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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

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Contact us

To Keith Addison
keith@journeytoforever.org
To Midori Hiraga
midori@journeytoforever.org
Homepage
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Handmade Projects
Ichijima
Japan

Rubber

Pure biodiesel will eventually devour any natural or butyl rubber parts in the fuel system (hoses and seals). Check with the vehicle manufacturer and replace the parts with resistant synthetic parts (such as Viton B). See **Durability of plastics** table. Newer motors don't use

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

rubber. See also **Biodiesel and your vehicle**.

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.)

Midori checks the temperature of the oil.

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.

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.

Keith checks the pH of the waste oil.

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.

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.

For fire risks, see **Hazards**

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