energy self sufficient on one's farm was more important than cheap fuel, if that is the case then the business plan can reflect that goal and producing biodiesel at or less than the cost of diesel is not important. Carefully consider why you want to be in the business – and do it honestly.

2. What is the source of feedstock: One should not assume that just because you build a plant feedstock would be readily available. The author has been told many times that someone has a source of readily available used vegetable oil. Reportedly local businesses are dissatisfied with the current collection company and often they have to pay to have their used oil collected. All of this may be true, but to think that one can start a parallel business with the investment of tanks, trucks, employees, and a rendering plant at minimal or no cost is naïve. Sure an individual might pick up a few gallons a week but developing a business to handle hundreds of thousands of gallon is not trivial. It might be best to partner with existing companies. And even then, you will probably find that these businesses have existing customers that they are not anxious to abandon.

The collecting and recycling of used oils is a highly competitive business. An analysis of one of these companies reported that the most competitive part of their business was the obtaining of the product. Yellow grease goes into the manufacture of soap, textiles, cleansing creams, inks, glues, solvents, clothing, paint thinner, rubber, lubricants and detergents to list a few. Its principle use is as a livestock feed additive. It makes the feed less dusty, adds lubrication to the feed reducing wear on milling machinery. It is a dense source of energy, which is important for animals like cattle and horses that have a hard time eating more than they already do.

Starting with virgin oils is more expensive but probably will provide opportunity for a more consistent quality product. Carefully consider the local agriculture to determine what vegetable oil crops might be best suited for the area. Starting with virgin oils in areas which do not now raise vegetable oils means one must also construct a crushing plant. Some plants plan to purchase their oils elsewhere and bring the degummed oil to the plant by rail car or truck. Be certain you have a long term supply or be aware of how increases in the price of oil on the commodity market can potentially affect your business plan.

A vegetable oil crop such as safflower at 2200 # per acre, 40% oil and 90% extraction produces about 104 gallons of biodiesel per acre. Thus a plant with an estimated 10,000,000 gallons annual capacity requires about 100,000 acres of contracted cropland. The total cropland in the US is 363.3 Million acres (2002 Census of Agriculture). At 100 gallons per acre this would represent 36.3 billion gallons of biodiesel. Only 10 percent more than the total on-road diesel fuel used in the US. In other words, 90% of our ag land would be required to produce enough biodiesel for our on-road needs.

Computations of the land that could realistically be used for vegetable oil production are complicated. Land must be available for domestic food production. It is logical to assume that some production of food for export will continue to be needed. It is also reasonable that crop rotations will require that only a portion of the land could be in vegetable oil production in any one year. In 2002, 37 million acres of cropland were reported as idle. This idle cropland could produce 3.7 billion gal of vegetable oil per year or 11 % of the diesel used in transportation. In an earlier report, the author made an estimate of additional cropland potentially available for vegetable oil production by comparing crop production for several of the major crops with domestic use. Any production over domestic use was termed excess and, using the national average production for that crop, an estimate of excess crop production land of 62 million acres was calculated. This land could produce and additional 6.2 billion gallons of vegetable oil or an additional 18.7% of our on-highway diesel fuel consumption at the expense of foreign exports of the commodities currently produced on that land.

How much edible fats and oils do we currently produce in the U. S.? In 1997, the U. S. produced 29,985 million pounds (approx. 3.945 billion gallons) of edible fats and oils. Of this, 70 percent comes from soybeans, 10% from corn, 10% from lard and tallow, 3% from cottonseed, 1% from peanuts, 2% from Canola, 0.3% from safflower and 2% from sunflower. The U. S. imported 3630 million pounds (0.48 bil. gal.) and exported 6040 million pounds (0.79 bil. gal.) of edible fats and oils. Current vegetable oil production is equivalent to somewhat more (1.26 times) the on-farm use of diesel fuel, about 12% of on-highway diesel use, or about 7% of total fuel oil and kerosene. An estimate of the annual production of fats and oils from Pearl (2002) is given in Table 2.

Table 2
Total Annual Production of US Fats and Oils*

Vegetable Oil Production (Billion Gallons)	
Soybean	2.44
Peanuts	0.29
Sunflower	0.13
Cottonseed	0.13
Corn	0.32
Others	0.09
Total Vegetable Oil	3.15
Animal Fats	
Inedible Tallow	0.51
Lard and Grease	0.17
Yellow Grease	0.35
Poultry Fat	0.30
Edible Tallow	0.21
Total Animal Fat	1.55

*From Pearl, G. G., "Animal Fat Potential for Bioenergy Use," Bioenergy 2002, The Tenth Biennial Bioenergy Conference, Boise, ID, Sept. 22-26, 2002.

World Vegetable Oil Production -- The production of vegetable oil in the entire world is estimated at 26.9 billion gallons, Table 3. The world production of vegetable oil is equivalent to 81 % of the U. S. on-highway diesel fuel use or 47% of the total fuel oil and kerosene use of the U. S. in a year. It would require more than the entire world production of these vegetable oils to replace the U.S. on-highway diesel fuel use.

Table 3. World Vegetable Oil Production

	2002/2003 Billion Gallons
Soybean	8.8
Palm	7.4
Sunflower	2.4
Rapeseed	3.3
Cottonseed	1.0
Peanut	1.3
Coconut	0.95
Olive	0.69
Palm Kernel	0.93
Total	**26.9**

It would be very ambitious to have a 0.5 billion gallon per year biodiesel industry. This would be only 1.5% of our on-highway diesel fuel or less than 1% of our total fuel oil and kerosene use. A 0.5 billion gallon per year industry would require all of the surplus vegetable oil (0.13 bil. gal.), half of the used oil (0.17 bil. gal.), and all of the oil which could be produced on the 37 million acres of idle crop land (approx. 0.3 billion gal.) or the equivalent by displacing current crops.

It is apparent that a challenge for biodiesel production will occur at about 0.2 – 0.3 billion gallons when the acquisition of additional feedstocks will become very difficult.

The other side of this argument is that a 0.2-0.5 bil. gal. biodiesel industry would have a very significant beneficial impact on agriculture and rural communities. It would provide an outlet for surplus vegetable oil crops and land currently being used to produce surplus crops could be switched to vegetable oil to provide additional feedstock for biodiesel.

3. What are your markets?: A growing number of firms market biodiesel nationwide as a replacement or additive to diesel fuel. An inherent advantage of biodiesel is selling to local markets, and it provides the best opportunity to get the highest price for the product.

How much petroleum diesel do we use? As shown in Table 1 for the year 2000, total use of oil and kerosene in the U. S. amounted to 57.1 bil. gal. This is divided into 33.1 bil. gal. for on-highway diesel, 2.8 bil. gal. for off-highway use, 3.1 bil. gal. for farm use, 1.13 bil. gal. for electric power, 0.23 bil. gal. for military, 3.0 bil. gal. for railroad use, and 11.5 bil. gal. for residential, commercial and industrial heating applications.

Table 1
Annual sales of diesel fuel – year 2000 – US only
(billion gallons)

On-highway Diesel	33.13
Off-highway	
Farm	3.1
Electric Power	1.13
Military	0.23
Railroad	3.0
Total Fuel Oil and Kerosene	57.1

Do not assume that just because you produce biodiesel it will sell. I have been told many times that we have more production capacity in the US than we are selling. I often ask, if biodiesel sells so readily why are we exporting biodiesel from the US to Europe and why are we shipping Midwest produced biodiesel to the West Coast.

4. What are you going to do with your by-products?: Meal and glycerin will be produced if the plant includes a crusher, glycerin if the plant purchases all of its oil. There is a large market for glycerin in the U.S. but it requires the glycerin be purified before sale. A glycerin purification plant may be as large or larger investment than the biodiesel plant. Also, because of the large amount of biodiesel being produced the glycerin market is depressed and is likely to stay depressed. At a recent meeting when a producer of biodiesel was asked what he does with his glycerin, he answered he wouldn't tell us for fear of losing his market. A potential producer must determine what the ultimate end use of the glycerin will be as it will amount to about 10 percent of the biodiesel production.

Meal from some vegetable oil crops can be used for livestock feed. One should consult with local livestock firms to determine the potential sales. Again as biodiesel expands it potentially could weaken the price of feed meal.

As Dr. Brown will be discussed meal from some vegetable oil crops might have unique uses such as for pesticides or herbicides. Be careful to understand the regulations and limitations of this potential market before assuming that your meal can be sold for these uses.

5. What is your plan to produce a quality fuel?: For a commercial operation there is no more important factor than producing a quality product. It is relatively easy for someone, even in his or her backyard, to produce a biodiesel fuel. It is not as easy or as inexpensive for one to produce a quality fuel that will meet requirements of a modern diesel engine. One of the first actions of the biodiesel industry was to develop a standard for biodiesel. This standard, known as "The Biodiesel Standard", was created under the auspices of the American Society of Testing Materials (ASTM D 6751, Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels). The purpose is to provide a biodiesel product that meets the requirements for blending with diesel fuel in a manner that will not adversely affect engine operation or drivability. The complete standard can be purchased from ASTM. Further information on the standard is available on the ASTM website.

Every commercial biodiesel plant should have a plan for regular testing of its product to assure compliance. Table 2 provides an overview of the requirements. There are commercial operations that can perform the tests for a fee although there could be a large time lapse. Larger plants will need an analytical laboratory capable of performing many of the tests on-site.

Table 2 - Summary of Biodiesel Fuel Standard*

PROPERTY	LIMITS	METHOD
Flashpoint	130 ºC Min	D 93
Water & Sediment	0.050 % by volume max.	D 2709
Kinematic Viscosity, 40 ºC	1.9 – 6.0 mm2/s	D 445
Sulfated Ash	0.020 st. % max	D 874
Total sulfur	0.05 wt % max	D 5453
Copper Strip Corrosion	No. 3 max	D 130
Cetane Number	47 min	D 613
Cloud Point	Report to customer	D 2500
Carbon residue	0.050 wt. % max	D 4530
Acid Number	0.80 mg KOH/g max	D 664
Free glycerin	0.020 wt. % max	D 6584
Total glycerin	0.240 wt. % max	D 6584
Phosphorous	0.0010 wt % max	D 4951
Vacuum Distillation End Point	360 ºC max at T-90	D 1160
Storage Stability	N.A.	Not yet developed

*ASTM D 6751, " Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels," ASTM International. For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

Expect to invest as much as $250,000 for a laboratory to conduct the required testing or expect to spend as much as $800 to $1100 dollars to send the fuel outside for testing.

Suggestion, use a three tier approach:

A. Some properties need continuous monitoring
- Free and Total glycerin
- Acid Number
- Total Sulfur
- Viscosity
- Flash point

B. Some properties should be checked regularly
- Cloud point
- Water and sediment
- Phosphorous
- Pour point
- Carbon Residue
- Sulfated ash

C. Some may only need evaluation when the feedstock changes:
- Cetane number
- Copper strip corrosion
- Vacuum distillation

6. Do you have a business plan?: Your plan needs to incorporate each of the above concepts. You should have a realistic project development plan and a projected time line. The Project Development Plan on the next page can be used as a guide to help identify all of the required steps.

Conclusions:

At the present time, the United States (U.S.) is almost totally dependent upon petroleum for liquid energy. U.S. energy 86% comes from oil and natural gas while less than 3 % comes from biomass. Currently, the U. S. uses about 20.7 million barrels of petroleum per day (0.87 billion gallons per day), 25 % of total world consumption. Approximately 64 % of the petroleum is imported. For agricultural produced renewable fuels, such as biodiesel, to make a significant contribution to this mammoth energy consumption will require every foreseeable agriculturally produced energy source which can be developed.

In addition to the oil produced, a vegetable oil crop such as winter rape also produces considerable biomass. It has been estimated that a 2000 lb/acre crop of winter rape produces 100 gal/acre of oil, 1250 lb/acre of meal and 5000 lb/acre of biomass normally left on the field at harvest. It is estimated that the energy equivalent of these by-products is 350 gal/acre of diesel fuel equivalent to 8.33 bbl/acre. The meal can also be used as a high-protein livestock feed. If there is a major shift of land into production of vegetable oil crops for energy, these by-products would likely be used for direct combustion or for production of ethanol. Utilization of the entire crop leads to the concept of a complete "energy" crop. Agricultural policy makers need to seriously consider means to encourage the development of these energy crops.

The magnitude of our energy needs provides an inexhaustible market for our total agricultural production capacity at the highest possible level. We could put the farm back to work providing for our food needs and also growing crops and livestock for energy. Energy is the only crop that could never grow in surplus.

Project Development Flow Chart