Make your own biodiesel

Anybody can make biodiesel. It's easy, you can make it in your kitchen -- and it's BETTER than the petro-diesel fuel the big oil companies sell you. Your diesel motor will run better and last longer on your home-made fuel, and it's much cleaner -- better for the environment and better for health. If you make it from used cooking oil it's not only cheap but you'll be recycling a troublesome waste product. Best of all is the GREAT feeling of freedom, independence and empowerment it will give you. Here's how to do it -- everything you need to know.

Three choices

There are at least three ways to run a diesel engine on bio-power, using vegetable oils, animal fats or both. All three work with both fresh and used oils.

- Use the oil just as it is -- usually called SVO fuel (straight vegetable oil);
- Mix it with kerosene (paraffin) or diesel fuel, or with biodiesel;
- Convert it to biodiesel.

The first two methods sound easiest, but, as so often in life, it's not quite that simple.

1. Mixing it

If you're mixing SVO with kerosene or petroleum diesel ("dinodiesel") you're still using fossil-fuel -- cleaner than most, but still not clean enough, many would say. Still, for every gallon of vegetable oil you use, that's one gallon of fossil-fuel saved, and that much less carbon in the atmosphere.

Most people use a mix of up to 30% kerosene and 70% vegetable oil, some use 50/50 mixes. Some people just use it that way, others say it needs at least pre-heating and probably a two-tank system too, like SVO (see below), and we agree with that. The same goes for mixes with vegetable oil and biodiesel -- usually 50/50. In both cases, you might get away with just using it with an older Mercedes 5-cylinder IDI diesel, which is a very tough and tolerant motor. Otherwise, not wise.

So, to be safe, you're going to need what amounts to an SVO two-tank system with heating anyway, so you don't need the kerosene. If you're mixing SVO with biodiesel, you'll use very much less biodiesel by using it in the second tank for start-ups and stops rather than mixing it 50/50. (See next.) Or just use 100% biodiesel and don't bother with two tanks and heating. (See after next.)

Mixes are a poor compromise. But they do have advantages in cold weather. Some kerosene or #1 diesel mixed with biodiesel lowers the temperature at which it starts to gel, and a 50/50 mix with biodiesel will do the same for an SVO system.

Message to the **Biofuel mailing list**:

"I stuck 3 litres of pure rapeseed oil from my local supermarket straight into the tank of my 1998 VW Caddy van. There were about 3-4 litres of dino-diesel in the tank. Once the dino had cleared the fuel lines, I was running on about 50% dino to 50% oil. The only differences I noticed were: A) the engine ran about 10 deg C cooler; B) the exhaust smelt like a roadside burger bar. Apart from that,

no problems! As the weather is finally starting to warm up here, I may increase the oil/diesel ratio and see that happens. -- Nick"

Reply:

"One thing that will happen is that your cold starts will begin to deteriorate. Then your filter will probably start plugging. Then your injectors will likely, in time, get coked up. Then the spray pattern will be wonky. Then you'll set the stage for ring sticking, glazing of the cylinder walls, increased lube oil consumption and eventual engine failure -- if you can continue to get the thing started in the morning. More than 20% or so in the diesel is not a good plan for more than short term 'experiments'. Unfortunately, you're not doing anything new here, Nick, and if it was as easy as running high percentages of SVO in diesel, and being able to maintain reliability, we'd all have gone that way long ago. Regards, Edward Beggs, Neoteric Biofuels Inc <info@biofuels.ca>

A variation on this theme is adding a solvent to the veg oil to lower the viscosity -- usually 3% white spirit (a.k.a. mineral turpentine, Stoddard solvent, turpentine substitute). This raised a lot of interest after it was publicized on a British TV program -- "just add a spoonful". It also raised a lot of scepticism: "'experimental' at best" was the view of experienced SVO'ers, and "steer well clear" unless you have a 5-cyl IDI Mercedes (in which case you don't even need the white spirit). We agree. Work on blends of SVO with other solvents, such as butanol and ethanol, is still experimental. By all means go ahead and experiment, but there are no guarantees.

2. Straight vegetable oil

With SVO you have to start the engine on ordinary petroleum diesel or biodiesel to warm it up, then switch to the straight vegetable oil, and switch back to petro- or biodiesel before you stop the engine. If you don't do that you'll coke up the engine and the injectors. This means having two fuel tanks -- no simple matter with diesels, which have airtight fuel systems. Using SVO also means pre-heating the oil or it'll be too viscous (thick).

But there's a lot to be said for straight vegetable oil systems -- running on straight vegetable oil while starting up and shutting down on biodiesel can be a clean, effective and economical option.

More information on straight vegetable oil systems **here**.

3. Biodiesel

Biodiesel has some clear advantages over SVO: it works in any diesel, without any conversion or modifications to the engine or the fuel system -- just put it in and go. It also has better cold-weather properties than SVO (but not as good as petro-diesel -- see **Using biodiesel in winter**). And, unlike SVO, it's backed by many long-term tests in many countries, including millions of miles on the road.

Biodiesel is a clean, safe, ready-to-use, alternative fuel, whereas it's fair to say that SVO systems are mostly still experimental and need further development.

On the other hand, biodiesel can be more expensive, depending what you make it from and whether you're comparing it with new or used oil (and where you live). And, unlike SVO, it has to be

processed -- you have to make it. But the large and rapidly growing worldwide band of homebrewers don't seem to mind -- they make a supply every week or once a month and soon get used to it. Many have been doing it for years.

And anyway, you have to process SVO too, especially WVO (waste vegetable oil, used, cooked), which many people with SVO systems use because it's cheap or free for the taking. WVO has to be filtered and dewatered, and probably should be deacidified.

Biodieselers say, "Well, if I'm going to have to do all that I might just as well make biodiesel instead." But SVO types scoff at that -- it's much less processing than making biodiesel, they say. To each his own.

	Needs processing	Guaranteed trouble-free	Engine conversion	Cheaper
Biodiesel	Yes	Yes	No	Sometimes
SVO/WVO	Less	No	Yes	Usually

Costs and prices: Biodieselers using waste oil feedstock say they can make biodiesel for 60 cents US per gallon or less. Most people use about 600 gallons of fuel a year (about 10 gallons a week) -- say US$360 a year. An SVO system costs from $300 to $1,200 or more. So with an SVO system you'll be ahead in a year or two, which is not a long time in the life of a diesel motor. But will it last as long with SVO? Too soon to tell. Probably, if you use a good system. Recommendations, and much more, **here**.

Biodiesel

Converting the oil to biodiesel is probably the best of the three options (or we think so anyway).

You could simply **buy** your biodiesel instead. Most major European vehicle manufacturers now provide vehicle warranties covering the use of pure biodiesel -- though that might not be just *any* biodiesel. Some insist on "RME", rapeseed methyl esters, and won't cover soy biodiesel in the US, but this seems to be more a trade-related issue than a quality-control one. Germany has more than 1,500 filling stations supplying biodiesel, and it's cheaper than ordinary diesel fuel. It's widely used in France, the world's largest producer. Virtually all fossil diesel fuel sold in France contains between 2% and 5% biodiesel. New EU laws will soon require this Europe-wide. Some states in the US are legislating similar requirements. There's a growing number of US suppliers. Biodiesel is more expensive than ordinary diesel in the US but sales are rising very fast and prices will drop in time. In the UK biodiesel is taxed less than petrodiesel and it's available commercially.

But there's a lot to be said for the GREAT feeling of independence you'll get from making your own fuel (and it's more than just a feeling -- it's real!).

If you want to make it yourself, there are **several good recipes** available for making high-quality biodiesel, and they all say what we also say: some of these chemicals are dangerous, take full safety precautions, and if you burn/maim/blind/kill yourself or anyone else, that will make us very sad, but not liable -- we don't recommend anything, it's nobody's responsibility but your own.

On the other hand, a lot of people are doing it -- it's safe if you're careful and sensible. "Sensible"

also mean not over-reacting, as some people do: "I'd like to make biodiesel but I'm frightened of all those terrible poisons." In fact they're common enough household chemicals. Lye is sold in supermarkets and hardware stores as a drain-cleaner, there's probably a can of it under the sink in most households. Methanol is the main or only ingredient in barbecue fuel or fondue fuel, sold in supermarkets and chain stores as "stove fuel" and used at the dinner table; it's also the main ingredient in the fuel kids use in their model aero engines. So get it in perspective, no need to be frightened. See **Safety** for further information. Learn as much as you can first -- **lots of information** is available. Make small **test batches** before you try large batches. Make it with **fresh oil** before you try waste oil.

Where do I start?

Start here: make a test batch of biodiesel using 1 litre of fresh new oil in a blender. If you don't have a spare blender, either get one (you can pick them up quite cheap second-hand), or try **this**. Or, better, make a simple **Test-batch mini-processor**.

Go on, do it! Get some methanol, some lye and some new oil at the supermarket and go ahead -- it's a real thrill!

Here's the recipe, just use 1 litre of oil instead of 10 litres, and 200 ml of methanol instead of 2 litres, with 3.5 grams of lye. **Here's** how to use a blender, and **here's** how to mix the sodium methoxide -- "Methoxide the easy way" (also the safe way).

What's next?

Learn. You have some decisions to make. It's all quite simple really, thousands of people are doing it, very few of them are chemists or technicians, and there's nothing a layman can't understand, and do, and do it well. But there is quite a lot to learn. You should find everything you need to know right here. We've tried to make it easy for you. You start off with the simplest process that has the best chance of success and move on step by step in a logical progression, adding more advanced features

First, here's how we started.

The process

Vegetable oils and animal fats are triglycerides, containing glycerine. The biodiesel process turns the oils into esters, separating out the glycerine. The glycerine sinks to the bottom and the biodiesel floats on top and can be syphoned off.

The process is called transesterification, which substitutes alcohol for the glycerine in a chemical reaction, using lye as a catalyst.

We use methanol to make methyl esters. We'd rather use ethanol because most methanol comes from fossil fuels (though it can also be made from biomass, such as wood), while ethanol is plant-

based and **you can distill it yourself**, but the biodiesel process is more complicated with ethanol. (See **Ethyl esters**.)

Ethanol (or ethyl alcohol, grain alcohol -- EtOH, C2H5OH) also goes by various other well-known names, such as whisky, vodka, gin, and so on, but methanol is a deadly poison: first it blinds you, then it kills you, and it doesn't take very much of it. It takes a couple of hours, and if you can get treatment fast enough you might survive. (But don't be put off -- it's easy to do this safely. Safety is built-in to everything you'll read here.)

Methanol is also called methyl alcohol, wood alcohol, wood naphtha, wood spirits, methyl hydrate (or "stove fuel"), carbinol, colonial spirits, Columbian spirits, Manhattan spirits, methylol, methyl hydroxide, hydroxymethane, monohydroxymethane, pyroxylic spirit, or MeOH (CH3OH or CH4O) -- all the same thing. (But, confusingly, "methylcarbinol" or "methyl carbinol" is used for both methanol and ethanol.) In the US you can usually get it at race tracks.

Methylated spirits (denatured alcohol) doesn't work; isopropyl alcohol (rubbing alcohol) also doesn't work.

The lye catalyst can be either sodium hydroxide (caustic soda, NaOH) or potassium hydroxide (KOH), which is easier to use, and it can provide a potash fertilizer as a by-product. Sodium hydroxide is often easier to get and it's cheaper to use. If you use potassium hydroxide, the process is the same, but you need to use 1.4 times as much. (See **More about lye**.) You can get KOH from soapmakers' suppliers and from chemicals suppliers. Other chemicals, such as isopropyl alcohol (isopropanol) for titration, are available from chemicals suppliers.

CAUTION:
Lye (both NaOH and KOH) is dangerous -- don't get it on your skin or in your eyes, don't breathe any fumes, keep the whole process away from food, and right away from children. Lye reacts with aluminum, tin and zinc. Use glass, enamel, stainless steel or HDPE (High-Density Polyethylene) containers for methoxide. (See **Identifying plastics**.)

See also **Making lye from wood ash**.

Our first biodiesel

This was just an investigative project for us when we made our first biodiesel more than five years ago in Hong Kong. Most of the equipment was improvised. Apart from chemicals and some beakers, syringes and things, the only thing we bought was a set of scales.

We got about 60 litres of used oil (WVO --waste vegetable oil) from Lantau Island's local McDonald's. There were four 16-litre cans of it, a mix of used cooking oil and residual beef and chicken fats. Two of the tins were solidified, the other two held a gloppy semi-liquid. We warmed it up a bit on the stove (to about 50 deg C) and filtered it through a fine mesh filter, and then again through coffee filter papers, but it was quite clean -- very little food residue was left in the filters.

We'd also bought 10 litres of the cheapest new cooking oil we could find -- we don't know what kind of oil it was, the tins only said "Cooking Oil" -- and used this for our first experiment.

It worked, but we've learnt a lot since then. Now it's easy to make high-quality biodiesel every time without fail. And we don't use open containers for processing now, and neither should you -- and mix the methanol in closed containers too.

Used cooking oil from McDonald's.

Practices, knowledge, technology, equipment and safety measures have all improved tremendously in the last five years since we brewed our first batch, thanks mainly to the collaborative work of thousands of biofuellers worldwide at the **Biofuel mailing list** and other Internet forums.

As a Biofuel list member said in 2002: "I just want to say how important what you all are doing here is. Closed-system fuel production, on a local or small regional scale, tied to local resources, using accessible technologies, and dependent on entrepreneurial innovation combined with open-source information exchange -- it's AWESOME. Keep up the good work everyone, before the planet fries."

Biodiesel from new oil

Make your first test-batch using new oil (fresh, virgin, uncooked). Follow the instructions below, but use 1 litre of oil instead of 10 litres, and 200 ml of methanol instead of 2 litres, with 3.5 grams of lye. Check the quality of your biodiesel with this basic **quality test**.

We had difficulty finding pure methanol in Hong Kong, and eventually paid the very high price of US$10 per litre for 5 litres from a wholesale chemical supply company. It has to be 99% pure or better. (See **How much methanol?**)

In the US, for small test batches, you can get DriGas from the hardware store. One type of DriGas is methanol, another is isopropanol, make sure to get the methanol one.

We used 2 litres of methanol to 10 litres of vegetable oil, and 3.5 grams of pure, granular lye (sodium hydroxide) per litre of oil -- 35 grams for 10 litres. (See **More about lye**.)

You can get lye at most hardware stores (Red Devil lye in the US). Shake the container to check it

hasn't absorbed moisture and coagulated into a useless mass, and make sure to keep it airtight.

We had to be quick measuring out the 35 grams of lye required -- summer humidity in Hong Kong is usually about 80% at 30 deg C or more, and the lye rapidly got wet, making it less effective.

We mixed the lye with the 2 litres of methanol in a strong, heatproof glass bottle with a narrow neck to prevent splashing. It fumed and got hot, and took about 15 minutes to mix. See **Methoxide the easy way**. (Use closed containers for mixing methoxide.)

This mixture is sodium methoxide, an extremely powerful base which enjoys eating stuff like human flesh -- take full safety precautions when working with sodium methoxide, have a source of running water handy.

Meanwhile we'd warmed the 10 litres of new oil in a steel bucket on the stove to about 40 deg C (104 deg F) to thin it so it mixed better. In fact, 55 deg C (131 deg F) is a better processing temperature. Don't let it get too hot or the methanol will evaporate. (Methanol boils at 64.7 deg C, 148.5 deg F.)

We'd made a wooden jig with a portable vice clamped to it holding a power drill fitted with a paint mixer to stir the contents of the bucket. This did a good job without splashing.


Midori checks the temperature of the oil.

Stirring well, we carefully added the sodium methoxide to the oil. The reaction started immediately, the mixture rapidly separating into a clear, golden liquid on top with the light brown glycerine settling out at the bottom. We kept stirring for an hour, keeping the temperature constant. Then we let it settle overnight.

The next day we syphoned off 10 litres of biodiesel, leaving two litres of glycerine in the bottom of the bucket.

Biodiesel from waste oil

This is more appealing than using new oil, but it's also more difficult.

First, check for water content. Used oil often has some water in it, and water in the oil will interfere with the lye, especially if you use too much lye, and you'll end up with jelly. Test first for water content -- heat half a litre or so in a saucepan on the stove and monitor the temperature with a thermometer. If there's water in it it will start to "snap, crackle and pop" by 50 deg C (120 deg F) or less. See **Removing the water.** If it's still not crackling by 60 deg C (140 deg F) there's no need to dewater it.

Here's another way, from **Aleks Kac** -- it uses less energy and doesn't risk forming more Free Fatty Acids (see below) by overheating. Heat the oil to 60 deg C (140 deg F), maintain the temperature for 15 minutes and then pour the oil into a settling tank. Let it settle for at least 24 hours. Make sure you never empty the settling vessel more than 90%.

Waste oil needs more catalyst than new oil to neutralize the Free Fatty Acids (FFAs) formed in cooking the oil, which interfere with the transesterification process.

You have to titrate the oil to determine the FFA content and how much lye will be required to

neutralize it. This means determining the pH -- the acid-alkaline level (pH7 is neutral, lower values are increasingly acidic, higher than 7 is alkaline). An electronic pH meter is best, but you can also use pH test strips (or litmus paper), or phenolphthalein solution (from a chemicals supplier).

We also thought of using red cabbage juice, which changes from red in a strong acid, to pink, purple, blue, and finally green in a strong alkali (see **Natural test papers**). We didn't have a pH meter then so we used phenolphthalein solution. Phenolphthalein is colorless up to pH 8.3, then it turns pink (or rather magenta), and red at pH 10.4.

Dissolve 1 gm of lye in 1 litre of distilled water (0.1% lye solution). In a smaller beaker, dissolve 1 ml of the cooled oil in 10 ml of pure isopropyl alcohol. Warm the beaker gently by standing it in some hot water, stir until all the oil dissolves in the alcohol and turns clear. Add 2 drops of phenolphthalein solution.

Using a graduated syringe, add 0.1% lye solution drop by drop to the oil-alcohol-phenolphthalein solution, stirring all the time, until the solution starts to turn pink and stays that way for 10 seconds. Take the number of millilitres of 0.1% lye solution you used and add 3.5. This is the number of grams of lye you'll need per litre of oil. (See **Better titration**.)

Our first titration took 6 ml of 0.1% lye solution(not very good oil), so we used 6 + 3.5 = 9.5 grams of lye per litre of oil: 95 grams for 10 litres.

Then proceed as with new oil: measure out the lye and mix it with the methanol to make sodium methoxide -- it will get even hotter and take longer to mix, as there's more lye this time. Make sure the lye is completely dissolved in the methanol.

Carefully add the sodium methoxide to the warmed oil while stirring, and mix for an hour. Settle overnight, then syphon off the biodiesel.


Keith checks the pH of the waste oil.

The first five times we did this, using 10 litres of waste oil each time, we got biodiesel (a bit darker than the new oil product) and glycerine three times, and twice we got **jelly**. The answer is to be more careful with the titration: do it twice, just to be sure. Read on, and you'll learn how to make high-quality biodiesel every time, without fail.

The production rate was less than with new oil, ending with 8-9 litres of biodiesel instead of 10. The acid-base **Foolproof method**, developed since, will get much higher production rates with heavily-used oil.

Check the quality of your biodiesel with this basic **quality test**.

For a more detailed description of making biodiesel from WVO, see **Mike Pelly's method**.

Washing

Biodiesel should be washed to remove soap, catalyst and other impurities. Some people insist on it, others don't and argue that the small amounts of impurities cause no engine damage.

We recommend washing it. In fact we insist on it -- good-quality biodiesel must be washed.

See **Bubble washing**

Using biodiesel

You don't have to convert the engine to run it on biodiesel, but you do need to make some adjustments and check a few things.

Retard the injection timing by 2-3 degrees -- this overcomes the effect of biodiesel's higher **cetane** number. It also causes the fuel to burn cooler, thus reducing **NOx emissions**.

Petro-diesel leaves a lot of dirt in the tank and the fuel system. Biodiesel is a good solvent -- it tends to free the dirt and clean it out. Be sure to check the fuel filters regularly at first. Start off with a new fuel filter.

Check there are no natural rubber parts in the fuel system. If there are, replace them. Viton is best.

See **Biodiesel and your vehicle**

Safety

Wear proper protective gloves, apron, and eye protection and do not inhale any vapors. Methanol can cause blindness and death, and you don't even have to drink it, it's absorbed through the skin. Sodium hydroxide can cause severe burns and death. Together these two chemicals form sodium methoxide. This is an extremely caustic chemical. These are dangerous chemicals -- treat them as such! Gloves should be chemical-proof with cuffs that can be pulled up over long sleeves -- no shorts or sandals. Always have running water handy when working with them. The workspace must be thoroughly ventilated. No children or pets allowed.

Organic vapor cartridge respirators are more or less useless against methanol vapors. Professional advice is not to use organic vapor cartridges for longer than a few hours maximum, or not to use them at all. Only a supplied-air system will do (SCBA -- Self-Contained Breathing Apparatus).

The best advice is not to expose yourself to the fumes in the first place. The main danger is when the methanol is hot -- when it's cold or at "room temperature" it fumes very little, and this is easily avoided. Don't use "open" reactors -- **biodiesel processors** should be closed to the atmosphere, with no fumes escaping. All methanol containers should be kept tightly closed anyway to prevent water absorption from the air.

We transfer methanol from its container to the methoxide mixing container by pumping it, with no exposure at all. This is easily arranged, and an ordinary aquarium air-pump will do (the same one you use for washing the biodiesel). The methoxide is mixed like this -- **Methoxide the easy way**, which also happens to be the safe way. The mixture gets quite hot at first, but the container is kept closed and no fumes escape. When mixed, the methoxide is again pumped into the (closed) biodiesel processor with the aquarium air-pump -- there's no exposure to fumes, and it's added slowly, which is optimal for the process and also for safety. See **Adding the methoxide**.

Once again, making biodiesel is safe if you're careful and sensible. "Sensible" also mean not over-reacting, as some people do: "I'd like to make biodiesel but I'm frightened of all those terrible poisons." In fact they're common enough household chemicals. Lye is sold in supermarkets and hardware stores as a drain-cleaner, there's probably a can of it under the sink in most households. Methanol is the main or only ingredient in barbecue fuel or fondue fuel, sold in supermarkets and chain stores as "stove fuel" and used at the dinner table; it's also the main ingredient in the fuel kids use in their model aero engines. So get it in perspective: be careful with these chemicals -- with ALL chemicals -- but there's no need to be frightened of them.

Ethyl esters -- making ethanol biodiesel

Making ethyl-esters biodiesel using ethanol is a tricky process, not as simple as making methyl esters with methanol. But it can be done -- the following technical papers are available online in our Biofuels Library, and there's sound advice below from a master home-brewer who routinely makes his own ethyl-esters biodiesel.

Optimization of a Batch Type Ethyl Ester Process -- a recipe for biodiesel from ethanol (which you can make yourself), instead of methanol (which is toxic, fossil-fuel derived, and you can't make it yourself).

Production and Testing of Ethyl and Methyl Esters, University of Idaho, Dec 1994.

Transesterification Process to Manufacture Ethyl Ester of Rape Oil by Roger A. Korus, Dwight S. Hoffman Narendra Barn, Charles L. Peterson, and David C. Drown, Department of Chemical Engineering, University of Idaho, Moscow, Idaho, USA (Acrobat file, 672Kb)

Making and Testing a Biodiesel Fuel Made From Ethanol and Waste French-Fry Oil by Charles L. Peterson, Daryl Reece, Brian Hammond, Joseph C. Thompson, Sidney Beck, University of Idaho, Idaho, USA (Acrobat file, 2.4Mb)

Biofuels mailing list member Ken Provost, who has much experience making ethyl esters, sent us the following tips&tricks sheet.

Ethanol-based Biodiesel

1. Get plenty of experience making biodiesel with methanol before you try it with ethanol. Get comfortable titrating your oil for FFAs (free fatty acids); you'll need to do that when you use ethanol.

2. Try to find a source of KOH (potassium hydroxide) to use instead of lye with ethanol. Lye (NaOH, sodium hydroxide) will work, but it dissolves VERY slowly in ethanol. You'll need to use more of either one -- 7g per liter of clean oil with NaOH, 10g per liter of clean oil with KOH. More as required per your titration level.

3. Your ethanol will have to be EXTREMELY dry. 199-proof or higher. "Absolute" ethanol. Any more than one half of one percent water can kill the reaction. Denaturants like methanol, isopropyl alcohol, MIBK, etc., are fine. But no water. Ethanol that dry is difficult to find cheap, especially in the US. If you want to try to make it yourself, you'll need molecular sieve, quicklime, or something else to do a "chemical" drying. Distillation alone can't get the water under 5% -- still way too much. (See below -- Anhydrous ethanol)

4. If you're interested in ethanol for environmental reasons, be careful. Even if you find anhydrous ethanol, it may come from fossil fuel. The denatured alcohols used by painters, or in other industrial applications, may be anhydrous but still derived from petroleum. In fact, since fermentation uses water, it's cheaper to make 200-proof starting with petroleum. The only way to know is to call the original manufacturer of the formula. Ask if the ethanol is "synthetic" or "fermentation". One type of denatured anhydrous ethanol that is almost always fermented is "fuel-grade", which is 199-proof

denatured with gasoline. It's what they add to gasoline to make gasohol.

5. Your oil will also have to be EXTREMELY dry. Heat the oil to 120 deg C (248 deg F) and hold it there until you can turn off the flame and see the bubbling stop almost immediately. You might want to throw in some clumping cat litter (bentonite clay) and/or silica gel to scarf up any remaining water, let it settle half a day, and take the oil off the top. Sometimes that's still not dry enough. Remember -- any more than 0.5% water can kill the reaction.

6. Your oil will have to be fairly low in FFAs. You'll want to do a titration on every batch to make sure. Anything over 2 ml titration (using 0.1% NaOH solution) can cause failure of the glycerine to separate -- under 1 ml is a good idea. Most waste oil is too high, and either needs to be refined with NaOH first, or cut with clean oil to neutralize FFAs.

7. You need to use more ethanol to get full conversion. Somewhere between 275 and 300 ml per liter of oil is about right for most oils. Coconut oil will need more, maybe 350 ml. Theoretical is about 180 ml per liter, and the rest is excess to drive the reaction all the way.

8. Even when you do all the above, getting the glycerine to separate is a matter of good luck and fervent prayer. Sometimes separation occurs just like a methanol batch. Other times you won't start seeing a glycerine layer for 3 or 4 hours, or maybe overnight. Then again, sometimes it NEVER separates. Until you get separation, you haven't made biodiesel. I've heard of folks who don't wait for separation -- they just pour the whole mess right into the tank, or do some kind of water wash and think it's good biodiesel. It might burn, but it's not biodiesel. It must separate.

9. If it doesn't separate, you can sometimes force it by adding some methoxide mix. You can also make it more likely to separate by including some methanol with the ethanol right from the start. For example, you could try using an initial mix of 5 to 7 parts ethanol and 1 part methanol. Give it a few hours to separate. If it doesn't, add some straight methoxide to the kettle, using enough methanol to bring the alcohols ratio down to 3:1 eth:meth, and containing another 2g of KOH per liter of oil. That usually initiates separation within an hour. Fresh, refined edible oil might even work the first time with straight ethanol. If you use a mixture of ethanol and methanol, you can get away with 275 ml of initial mix per liter of oil.

10. If you're not scared off yet, Good Luck!
-- Ken Provost

Anhydrous ethanol

To make ethyl esters the ethanol must be anhydrous, 99%+ pure -- with less than 1% water content. The purest ethanol that can be produced by ordinary distillation is only 95.6% pure, the rest being water, which interferes with the transesterification reaction in making ethyl esters. More common for home distillation is 170-190 proof -- 85-95% pure.

Members of Journey to Forever's **Biofuels mailing list** have succeeded in making ethyl esters using 85% ethanol they've distilled themselves, by removing the excess water with quicklime (CaO). See "The Manual for the Home and Farm Production of Alcohol Fuel" by S.W. Mathewson, **Chapter 12 -- Drying the Alcohol**, Drying with lime.

An easier method is to use 3A zeolite molecular sieve. Biofuels group member Ken Provost reports: "Zeolite (aka 'molecular sieve') works BEAUTIFULLY to suck the last bit of water out of distilled

ethanol. I got a sample of Type 3A Molecular Sieve from **Adcoa** in Southern California: http://www.thomasregister.com/olc/adcoa/molecula.htm

"I got a can of the 4-8 mesh -- little balls of rock about 1/8" diameter. They absorb about 20% of their weight of water over the course of a few hours. Take a liter of 95% ethanol, throw in 250g of the stuff, swirl occasionally, filter out the next day through a strainer, and presto! Anhydrous ethanol. Not expensive either -- US$2.05 a pound in 10 lb quantities, and reusable indefinitely. You drive off the water under a broiler for an hour."

An alternative is to run the ethanol vapours through 3A molecular sieve in a column during the distillation process.

Cornmeal Adsorber for Dehydrating Ethanol Vapors -- by Michael R. Ladisch et al., Laboratory of Renewable Resources Engineering, Purdue University. About half the ethanol now produced in the US is dried using corn grits. When the corn's drying capacity is worn out, it can be fermented and distilled to make more ethanol. This 1981 paper is the original work on the subject.

Separating Ethanol From Water -- by Renaldo V. Jenkins of Langley Research Center, Hampton, Virginia, USA. More economical methods of separating water from ethanol to produce anhydrous ethanol, using sulphur or castor oil. Provided by F. Marc de Piolenc.

Absolute Alcohol Using Glycerine -- Mariller-Granger Processes, from E. Boullanger: Distillerie Agricole et Industrielle (Paris: Ballire, 1924). Mariller's absolute alcohol production process by dehydration using glycerine, various systems examined and explained. Translation from the French by F. Marc de Piolenc.

Reclaiming excess methanol

Depending on the kind of oil you're using, it takes from 110-160 milliliters of methanol per liter of oil to form the methyl esters molecule. But you also need to use an excess of methanol to push the conversion process towards completion -- the total used is usually 20% and more of the volume of oil used, 200 ml per liter or more.

Much of the excess methanol can be recovered after the process for reuse, simply by boiling it off in a closed container with an outlet leading to a simple condensor. Methanol boils at 64.7 deg C, 148.5 deg F, though of course it starts vaporizing well before it reaches boiling point. Unlike ethanol, methanol does not form an azeotrope with water and relatively pure methanol can be recovered -- pure enough to reuse in the next batch.

Methanol can be recovered at the end of the process, or just from the glycerine by-product layer, since most of the excess methanol collects in the by-product and it's that much less material to heat. See **Methanol condenser**. Start at 65-70 deg C (149-158 deg F); as the proportion of methanol left in the by-product mixture decreases the boiling point will increase, so you'll have to raise the temperature to keep the methanol vaporizing, perhaps to as high as 100 deg C (212 deg F) or more, though the bulk of it should have been recovered by then.

If you're planning to separate the glycerine from the soaps (FFAs) and catalyst it's best to leave methanol recovery to later as the by-product probably won't separate without the methanol. The excess methanol can then be recovered from the separated glycerine layer.

See Methanol recovery

More about lye

The catalyst used in transesterification of vegetable or animal fats and oils is lye -- either sodium hydroxide (NaOH, caustic soda), or potassium hydroxide (KOH).

Lye is hygroscopic -- it absorbs water from the atmosphere. So make sure you get fresh lye, and keep the container tightly sealed.

When weighing it out, don't leave it exposed to the air too long. In humid weather we weigh it out into plastic bags, one on either side of the scale to equalise the extra weight of the bag. As soon as it's weighed out, close the container, close the bag, and add the lye to the methanol as quickly as possible.

Lye also absorbs carbon dioxide from the atmosphere and becomes carbonated if not stored properly. Carbonated lye is white, fresh lye is almost translucent. You can still use carbonated lye, but you'll have to use a bit more (add about 25%).

Sodium hydroxide (NaOH) is more readily available than potassium hydroxide (KOH) and cheaper. It usually comes in three grades: flakes and 5mm pearls or half-pearls are 96-97%, small pearls (1-2 mm) are 99%+, but more expensive. Either will do. In the US, Red Devil lye is pure NaOH; don't use Drano Crystal, it's only 54.2% NaOH and includes aluminum -- it won't work for biodiesel.

KOH is not as strong as NaOH -- use 1.4 times as much KOH (actually 1.4025 times). Titration is the same, just use a 0.1% KOH solution instead of NaOH solution, and use 1 gm of KOH for every milliliter of 0.1% solution used in the titration. But instead of the basic 3.5 grams of NaOH lye per liter of oil, use 3.5 x 1.4 = 4.9 grams of KOH. So, if your titration was 5 ml, use 5 + 4.9 = 9.9 gm KOH per liter of oil.

One more complication -- check the purity of your KOH, it's generally not as pure as NaOH. Anhydrous grade KOH flake is usually about 92%, sometimes less -- check the label. We use half-pearls assayed at 85%. Adjust the basic quantity accordingly: the basic 4.9 grams would be 5.8 (5.775) grams for 85% KOH, or 5.3 (5.33) grams for 92% KOH.

KOH dissolves in methanol much more easily than NaOH does, and doesn't "clump" together as NaOH can do.

How much lye to use?

It requires 3.5 gm of NaOH lye per liter of oil as catalyst to transesterify new oil (virgin, uncooked).

Used oil (WVO) needs more lye than new oil, to neutralize the Free Fatty Acids (FFAs) formed in cooking the oil, which can slow or stop the transesterification process.

You have to titrate the oil to determine the FFA content and how much lye will be required. Titration measures the pH of the oil, ie the acid-alkaline level (pH7 is neutral, lower values are

increasingly acidic, higher than 7 is alkaline, or "base"). From this you can calculate how much extra alkali (lye) will be needed to neutralize the FFAs.

The extra lye converts the FFAs to soap, which drops out with the glycerine layer.

Too much lye will make extra soap, very alkaline biodiesel that's difficult to wash, with loss of production, or it can ruin the reaction; too little lye will mean some of the oil is left unreacted. See below:
How the process works
The basic lye quantity -- 3.5 grams?

Basic titration

An electronic pH meter is best, but you can also use pH test strips (or litmus paper), or phenolphthalein solution (from a chemicals supplier).

Dissolve 1 gram of lye in 1 liter of distilled or de-ionized water (0.1% lye solution).

In a smaller beaker, dissolve 1 ml of dewatered WVO oil in 10 ml of pure isopropyl alcohol. Warm the beaker gently by standing it in some hot water, stir until all the oil dissolves in the alcohol and the mixture turns clear. Add 2 drops of phenolphthalein solution.

Using a graduated syringe, add 0.1% lye solution drop by drop to the oil-alcohol-phenolphthalein solution, stirring all the time, until the solution stays pink (actually magenta) for 10 seconds.

Take the number of milliliters of 0.1% lye solution you used and add 3.5. This is the number of grams of lye you'll need per liter of oil.

With a pH meter or test strips, use the same procedure without adding the phenolphthalein. Add the 0.1% lye solution drop by drop as before until the pH reaches 8.5.

Better titration

Unless you have a very accurate scale, it's not easy to measure exactly 1 gram of sodium hydroxide. It's much easier to measure 5 gm than 1 gm, so mix 5 gm of sodium hydroxide with 500 milliliters of distilled or de-ionized water.

Before titration measure out 5 ml of the stock solution, add 45 ml of distilled or de-ionized water. This makes a 0.1% lye solution.

It's also not easy to measure exactly 1 milliliter of oil. Instead of the usual 1 ml of oil and 10 ml of isopropyl alcohol, mix 4 ml of oil in 40 ml of isopropyl alcohol in a glass beaker.

Warm the mixture gently by standing the beaker in hot water, stir until all the oil disperses and it becomes a clear mixture.

Then titrate as usual, measuring milliliters of stock solution used. When it reaches pH8.5 count up the number of milliliters used as normal and divide by 4. This will give a much more precise

measurement.

To save on isopropyl alcohol, use 2 ml of oil in 20 ml of isopropyl and divide the results by two -- still twice as accurate.

Accurate measurements

Truly accurate scales are expensive, unless you can pick up a second-hand set in good condition. Even then, it pays to check your scales for accuracy.

A good way of doing this is with new coins. Find out from your bank, or the Central Bank, what the weight is (in grams) of the coins in your country. If you get a full set of new coins you can use them to check accuracy of a wide range of weights.

With a balance-type scale (two sides with a fulcrum between them), get two full sets of coins, and figure out different combinations to put on each side; you should also be able to use this to achieve smaller gradations than your scale allows: it's useful to be able to measure a tenth of a gram.

If you have a standard milliliter measure that you know is accurate, use it to check all your various measuring flasks, syringes, pipettes, etc. Otherwise, check them against each other. With syringes or pipettes, whatever you use to add the 0.1% lye solution to the oil-alcohol mixture for titration, you should be able to measure 0.1 ml accurately.

pH meters

It's said you can't reliably use an electronic pH meter for titration, nor to check the pH of biodiesel, because biodiesel is not an aqueous solution. Not quite true -- biodiesel is hygroscopic and will always have about 1,200 ppm water content absorbed from the atmosphere, if from nowhere else. And laboratory-standard titration equipment uses electronic pH meters.

We have three pH meters, one of them rather expensive, and we did some comparisons, with phenolphthalein, fresh from a major laboratory supplies company in Tokyo, and with various test strips. We used WVO from several sources, and virgin oil as a check. The results were checked with test batches. In each case, the three pH meters agreed with each other and produced good test-batch results. Phenolphthalein results were consistently slightly higher, but the test-batch results were still good. The test-strips came a poor third -- nowhere near as precise as pH meters and phenolphthalein.

Good-quality oil that hasn't been cooked too much or overheated is quite forgiving, but with poor-quality WVO with a high FFA content, accurate titration is more important. The higher the FFA level, the more sensitive the reaction, the more precise you have to be with titration and everything else, the more reactive agents you'll need -- and the lower will be the production rate.

Phenolphthalein

Phenolphthalein is often confused with "phenol red", obtained at pool supply stores and used for checking water. It's not the same thing, and phenol red won't really do for titrating WVO, its pH range isn't broad enough. It ranges from pH 6.8, at which point it's yellow, through orange, to a maximum of pH 8.2, red. For accurate titration you need to be able to measure pH 8.5.

Phenolphthalein is colorless up to pH 8.3, then it turns pink (magenta), and red at its maximum of pH 10.4. When it stays pink for more than 10 seconds, it's measuring pH 8.5.

With good-quality oil with low FFA levels you might just get away with using phenol red for titration, but for higher FFA levels it isn't accurate enough. Use 1% phenolphthalein solution (1.0w/v%).

High FFA levels

Most people find their used cooking oil generally gives a titration of 2-3 ml, but some used oils can have much higher FFA levels than this -- we've seen horrific titration levels of 9.6 ml. "Horrific" because FFAs are not good for you -- it's a very bad idea to eat food from a restaurant that does that to their cooking oil. Another biodieseler reported titration levels of 16 ml -- black stuff with the consistency of sump oil.

We did succeed in making biodiesel with our 9.6 ml oil. It's not easy to process oil like this with the usual single-stage base process. You're likely to end up with about 50% production half the time, and maybe not a very good product, and glop the rest of the time. If you're really precise with everything you can do it -- we managed to get a consistent 75% production with the single-stage base process, good product, easy wash.

The oil has to be thoroughly dried first -- traces of water make a bigger difference with high FFA levels, because there's more lye for the water to react with. And the reaction itself releases traces of water, especially with high levels of lye.

The better answer is to use the **Foolproof** two-stage acid-base method, which effectively handles high FFA levels and still produces high production rates with low levels of reactants and easy washing.

You can also deacidify the oil.

Deacidifying WVO

In commercial oil refining this is done with lye (NaOH), which saponifies the Free Fatty Acids, converting them to soaps which can then be removed, but it usually requires a centrifuge to separate it. This is an easier way, no need for a centrifuge.

Use the titration amount of NaOH -- eg, 9.6 grams per liter of oil for our high-FFA 9.6 ml WVO (see above). Mix the NaOH with 40 ml of water per liter of oil. It gets hot. Use a stainless steel container, mix it outside (by stirring), and take care! This is very corrosive stuff, take full safety precautions, have running water handy.

When the NaOH is fully dissolved add the solution to the oil (room temperature), stir gently by hand

until thoroughly mixed. Be gentle!

Settle overnight. This leaves soapstock at the bottom. The water stays with the soapstock.

Filter to remove the soapstock -- no need for fine filtering, fine steel mesh will do (like a fine tea strainer). Again, do it gently.

Now process the filtered WVO as usual for virgin oil -- 3.5 grams NaOH per liter of oil, but use 25% methanol, process at 55 deg C (130 deg F), with good and prolonged agitation as usual.

In our tests the product was good, the production rate was 80%. With high-FFA oil like this, it's a a much easier process than the normal single-stage, and it's nice not to have to make such strong methoxide as a straight single-stage process would require with this oil, 13.1 grams of lye per liter oil, or more like 13.6 grams (it needs a bit of excess lye).

It's an alternative -- better than straight single-stage base for oil like this, and while it won't get as a high a production rate as the acid-base method, and it uses more catalyst and gives you more co-products, it's very quick and simple.

This is also useful if you're making **ethyl esters biodiesel**, using ethanol rather than methanol: the ethyl esters process doesn't work well with oils with more than about 2 ml titration.

As always with a new process, try it first with a small sample, say 1 liter of oil. Be gentle when mixing it -- if you agitate it too much it won't separate easily. If that happens, try heating it, and be more gentle next time.

You can add the soapstock to the glycerine layer after separation and neutralize as usual to **separate catalyst, glyc and FFAs**.

The soapstock can be used for producing soap, or turned into calcium soap, which is something like Dubbin and has an extremely low water solubility. Useful stuff. "Thus an equimolar amount of calcium chloride may be directly added to the soapstock and prompt separation of the calcium soap by precipitation from a relatively pure saline (NaCl) solution will ensue. Calcium soaps are useful industrial ingredients, for instance as demoulding agents." -- Chemical Reactions of Oil, Fat and Fat Based Products -- Neutralization (chemical processing)
http://alfa.ist.utl.pt/~fidel/creac/sec34b.html

Mix some calcium chloride in a little water (careful, it gets hot, don't splash) and add it to the soapstock a little at a time, stirring it in, until it separates.

No titration?

There are three ways of avoiding titration:

1. Use the **two-stage base-base method**;

2. Use the **two-stage acid-base "Foolproof" method**;

3. Do a series of **test batches** using graded quantities of lye and compare the results. Start off with maybe 6 gm of lye per liter (3.5 gm for the transesterification and 2.5 gm for the FFAs). If that works really well, then go ahead. Otherwise try more tests, at 5 gm, then at 7 gm; if, say, 7gm is better, try 6.5 gm and 7.5 gm, and so on until you get satisfactory results. (See also **Stock methoxide solution**, below.)

Satisfactory results mean that you get a good, clean "split" (ie separation), that it settles well, leaving a clear product with not too much soap formation, a good production rate, and, most important, that it washes easily without frothing.

There is a school of thought that holds that titration isn't necessary, just use 6.25 gm per liter and you'll be fine. Don't listen to them! They might have always done it that way and they've driven 20,000 miles already in their diesel without any problems, but 20,000 miles is nothing in the life of a diesel motor. Oils vary considerably from place to place -- even the fabled "stable source of supply" can't be all that stable, unless it's a food processing factory with a standardized operation. If it's the usual restaurant or canteen, that would mean they cooked exactly the same number of identical meals in exactly the same way, every day. It just ain't so.

Sometimes the "no titration" folks point to Aleks Kac's two-stage methods, neither of which use titration, though they're both based on an "average" lye requirement of 6.25 gm/liter. But two-stage processes work in a different way, and this cannot be applied to a single-stage process. In fact even with two-stage processes we'd want to do a titration, just to know what sort of oil we were working with.

They also point to Mike Pelly's statement that he usually needs between 6 and 7 gm of lye -- but Mike also says titration is the "most critical" step in the process: "Make your titration as accurate as possible." And: "It's a good idea to do this entire process [titration] more than once to ensure that your number is correct." In fact Mike has a stable source of supply for his WVO, but he checks it regularly just the same, by titration and/or with test batches.

The basic lye quantity -- 3.5 grams?

This is the amount of lye (NaOH, sodium hydroxide) required as catalyst to transesterify 1 liter of virgin, uncooked oil. For used oils, titration determines the amount of lye needed to neutralize the Free Fatty Acid (FFA) content, and this quantity is added to the basic figure of 3.5 grams per liter.

In fact 3.5 grams is an empirical measure -- an average. Different oils have slightly different requirements, and even the same type of oil varies according to how and where it's grown. Other estimates are 3.1 gm, 3.4 gm, and some people have set it as high as 5 gm.

Here is what we've found. For most virgin oils and low-FFA used oils (with titration levels less than 2-3 ml), 3.5 grams works just fine. For high-FFA used oils, use more lye -- up to about 4.5 gm instead of 3.5 gm. Do small test batches to see what works best.

Different oils also require different amounts of methanol -- see **How much methanol?** For oils and fats requiring more methanol -- coconut, palm kernel, as well as tallow, lard, butter -- again, use more lye, up to 4.5 gm, even with new oils, and especially when it's used. Once again, do small test batches first.

Mixing the methoxide

See **Methoxide the easy way**. You can use the easy method with 4-gallon HDPE carboys or similar containers with screw-on caps (preferably with bungs as well). First the methanol, then add the lye gradually. Swirl it about from side to side rather than shaking it up and down.

If you shake it a lot, and often, it can be ready a lot sooner than 24 hours -- in just a few hours, or even less, some people say. But DON'T use it until ALL the lye is thoroughly dissolved. If you use a white translucent HDPE container you can see any undissolved lye at the bottom of the container.

We use HDPE carboys with two screw-on caps and an aquarium air-pump to transfer the mixed methoxide to the reactor vessel via plastic tubing (the braided translucent type), with no exposure at all. Clean, safe and simple. We transfer the methanol from its tank to the carboys the same way.

For HDPE, see below, **Identifying plastics**

Stock methoxide solution

Stock methoxide solution is very useful for making test batches, with a series of tests made in a blender using different amounts of lye for each. Rather than measuring tiny amounts of lye for each half-liter (or whatever) test batch, make a stock solution using one liter of methanol and 50 grams of lye. Then you can dilute quantities of the stock solution to whatever strength each test batch requires. If you're making half-liter test batches and using 20% methanol, measure out the methoxide this way:

If titration was, say, 3 ml, you'll need 3 + 3.5 grams of lye (the basic amount) for the reaction -- that's 6.5 grams per liter of oil. For half a liter of oil, that would be 3.25 grams and 100 ml of methanol at 20%.

It's easy to calculate that 65 ml of the stock methoxide solution will contain 3.25 grams of lye. So measure out 65 ml of the stock, and top it up with 35 ml of pure methanol to make 100 ml (20%).

For a test of 6 grams per liter of oil, you'll need 60 ml of the stock, top it up with 40 ml of pure methanol to make 100 ml. For a 7 grams per liter test, measure out 70 ml of the stock, top up with 30 ml of pure methanol. And so on.

Didn't figure the calculation? For a half-liter test at the rate of 6.5 grams of lye per liter of oil, divide 6.5 by 2 = 3.25 grams. To calculate the stock solution amount, multiply 1000 (1000 ml per liter) by 3.25 divided by 50 = 65 ml. For 20% methanol, 20% of 500 ml (half a litre) = 100 ml. 100 ml minus 65 ml = 35, so add 35 ml of pure methoxide to the 65 ml of stock to make up 100 ml containing 3.25 grams of lye, equivalent to 6.5 grams per liter of oil with 20% methanol.

Once mixed, methoxide won't last forever, but it's certainly good for a few weeks. Don't make large amounts -- one liter is good for a dozen or more tests. If in any doubt, make up a fresh batch. Include what's left of the old mixture in the methoxide for your next batch of biodiesel. (With thanks to Todd Swearingen of Appal Energy.)

How much glycerine? Why isn't it solid?

Just made 20 minutes earlier, and still settling.

Newcomers to biodiesel making their first batches sometimes think it all went wrong because the glycerine didn't go solid.

Messages sent to the **Biofuel mailing list**:

> "I did my first test batch of wvo biodiesel over the weekend. Although I appear to have formed a layer of glycerine on the bottom of the flask, it is not congealed, but is still liquid at room temperature (24 hours later). Did something go wrong?"

> "The glycerin I got from my first batch is thinner than molasses at room temp. Why would it remain so thin? The information I have found suggests that it should be solid, or close to it, at room temperature."

Others think it "didn't work" because there wasn't "enough" glycerine:

> "I did a first test batch of 3 liters WVO, adding 600ml methanol and got only 350ml of glycerine. I didn't really know what to expect, but 10% relative to the original stock seemed kind of low to me."

> "I did a blender test batch of biodiesel last night. I titrated to 2ml, so I used 5.5g of lye and mixed it in with 200ml of methanol. I then heated the oil up (1 litre), and put it in the blender, and mixed for 15-20 minutes. It quickly began to separate and the biodiesel at the very top inch of the blender after the first 15 minutes or so was quite clear. I woke up in the morning and only 125 ml or glycerine settled out. Shouldn't there be at least 200 ml of glycerine settled at the bottom? There are only two layers, the top, light and slightly cloudy, and the dark glycerine. Where is the extra 75 ml of glycerine?"

In fact in all four cases the tests worked just fine.

There is no "set" amount of by-product, such as 200ml per liter, and there is no rule that the by-product must be solid at room temperature.

What's much more important is that in each of the cases above, the test batch produced a good "split" -- the glycerine separated and settled to the bottom, and, if they'd followed the directions carefully, the rest would have been good biodiesel, needing no more than settling and washing. It "worked", it's just fine, move on to bigger and better things!

How much glycerine?

The rule of thumb is 79 milliliters of glycerine for every liter of oil used (7.9%). And crude glycerine is not solid at room temperature. But the so-called "glycerine layer" is not just glycerine, it's a variable mixture of glycerine, soaps, excess methanol, and the catalyst (lye).

The quantity varies according to the oil used (more with heavily-used oil), the process used (less with the **acid-base two-stage method**), the amount of excess methanol used (most of the excess methanol ends up in the by-product layer).

Why isn't it solid?

It's mainly the soaps combined with the glycerine that can cause it to solidify. Soaps made from saturated fats such as stearin are harder than those made from unsaturated fats such as olein, so the type of oil used makes a difference (see **How much methanol?** for compositions of different oils).

More important is how much soap there is -- the more soap, the more likely the by-product layer will solidify, no matter what oil you used.

Other factors:

- Excess methanol makes the by-product layer thinner
- Too much lye creates excess soap
- Potassium hydroxide (KOH) makes the by-product slightly thinner than sodium hydroxide (NaOH).

See: **Glycerine**

PET bottle mixers

This isn't a good method of making test batches, though if you're careful it does work up to a point. It is useful if you're doing a demonstration. Do a test-run first in private before you stick your neck out in front of a crowd.

PET bottles are transparent plastic soft-drinks bottles, generally 1.9 liters. "PET" stands for Polyethylene Terephthalate -- see below, **Identifying plastics**

Here's how they do it: warm up the oil (or maybe not), funnel it into the PET bottle, add the (pre-mixed) sodium methoxide, screw on the cap, shake the bottle vigorously up and down 40 times, leave it for an hour, and it's done.

Well, maybe. Or maybe not -- it's a good recipe for an inadequate reaction.

Here's a better way: warm the oil to 55 deg C (131 deg F). Pour it into the PET bottle, add the

methoxide, screw on the cap, shake vigorously up and down 40 times or more. Then stand the bottle in a bath of hot water to maintain the temperature -- keep the water in the bath at a minimum of 55 deg C. Shake again every 5 minutes, for a total of at least two hours, maintaining the heat all the time. This will have a much better chance of not leaving unreacted and partly reacted material in the mix. See below: **How the process works**.

For demonstration purposes, the value of the "method" is that it doesn't matter much if the reaction is inadequate and leaves unreacted material in the mix, just as long as you get separation and the glycerine drops out -- you're demonstrating the process, NOT making fuel, and in a transparent PET bottle you can clearly see it all happening. And it's non-messy.

Viscosity testing

Viscosity is a useful comparative indicator of biodiesel quality. Unfortunately, and despite claims to the contrary, that's all it is -- a comparative indicator: this batch is better than that batch. Even at the laboratory or industrial level, viscosity testing alone cannot tell you if the process has gone far enough before reaching equilibrium -- in other words that there are not unacceptably high levels of harmful unreacted and partly reacted materials in your fuel. Unconverted monoglycerides and diglycerides are very similar in viscosity to biodiesel and stay in solution with it after an incomplete reaction. The allowed maximums are low -- less than 1% for DGs and less than half that for MGs. Viscosity tests might get you within 5% accuracy, not nearly close enough. The same goes for density -- specific gravity measures (SG). Even both viscosity and density together can't assure you of a completed reaction. The only way to know that is with a Gas Chromatography test, which very few biodieselers have available. Short of a GC, the best indicator of a completed reaction is the wash -- easy washing and a crystal-clear product. See below: **How the process works**.

Nonetheless, viscosity is a useful indicator, especially with test batches. You can check viscosity with a 100 ml pipette and a stopwatch -- time exactly how long it takes 100 ml of your fuel to empty from the pipette. Or use a proper viscosity meter. Excess methanol in the fuel will render the results meaningless, so you must wash the biodiesel first. Measure some petro-diesel for a comparison. Remember that viscosity is sensitive to temperature -- try it at two or three different temperatures. See the various quality-specification tables **here** for some guidance.

Measure specific gravity (SG) by weighing a specific volume of the fuel. Remember that volume is also sensitive to temperature. A liter should weigh about 880 gm at 15.5 deg C.

See **Quality testing**

How the process works

What is meant by "completion" and "equilibrium"?

First, vegetable or animal fats and oils are triglycerides (TGs), composed of three chains of fatty acids bound by a glycerine molecule (see diagram in next section below).

Triglycerides are esters. Esters are acids, such as fatty acids, combined with an alcohol, and glycerine (glycerol) is a heavy alcohol.

The transesterification process converts triglyceride esters into alkyl esters (biodiesel) by means of a catalyst (lye) and an alcohol reagent (usually methanol, which yields methyl esters biodiesel).

In transesterification the triglyceride molecule is broken into three separate methyl ester molecules plus glycerine as a by-product. The lye catalyst breaks the bond holding the fatty acid chains to the glycerine, the glycerine falls away, the fatty acid chains then bond with the methanol.

It happens in three stages (this has nothing to do with the single-stage or two-stage processes). First, one fatty acid chain is broken off the triglyceride molecule and bonds with methanol to form a methyl ester molecule, leaving a diglyceride molecule (DG) -- two chains of fatty acids bound by glycerine. Then a fatty acid chain is broken off the diglyceride molecule and bonded with methanol to form another methyl ester molecule, leaving a monoglyceride molecule (MG). Finally the monoglycerides are converted to methyl esters -- completion.

The problem is that the process can run out of reagent or catalyst before it gets that far, or agitation, temperature or processing time may be inadequate.

The result is some unconverted or partly converted material remaining in the biodiesel. Well, so what if the process isn't completed? SVO (straight vegetable oil) is a good fuel anyway, so what's it matter if some of it is unreacted? But it's not just unreacted material that's the problem so much as the partly-reacted stuff. Diglycerides and monoglycerides are bad things to put in your diesel. Diglycerides don't burn well and lead to coking problems, monoglycerides can lead to corrosion and other problems -- bad fuel.

"The level of glycerol, mono- and diglycerides at levels of 0.1% (a factor of 1/1000 or less of the main ester components) or lower appears necessary for optimum engine performance." (International Conference on Standardization and Analysis of Biodiesel, Session 2, "Interaction Between Engine and Fuel", Vienna, November 6-7, 1995 -- to be published.) -- From "Analytical Methodologies for the Determination of Biodiesel Ester Purity -- Determination of Total Methyl Esters", NBB Contract #:520320-l, Richard W. Heiden, Ph.D., R. W. Heiden Associates, February 27, 1996
http://www.biodiesel.org/resources/reportsdatabase/reports/gen/gen-221.pdf

So, either don't process it at all and use SVO (which can have its own problems), or process it PROPERLY.

In fact the process never reaches 100% completion, it always reaches equilibrium first, so there will always be some unreacted glycerides left. The various **national biodiesel standards** stipulate just how much is allowable, and it's not very much at all: diglycerides range from less than 0.4% to less than 0.1% by mass, monoglycerides less than 0.8% by mass.

The first part of the process happens rapidly, which is why some people think it only needs a few shakes and that's it. Not so. If it takes X minutes to convert half the TGs to DGs, it takes almost as long, another X minutes, to convert half the remaining TGs, then a further X minutes for the remaining half, and so on. So the process goes more and more slowly, and never quite arrives -- there's always half left. Finally comes a point when the remaining half is insignificant, and, indeed, within the limitations set by the various quality standards. But it's very easy to fall short of that point and end up with nasties in your beautiful clean eco-friendly nice-smelling home-brewed fuel, and in your motor.

See **Kinetics of Palm Oil Transesterification in a Batch Reactor**, by D. Darnoko and Munir Cheryan, University of Illinois, for what actually happens during the biodiesel process

reaction. (Acrobat file, 72Kb)

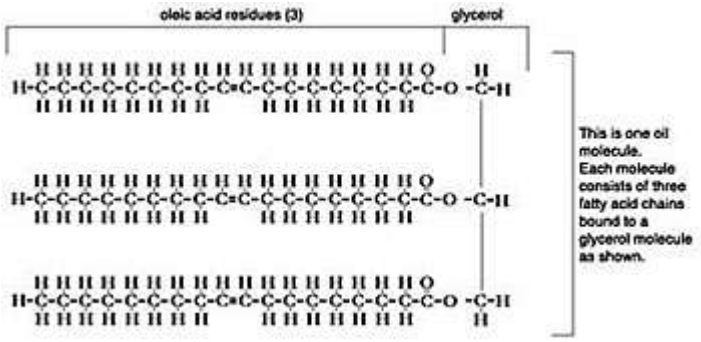
You CAN make high-quality biodiesel, all it takes is a little care. On analysis, biodiesel made by home-brewers with no qualifications and no special equipment using the methods detailed at this website has proved the equal of professionally made commercial fuel. Professional mechanics checking their motors have been amazed by the lack of wear and corrosion. You can do it too. See **Quality**

For beginners, start off with good practices: follow the instructions carefully, be meticulous with your titration, make sure your measurements are as accurate as you can make them. Learn as much as you can. You'll soon get a feel for it, and then, once you're familiar with the process in all its aspects, you'll be able to decide what's best for you in your situation, with your source of oil, on your budget, and just where you can relax a little and take calculated shortcuts, based on your own experience.

NOTE: It's a common misconception that biodiesel has lower viscosity than SVO or WVO because the transesterification process shortens the carbon chain length of the fatty acid molecules in the oil.

Thisis not so. The biodiesel molecule is indeed smaller and less complex. Transesterification converts the triple-chain triglyceride vegetable oil molecule to three single-chain methyl ester molecules, but the chain lengths of the fatty acids themselves remain the same. The fatty acid composition of biodiesel depends on the feedstock and is not changed by transesterification.

What are Free Fatty Acids?



Oil molecule -- graphic by Jeff Welter

Again, vegetable or animal oils and fats -- what we make biodiesel from -- are triglycerides, composed of three chains of fatty acids bound by a glycerine molecule.

Free fatty acids (FFAs) are fatty acids that have become separated from the triglycerides, leaving diglycerides, monoglycerides and free glycerine. This is caused by heat, water in the foods cooked in the oil, or oxidation. The hotter the oil gets and the longer it's cooked, the more FFAs it will contain.

As glycerine is an alcohol (glycerol), a fatty acid attached to it (a glyceride) forms an ester. A "transesterification" is the conversion (switching) of one ester into another -- a glyceride ester into an alkyl ester in the case of biodiesel, where methanol (or ethanol) replaces the glycerine.

An "esterification" is the conversion of a non-ester into an ester. FFAs are non-esters. FFAs are converted into esters by acid esterification in the first stage of the two-stage acid-base biodiesel

process, but cannot be converted by the more common single-stage base transesterification process. Here the FFAs must be removed from the process, or they will dissolve in the biodiesel being formed, yielding an acidic, poor-quality fuel that will not meet quality standards.

In transesterification, extra lye is used to neutralize the FFA content of the oil, turning it into soaps. These soaps drop out of the process as a by-product, joining the so-called "glycerine layer" at the bottom -- often more of a "soap layer" as it may contain more soap than glycerine.

The basic lye quantity used in transesterification acts as a catalyst, not a neutralizer. Lye attacks ester bonds, breaking the bond, and the alcohol drops off, leaving an open-ended fatty acid chain. With glycerides the alcohol that drops off is glycerine. The affinity of the replacement methanol or ethanol for the resulting open bond is strong enough to prevent the glycerine reattaching to the fatty acid.

This is also why it is critical that a minimal amount of lye is used, as lye will continue to attack ester bonds, even those of biodiesel. Too much lye will break the biodiesel ester bonds; some of the broken bonds will mate with the lye and form excess soap, and others will match up with a water molecule to form FFAs, which dissolve back into the biodiesel. It is this excessive formation of FFAs that the "acid number" in the US ASTM and other national quality standards refers to.

While it is unavoidable that some FFAs are formed by biodiesel ester bonds being broken, excess lye increases the proportion.

According to the **Fuel Injection Equipment (FIE) Manufacturers** (Delphi, Stanadyne, Denso, Bosch), FFAs can corrode fuel injection equipment, cause filter plugging and the build-up of sediments on fuel injection parts.

-- With information from Todd Swearingen of Appal Energy, and DieselNet/Ecopoint Inc.
http://www.dieselnet.com/

Which method to use?

Three main choices, all of them here:

Single-stage base -- Mike Pelly;
Two-stage base-base -- Aleks Kac;
Two-stage acid-base "Foolproof" method -- Aleks Kac.

What's the difference?

The single-stage base method is the place to start. The two-stage processes are advanced methods, not for novices -- learn the basics thoroughly first. Single-stage base is the original method, and still the most widely used, tried and trusted. It's the simplest method, especially for new oils which don't need titration.

A lot of beginners want to use WVO but they're put off by the titration, thinking it's too complex. Actually it's simple enough -- just follow the directions. However, the single-stage process produces more and more uncertain results the higher the FFA content gets in WVO, with lower production levels even when it works well.

The two-stage base-base method avoids the need for titration and produces good results even with higher FFA levels. It's the method-of-choice for animal fats.

Growing numbers of biodieselers are now turning to the "Foolproof" two-stage acid-base method, especially with high-FFA oils. Here are some of the reasons:

- Less base catalyst needed.
- Less soap production.
- Higher conversion rates as a result of less soap formation.
- Less emulsion formation in the wash.
- Less loss of fuel in the wash as a result of emulsion formation.
- Less wash water as a result of less soap formation.
- Less neutralizing acid needed for the wash.
- Less acid needed to neutralize base during glycerine recovery.
- High-quality product.

The negatives:

- A little extra processing time.

Even with higher-FFA oils the production rate should be 100% or more by volume (biodiesel has a lower density than the original oil).

In fact the same advantages apply to new oil, although to a lesser extent. Many biodieselers who turn to the "Foolproof" method for high-FFA oils soon make it their method-of-choice for all oils.

Here's some advice from Aleks Kac on using the Foolproof method: "Stick to the recipe, to the letter. There's two years of trial and error research in this. Do not change, simplify or speed up anything. It will take care of all sorts veg fats, even heavily used. The 'solid' portion must be reduced to less than 50% because of the much lower acid-stage temperature. Animal fats content is best at less than 25% for pork or chicken and less than 10% for bovine. These fats at greater concentration should be processed with the two-stage base-base method."

Still, if your oil is quite good and usually titrates at 3 ml or less, you might well be satisfied with the single-stage process.

Why can't I start with the Foolproof method?

It says at the top of the **Foolproof acid-base process** page: "NOTE: The two-stage biodiesel processes are advanced methods, not for novices -- learn the basics thoroughly first. The single-stage base method is the place to start. Start here."

Here being here:
Where do I start?

But novices sometimes take no notice and plow ahead with the acid-base process anyway. Sometimes they also take no notice of the advice on Test batches: "Whenever you're trying a new method, it's always a good idea to make small test batches of a liter or less first to familiarize yourself with the process before moving on to bigger batches."

All too often it results in a highly discouraging 40 gallons of glop. "It doesn't work!" they wail. It works. It also works to heed the advice of the many who've gone before you. "DO AS THEY RECOMMEND and bio will come," said a recent novice at the Biofuel list.

"But it doesn't sound difficult at all, in fact it sounds easier since there is no need to titrate. So what am I missing?"

Quite a lot. First, we think it's worthwhile titrating your oil anyway -- the more you know about it the better, and titration will tell you more than anything else.

Avoiding learning how to do titration is a VERY BAD reason for using the acid-base process! Titration is a basic skill needed for making biodiesel. Anyway, it's easy enough:
Basic titration
Better titration

Second, it's not just a question of whether or not novices can get it to work. Some do -- mostly they seem to get away with it. But that's a pity just the same, because it's doubtful that they'll get the best out of it. The acid-base method is very flexible, people bend it and twist it every which way in adapting it to their preferences and needs, and you just can't do that unless you have a good overall feel of the process as a whole, not just of this one method.

Another novice at the Biofuel list said he had good chemistry knowledge so he could afford to skip the "newbie" stuff. But: "Well, my first test batch is done, and the end result is less than spectacular..."

Suddenly he found himself facing an ocean of variables, and since he had no "feel" for what was supposed to be happening he had no way of finding out what he'd done wrong. Several things, as it turned out.

One answer:

> "This is why this isn't a good place to start. If you were more experienced you might have had a better idea of how to translate the mixing instructions for a full-sized batch to the small scale you're using. Maybe it translates direct, maybe not -- I don't know how fast your drill stirs it, nor what rate of agitation it gets with that paint stirrer, but, comparatively, neither do you, and that makes it difficult for you. Starting instead with single-stage base and virgin oil, you begin with fewer variables and they're less critical, and it's a logical progression from there. Now you're facing too many variables and you don't have the experience to assess them -- and you're more likely to make mistakes anyway because you lack a basis of comparison."

He relented and went back to the beginning, processing 1 litre of virgin oil by the single-stage base method. "Despite people saying that in different ways, I hadn't heard it until now. All I was hearing was that you have to start with the single-stage process then graduate to the foolproof process. This just seemed like trying to learn something one way then do it in a completely different way, which doesn't make sense."

"... so what am I missing?"

One answer:

> "If everything goes exactly right, nothing. The problem is when something doesn't, and you have NO IDEA what's going on 'cuz you've never seen all the possible quirks of even the basic process.
>
> "...What's all this white stuff?... Nothing seems to be happening... There's this weird layer, and I'm wondering if it's biodiesel... etc etc."

Another answer:

> "I can mention that from a beginner's perspective, starting with pure vegetable oil and single-stage base is a really valuable learning process. It gives you an idea of what outcomes look like, and the shake test biodiesel_vehicle.html#quality provides feedback on the quality of the process. I am still playing around with variables (processing time, %lye, %methanol, etc.) using pure vegetable oil, before moving to waste vegetable oil.
>
> "As many people continue to emphasize, process quality is really important, and that seems to be best learned in small steps. My game plan is also to get to the 2-stage acid/base with waste vegetable oil, but I still have a lot to learn before getting there. I think what the experienced folks are cautioning is that troubleshooting a more complex process is extremely difficult (and perhaps frustrating) if you don't have a solid grounding in the basics. I hope this helps. Good luck with your experiments!"

The response:

> "After reading the links to the discussion groups that you attached I see that the basics is to get a feel of the process and see the correct colors and textures using the process that has the

> best chance of success, then use that as a baseline for future mini batches using WVO. Then progress to larger scaled processing, then full scaled process, and then finally graduate to the two-stage method, with knowledge that the resultant biodiesel is clean and pure enough to run through my beloved TDI."

Right!

After all, it's you and your kitchen vs ExxonMobil -- and the kitchen wins! Not only that but it's better fuel! Isn't that good enough? Why take short-cuts? Just do it right.

Other uses

Wood treatment. Biodiesel is very useful stuff. "We must be crazy to burn it!" Mike Pelly once said, only half-jokingly. He's a carpenter and had just finished refitting his house with wooden interiors. He and his wife treated all the wood with biodiesel, floors included. The smell was soon gone (and it's a pleasant enough smell anyway), and the results were fine. We also use it for wood treatment, nice!

It's an excellent **lubricant**, very slippery stuff indeed. It's better than household lubricating oils, and it's non-obnoxious and non-toxic -- it doesn't matter much if the kids swallow some by mistake. Great for gardeners, especially organic gardeners, nothing better for lubricating your tools and keeping them clean and rust-free, and non-toxic. And great in the workshop.

You can also use biodiesel as a **lubricating additive** for low-sulphur fuels. With diesels, engine parts are lubricated by the fuel itself. There are already indications that diesel motors are not lasting as long as they did because of the lack of lubrication with low-sulphur fuel (500ppm), let alone the new ULSD ultra-low-sulphur fuel (15 ppm), and biodiesel can fix that. Adding just 1% biodiesel improves the lubricity up to 65%. Research suggests that just 0.4% to 0.5% is enough.

Biofuels mailing list member Martin R. of Australia uses biodiesel as **two-stroke oil** in his chain saw, at a mix of 20 to 1 with gasoline. "It works fine," he says. "After using the saw for 2.5 hours in one go on dead Australian hardwood with no hiccups I was very impressed to say the least."

Biodiesel does not travel up a wick very well, like kerosene or heating oil will, so it can't be used for ordinary wick lamps or stoves. However, tests have found that it will travel about 7cm up a wick but not more than that, and the wick should preferably be thick (about 1cm) and loosely wound -- tightly-woven commercial wicks won't work well. Biodiesel also might not work in heating furnaces or stoves, though some models work just fine, and others can be adjusted.

The **BriteLyt** Petromax multi-fuel lantern works just fine on biodiesel. "We are happy to report that the burn-time was over 8 hours, at the highest setting, and you did not have to re-pressurize the lantern as often as you would using other fuel-types. The performance was great, and the lantern was just as bright, and there was NO SMELL. Using the product inside, we noticed no smell at all." The lanterns also work with ethanol.
http://www.britelyt.com/
http://store.britelyt.com/

"Before I had a diesel car I used an International WhisperLite campstove to try out biodiesel -- the XGK model which is multifuel, designed for kerosene or diesel as well as white gas. I still suggest

these to people wanting to demonstrate biodiesel in a classroom, for instance -- the stoves cost somewhere between (US)$80 and $100 and are a perfect use for a using up a liter-size batch. I got great response from people who were familiar with the nasty smell of white gas camp stoves -- biodiesel makes the campsite just smell a bit like barbeque. I found it helped sometimes to use a tiny amount of white gas on the pad to start the flame... " -- Mark, **Biofuel mailing list**, 15 Mar 2003

WhisperLite Internationale™ 600:
http://www.msrcorp.com/prod/prod_stoves1.htm#4

-- Purifying vegetable oils for use in lamps: **Fixed oils: To Purify Rape Oil**.

Better than detergent

"A couple of weeks ago, while doing laundry, I opened up the dryer and found all the clothes and the inside of the dryer coated in a multitude of colors. A box of crayons had made the trip through the wash and disintigrated in the heat of the dryer. I tried using regular liquid detergent on a rag to remove the crayon stains and got almost nowhere with a lot of vigorous scrubbing. Well, I saturated a cloth with some homebrew biodiesel and started on the stains, with very little scrubbing, all the crayon was easily removed in seconds. totally took everything that was stained off the dryer drum, in seconds, no work at all!!!

"So, I sat down with a toothbrush and bowl of BD and started in on the 8 pairs of khakis, the scrubbing starting freeing up the chunks of crayon imbedded in the material, it didn't take it totally out but seemed to break it up greatly. After the pants were all scrubbed and saturated with BD, I put back into the wash on hot with normal liquid detergent and everything came out perfectly clean after the first wash, really impressive!!

"So I had a shirt with a deep ink stain in the pocket, poured some BD in the pocket and scrubbed with a toothbrush, went through a normal wash and the ink stain was gone in one wash, again, impressive!

"I do have one pair of white khakis that I haven't attempted to clean yet. I'm trying to "force" my son to wear them to school as an attempt to teach him a lesson about checking his pockets before washing the clothes. What I want to do is just soak them in BD and see if that would work instead of all the toothbrushing that was involved in cleaning his other clothes.

"Anyway, sometimes it pays to 'look outside the box', in this case, the detergent box." -- k5farms, **Biofuel mailing list**, 15 Mar 2003

"Found the same thing in 'dissolving' Ohio crude oil and crude/grime out of work clothes. Lay the clothing in a bathtub, 'saturate' the stain with a homemade liquid veg oil soap, brush a few seconds with a warm-water soaked scrub brush, apply biodiesel from a dish soap squeeze bottle. Scrub to your heart's content.

"The soap/water suspension pulls a good bit of the surface grunge off first, with the biodiesel removing the balance of the oil embedded and soaked into the fibers. The suspension also seems to keep the oily effect of the biodiesel from getting locked into the fiber, which can give the look of wet spots (oil soaked spots) even when the garment is dry.

"Prior to figuring this out the alternative was lacquer thinner, soap and water --- home 'dry cleaning' and toxic as hell." -- Todd Swearingen, **Biofuel mailing list**, 15 Mar 2003

Oil spill remediation -- CytoCulture's CytoSol Process

http://www.cytoculture.com/process.html
"Cleaning Oiled Shorelines with a Vegetable Oil Biosolvent", Port Technology International, 1998, London, UK
http://www.cytoculture.com/cytosolarticle.htm

Appropriate transport

>> **Renewable Energy Online Newsletter**
>> August 24, 2001
>> http://ens-news.com/ens/aug2001/2001-08-21-01.asp
>> Environment News Service:
>> European Government Support Growing for Biofuels
>
> <snip>
>> Since biofuels release none of the greenhouse gas carbon dioxide,
>
> Interesting... Perhaps a silicon-based fuel? With sand for exhaust?
> Tom
> New Mexico, USA

Silicon and sand? Whatever makes you think that? Bit primitive aren't you? We do it this way. Of course we use only the most advanced techniques to make our biodiesel, from whatever feedstock, and then use it in the normal way, giving a thorough application to all the exposed woodwork on the wagon, the wheel hubs, the front axle steering bolt, the canvas tarp cover, and all the leatherwork, harnesses, etc. Then we add the glycerine to the yak-dung in the biogas generator, which powers a small motor with an elbow crank connected to a long forward-mounted bamboo shaft on an offset fulcrum, causing it to waggle, shaking the carrot tied to the end of the shaft enticingly at some suitable point between the yaks' noses and our destination. No carbon emissions, just a bit of odd methane escaping when the yaks fart, but you get used to it. We only use organically grown carrots, of course.

Keith Addison
Journey to Forever

Identifying plastics

What is this "HDPE" plastic that people use for mixing chemicals, and how do you identify it? What sorts of plastics can withstand what sorts of chemicals?

Identifying different kinds of plastic and their properties, American Plastics Council:
http://www.americanplasticscouncil.org/benefits/about_plastics/resin_codes/resin.html

This helps even more: **Plastics Identification** -- Society of Plastics Engineers, Mid-Michigan

Section
http://www.midmichiganspe.org/education/identification.pdf

Chemical compatability -- Chemical Resistance Database, Cole-Parmer:
To search, select at least one of three criteria to search on, Chemical, Material, Compatibility Level. If you wish to search by compatability level, you must specify a chemical or material.
http://www.coleparmer.com/techinfo/ChemComp.asp