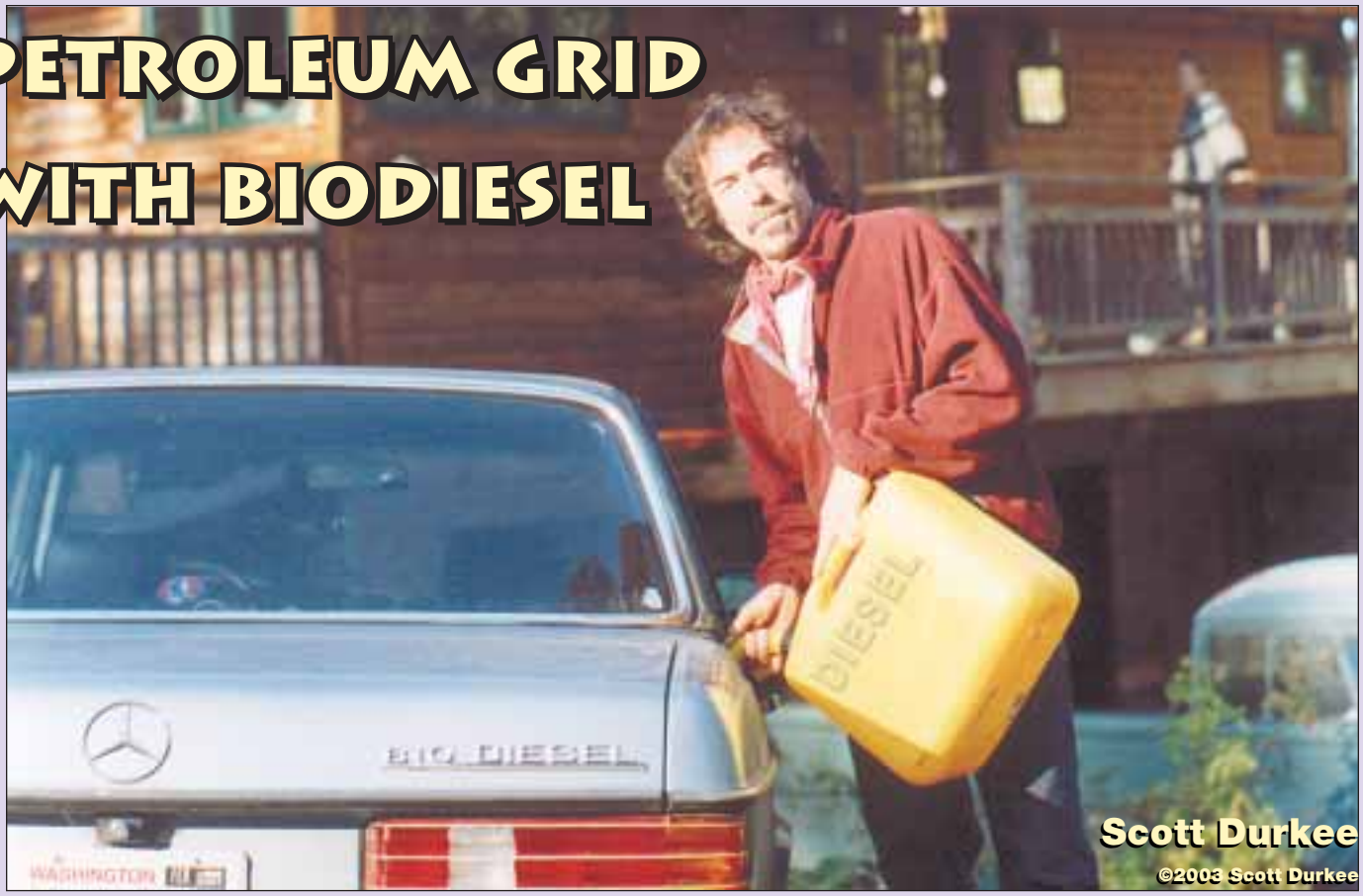
Getting Off the Petroleum Grid with Biodiesel



Scott Durkee topping off his rig with home brewed biodiesel.

Everyone in the renewable energy world talks about "getting off the grid." We all know that it means unhooking our electric umbilical cord from the central power company and making our own electricity. We do it well, harnessing the power of the wind, water, and sun. But what about fuel for our vehicles?

There's another grid that we're all hooked up to, and like energy junkies, hooked on: the petroleum grid. From exploration and drilling to refining and delivery, the petroleum grid is our lifeline.

Imagine a power outage. People on the grid are sitting in the dark, but you have some solar-electric panels, a wind turbine, batteries, and an inverter—and you know how to conserve. Now imagine the same outage, only this time it's an outage of petroleum products—gasoline and diesel.

"D" Is for Diesel

How long will the gas in your tank last? Don't worry, the shortage might not be long. But what are you going to do in the meantime? I don't know about you, but I use my car almost every day. I depend on my car. That's why I bought a 1982 Mercedes 240 D; the "D" is for diesel.

I am a carpenter by trade, and I live on Vashon Island in Washington State. I designed and built my own energy efficient house out of low-impact and recycled materials. One of my goals in life is to live simply and to leave a small footprint on our planet.

As a Peace Corps volunteer working in Nepal and training the local folks in appropriate technology, I lived among people who grow all of their own food, walk everywhere, and harvest firewood for heating and cooking. They use a tiny fraction of the energy that we Americans use. I, too, lived this way for over two years, though I have to admit it's impossible to do it in the United States. Even those of us with the most simple lifestyles don't even come close to the Nepali people.

So we all do the best we can. Since I bought the Mercedes, I've only put homemade biodiesel in the fuel

tank. My car runs better and cleaner than ever, and I can fill it up at home. The biodiesel I make replaces diesel fuel in all ways, except that the exhaust from my car smells like cooking french fries! Some people are even using biodiesel in their oil furnaces.

"B" Is for Biodiesel

Biodiesel is fuel made from vegetable oil. The oil can either be purchased new from a supplier in 55 gallon (208 l) drums, or be obtained used from the fryer of a restaurant (nearly every restaurant has a fryer). My friend Dan Little and I made an arrangement with the local supermarket to collect the used oil from the deli, which we then process into fuel to run our diesel vehicles. The deli produces 26 gallons (98 l) of waste oil per week. We're fortunate that it's canola oil (good for fuel) and that it's changed twice a week. They also strain out the bits of french fries for me, so the oil is clean and relatively pure.

As the test batch settles, two layers appear: biodiesel fuel on top and glycerin on the bottom.

I first discovered biodiesel in the great Northwest, here on Vashon Island. Every year on Vashon, there's a festival called the Island Earthfair, and as the coordinator of the renewable energy exhibits, I had contacted Mike Pelly, a "self-proclaimed, shade-tree chemical engineer." He drove up from Olympia in his biodiesel powered Nissan pickup, towing a trailer with his latest biodiesel-making contraption to demonstrate how to turn used fryer oil into pure biodiesel fuel.

As colorful flags fluttered and a Seattle band played on a solar powered stage, Mike talked to people about his system and his formula. At first it sounded too complicated, but as I listened to him describe the process, I realized that I could do it too.

The best book on the subject that I've seen is *From the Fryer to the Fuel Tank* by Joshua Tickell. This book lays out the whole process, from oil procurement to handling substances to processing glycerin to driving away on your homemade fuel. The recipe I use comes from this book.

Equipment

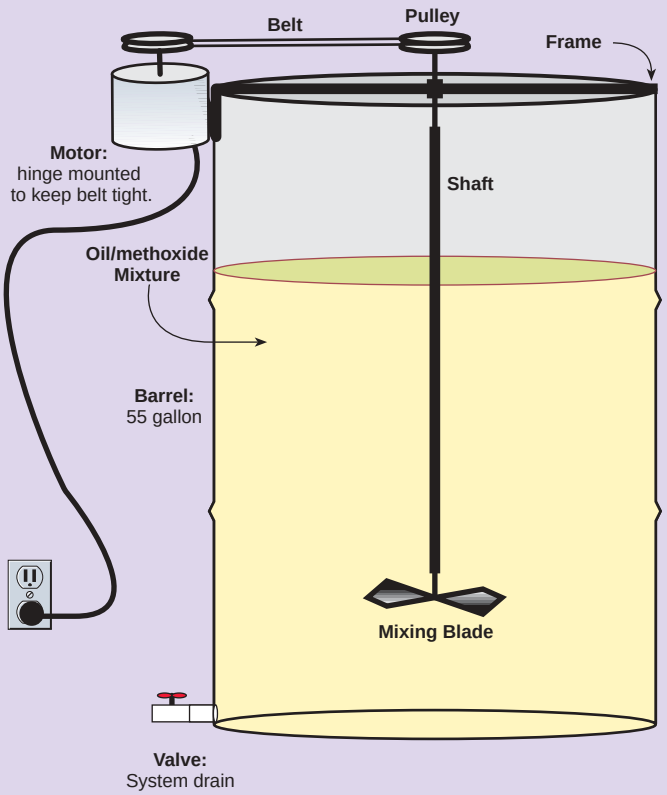
The basic tools and apparatus you will need for making biodiesel are:

- A container for mixing the oil and chemicals
- Some 5 gallon (19 l) plastic buckets
- A device to churn the oil/methoxide mixture

Fifty-five gallon drums (metal or plastic) are pretty easy to come by and work well for mixing the biodiesel. If possible, install a faucet or valve at the bottom of the barrel to drain out the final products. For churning the mixture, I use an old washing machine motor with a belt that turns a shaft. The shaft has a little blade on the bottom that agitates the whole barrel very well—like a big, upside-down blender.

But lately, I've found that it's easier to churn up the oil mixture by using a pump that's suitable for thick oil. Mike Pelly does it this way by pumping the mixture out of the barrel and then right back in. A water pump is mounted above the barrel, with 1 inch intake and outflow hoses in the barrel; switching on the pump begins the agitation. This method thoroughly blends the ingredients with excellent results. Mike bought his pump for US$35 through a catalog called Northern Tool, which also sells suction hoses for US$20 each (one

Biodiesel Mixing Barrel



hose cut in half is sufficient for agitating the oil in the barrel). The pumps are also available through Harbor Freight Tools.

My latest purchase is an American-made, 1/6 hp Water Dragon submersible utility pump that I got for US$80 from the Vashon True Value hardware store. I lower it into the barrel with the oil mixture and plug it in. It works very well to agitate the mixture—and it'll pump out a flooded basement, too! I used this pump, without any hoses attached, to make a 47.8 gallon batch, and the pressure was perfect. For a smaller batch, the pump might need to have a garden hose attached to the top to redirect the spray back into the drum; a smaller pump is also available. I found this solution to be very clean, simple, safe, and easy, though I don't know how well this pump will hold up over time.

The equipment and supplies necessary to make a 1 liter test batch.

Because the making of biodiesel is not yet common, there is no specific design for an agitator, no ready-made equipment for making biodiesel at home. Mike Pelley has been working on processors for over five years and has come up with a nicely refined unit that he hopes to make available for sale soon. So if you don't feel like making your own apparatus, maybe he can provide you with a self-contained unit that will make biodiesel either in batches or continuously. But at present, it's pretty much a do-it-yourself deal, so you'll need to be creative and willing to experiment a bit.

The cost of your equipment depends both on your design and on whether you buy the parts new or used. Check out the cost table for an idea about prices. Again, because there is no set design, you may be able to make your own equipment, using your own design, for less than either Mike or I have done.

The Ingredients

The process of making biodiesel is easy, but it takes some care. The proportions are as follows:

- 5 Parts used or new oil, strained through a window screen
- 1 Part methanol
- Crystal lye, amount determined per batch by testing

In the making of biodiesel, the proportions are very important. Before I begin the mixing process, I determine how much lye to use. This process, called titration, is not difficult, but I'm always very careful to be accurate in my measurements.

To do the titration, I use the following:

- A scale that's accurate from 0.1 to 500 grams
- Graduated pipettes, such as eyedroppers, marked in milliliters from 1 to 25
- Isopropyl alcohol, 99 percent pure
- A 0.1 percent lye/water solution (thoroughly dissolve exactly one gram of lye in one liter of distilled water)
- A small ceramic, stainless steel, or glass bowl for mixing the ingredients
- A small sample of the oil you're using
- Litmus paper to measure the pH (acidity)

To do the titration process, I measure out 10 ml of the isopropyl alcohol into the small bowl, and then add 1 ml of the oil sample and 2 ml of the lye solution. I mix it well with a small stirring stick, and then test the pH with the litmus paper. It will be somewhere around 7 or 7.5. By adding small amounts of the 0.1 percent lye solution—0.5 to 1.0 ml at a time, testing the pH each time—I bring the pH up to between 8 and 8.5.

Once I reach a pH near 8.5, I stop adding lye water. Now, including the very first 2 ml, I note the total amount of lye solution that I used, in milliliters, to reach a pH of 8.5, then I add 3.5 to that number. This is the number of grams of crystal lye per liter of oil that it takes to cause the chemical reaction. This amount could change with every new sample of oil, so I titrate every time I make a batch.

The Test Batch

Before I commit myself and my precious vegetable oil to a full-on batch, I next do a test batch. I do a test batch every time to make sure that the oil separates properly.

Here's how I do it: Using an old blender—one that won't be used to prepare food ever again—I mix 1 liter of used vegetable oil, 0.2 liters of methanol and X amount of lye. (Every batch is different, but it's usually between 5.5 and 6.5 grams of lye per liter of used vegetable oil, and 3.5 grams for new vegetable oil.) First, I mix the lye and the methanol together in the blender, put on the lid, and run it on low for about 5 minutes until the lye is completely dissolved. Then I pour the liter of oil into the methanol solution in the blender.

I run the blender on medium for about 15 minutes. When the time's up, I turn off the blender, pour the mixture into a clear jar, and let it sit for a couple of hours. After an hour or so (this is the fun part), the oil begins to separate into two layers: a heavy, dark layer at the bottom and a honey-colored layer on top.

Safety first—mixing the methanol and lye.

Measuring lye for the test batch. The red spray bottle contains an acidic vinegar solution to neutralize any spilled lye.

The dark substance at the bottom is mostly glycerin with a little wax and some other impurities. Have you heard of glycerin? Do you know what it's used for? One product is soap. You can use this brown glycerin to clean up the mess you've made while making biodiesel in your garage! Glycerin breaks up grease and oil like nothing else on Earth. It's a miraculous symbiotic relationship. (Remember to wear your gloves, when handling the glycerin, until all of the methanol has evaporated off.)

If there is a light-colored middle layer, it is made up of soaps. This layer is not typical and is caused by either

! CAUTION !

You must use safety precautions when mixing the lye and methanol. This is a very dangerous process! It's important to respect both the volatility and the caustic nature of the elements you're working with. You *must* wear a respirator and work in a very well-ventilated room. Wear chemical retardant gloves, long sleeves and long pants, good shoes, and safety goggles. Some folks like to use a chemical resistant apron and long-sleeved gloves for an extra measure of protection. If any of the methanol or lye gets on your skin, wash it off immediately. It's wise to have a spray bottle of vinegar handy to neutralize the alkaline lye mixture. Mixing methanol with lye creates sodium methoxide, which can cause nerve damage. *Don't breathe it!*

Scott Durkee going for a big batch—adding the sodium methoxide to the used vegetable oil that will soon be biodiesel fuel for his Mercedes 240 D.

using too much lye (catalyst) or by water somehow contaminating the mixture.

The top layer is biodiesel fuel. It's a pale, honey-colored liquid and, after settling for five or six days, it is ready to pump right into your fuel tank.

Now the Real Thing

If the mixture from the blender separated properly, it's time for the real thing. Using the same proportions as I did with the test mixture in the blender, I can mix a full batch. Any size batch is okay, as long as the proportions are the same. For example, using 100 liters of oil mixed with 20 liters of methanol and 550 to 650 grams of lye, the same separation will happen. But because it's in a barrel, I won't be able to see the layers.

When making the full batch, I'm always sure to mix the lye into the methanol very well. I pour the methanol into a 5 gallon bucket, then the lye, and then I churn the clear mixture with a paint stirrer in my drill motor. (See Caution sidebar.) I've drilled a hole in the lid of my 5 gallon bucket, and I put the paint stirrer through the hole before I put it in the drill. Then with the bucket covered, nothing sloshes or splashes out of the bucket while I'm mixing.

Once the lye is completely dissolved, I carefully pour the clear methanol/lye mixture into the drum of oil—still wearing my respirator and protective clothing—and then turn on the agitator or pump to begin the agitation. After it's been churning for 90 minutes, I turn off and remove the agitator or pump, then let it sit quietly to allow the mixture to separate out into biodiesel fuel and glycerin.

Partial separation will occur after about 5 hours; 99 percent separation could take as long as 24 hours. At some point—depending on the oil, the amount of lye used, and the temperature—the glycerin will begin to harden, to gel. Just before this happens, it's possible to drain off the liquid glycerin into a bucket. That's why it's good to have a valve on the bottom of the barrel. I can open the valve and drain out the dark brown, liquid glycerin.

Mike likes to use a water heating element in the barrel to keep the temperature at around 130°F (54°C), both to speed up the chemical process and to ensure that the glycerin will still be in liquid form after 24 hours. This electric element is available at any hardware store for under US$15 and can be plugged into a 120 VAC outlet. I think it's a good idea, and during the winter, I will heat my barrels, too.

But currently I just let the mixture settle overnight in the production barrel, then pump it into a settling barrel to sit for a week or so. From the settling barrel, I pump it into my car. Since most of the glycerin settles in the first 24 hours, at the bottom of the production barrel there is a thick disk of gelled glycerin that I slice into quarters and, wearing rubber gloves (because it still contains some methanol), scoop out. After a week, at the bottom of the settling barrel there will be some traces of glycerin, so it's important not to take the fuel from the very bottom of the barrel.

Remember, the top of the barrel has been cut open to allow access for the shaft or pump, so it's easy to reach to the bottom to get at the glycerin. Hey, at least the cleanup is easy: It's all soap! You will, no doubt, have your own experience with the glycerin and biodiesel, and you will learn how to deal with the separation.

Durkee Biodiesel Start-Up Costs

Equipment	*Cost (US$)*	*Yellow Pages Heading*
Shaft, frame materials, & welding	$145	Welding/Welders
Scale, 0.1 to 500 grams	125	Laboratory Equipment
Motor, 1/2 hp	100	Electric Motors
Bilge pump	55	Marine Equipment
2 Drums, 55 gal.	50	Barrels/Drums
2 Pulleys	40	Bearings
Respirator	25	Hardware
Electric water heater element	20	Hardware
Filter canister	15	Gasoline & Oil Marketers
4 Plastic buckets, 5 gal.	14	Hardware
Drill, used	10	Thrift Shops
Paint stirrer	7	Hardware
Fan belt	7	Auto Parts
Gloves, chemical resistent	7	Hardware
Valve	5	Hardware
Blender, used	5	Thrift Shops
Filters	5	Gasoline & Oil Marketers
Litmus paper	4	Pharmacies
Safety glasses	3	Hardware
Bowl	2	Grocers
Spray bottle	2	Hardware
Vinegar	2	Grocers
Graduated pipettes	1	Laboratory Equipment
Total for Equipment	$649	

Ingredients

Methanol, 55 gallons	$102	Gasoline & Oil Marketers
Lye, 510 grams	4	Grocers
Isopropyl alcohol, 99% pure	1	Pharmacies
Used vegetable oil	0	Grocers or Restaurants
Total for Ingredients	$107	
Grand Total	$756	

Clean, simple, and safe—a pump can be used to agitate the oil mixture too.

Cleanly into the Fuel Tank

If I am able to drain the bottom layer from the barrel, I'll see the color change from dark brown to honey-colored; that's when I close the valve. I set the glycerin aside and get out my fuel can because the next thing to come out of the barrel is biodiesel fuel. (If there is a soapy layer, the fuel may need to be washed with water, a process explained on the journeytoforever.org Web site.)

For each batch of fuel I make, I consistently get about 85 percent biodiesel and 15 percent glycerin; I get almost no soaps because the oil I use is so clean and I titrate very carefully. A good rule to estimate your yield is that the amount of fuel produced will be equal to the amount of vegetable oil used in the process.

When I use a pump to mix the oil and methanol, I drain it afterwards, and then flush it out with plain vegetable oil; otherwise the glycerin will set up inside the pump. But, if the glycerin sets up in my new submersible pump, it's no big deal because I can just place the pump in a warm water bath, melt the glycerin, and then wash it out. The pump will be a lot cleaner too!

I don't worry if there is any glycerin in the fuel at this stage because it will always separate out and sink to the bottom; then I can recover the pure biodiesel from the top. I put only the pure biodiesel in my fuel tank! Using a little 12 volt marine bilge pump, I transfer the fresh biodiesel into another 55 gallon drum to let it sit for a week, so that any excess glycerin and other impurities

can settle to the bottom of the barrel. These can easily be washed out once the fuel is pumped or syphoned into another barrel.

When I need a fill up, I pump it through a filter and a meter right into my Mercedes. Pumps, filters, and hoses are available at pump equipment supply stores. The cost of a hand-cranked pump is about US$100. A filter and refills are US$25 and US$5, respectively. Pumps are not absolutely required, but they make the job easier.

So, does it save me any money? I buy methanol for US$1.85 a gallon (3.8 l) and I use 7.8 gallons in a 47.8 gallon batch—that's 40 gallons (150 l) of

Function and education on the go—Mike Pelly and his biodiesel trailer.

AUTOMOTIVE TIPS

After running your first tank of biodiesel, you will have to change your fuel filter. Biodiesel cleans out all the petroleum sludge in your fuel system, which can then clog up the filters. While you're at the parts store, you might as well buy two filters; you'd be surprised how dirty petroleum diesel is! I recommend buying a little clear glass filter with a removable element that can be cleaned using biodiesel. Install this filter in front of the engine's stock filters. Once the filters are cleaned, you probably won't have to clean them again for quite a long time—as long as you don't use petroleum diesel again.

Older diesel engines—from the late 70s and earlier—are equipped with rubber hoses and seals. Over time, the methanol in the biodiesel will dissolve these parts. But in newer engines the hoses are synthetic and are not affected by methanol. The rubber parts in older engines can be easily replaced with synthetic parts.

Like petroleum diesel, biodiesel will gel in colder weather, but at a slightly warmer temperature. Fuel additives to prevent gelling—winterizing agents—are available at auto parts stores, and can be used with biodiesel just as they are with petroleum. I've had a jar of biodiesel in my fridge for several days at 37°F (3°C), and it has remained beautifully liquid—without the addition of any antigelling agents. Depending on the type and quality of the used vegetable oil, the amount of lye used, and the resulting fuel quality, biodiesel could begin to gel at 45°F (7°C). More impurities will cause the fuel to gel at a higher temperature.

There's a simple test I do for impurities in the fuel. I pour 1/2 cup of water and 1/2 cup of my biodiesel into a small glass jar with a lid. After shaking the jar thoroughly, I set it aside in a quiet place. After an hour or so, the mixture will begin to separate out into three layers: biodiesel on the top, a thin layer of impurities in the middle, and water on the bottom. Since the oil I use is so clean, the middle layer in my jar is always paper thin.

If biodiesel is not made using the proper proportions, the resulting fuel could be damaging to the engine. For example, if too much lye is used, a thin skin of gel will form over the fuel in the barrel; and after it's skimmed off, it will form again and again. This fuel should not be used. If too little lye is used, the reaction won't take place fully and the separation will be incomplete.

Burning biodiesel will reduce the overall emissions from your car or truck substantially. The only element in your exhaust that may increase is nitrous oxide, which is one of the irritants in diesel exhaust. But, by retarding the timing in your engine, you can eliminate this increase, too. In Europe they use a catalytic converter, which reduces the nitrous oxide to below normal levels. There is sometimes a 5 percent loss of engine power, but that's made up by a more lubricated, smoother running engine.

Scott's used veggie oil collection rig with barrel and pump.

used canola oil and 7.8 gallons (30 l) of methanol—for a total of US$14.43. Lye costs about US$4.00 for a 510 gram bottle and I use 6.25 grams per liter of oil, which equals 937 grams per batch. That's US$7.35 in lye. The oil is free. Total cost of the ingredients? US$21.78 for about 40 gallons of biodiesel, which works out to 54 cents a gallon (14 cents per liter). Not bad!

Don't be surprised if, while you're pulling into a parking lot in town, someone comes up to you to ask about the smell coming from your car. My friends find it hard to believe that I actually run my car on recycled vegetable oil. I don't make biodiesel to save money—although if I don't figure in labor or overhead, it certainly does. I do it so that I can run my car on a sustainable fuel, one that can be created in one season (on a farm) as opposed to over millions of years (fossil fuels)—and I do it to reduce air pollution.

Since I started making biodiesel, I've found that my driving habits have changed a little, too. Though I still try to combine my errands so that I only have to make one trip into town, I don't mind driving my children across the island to play with friends or volunteering to be the one to do the carpool. I figure it's better if I drive because, unlike the other cars on the road, I'm off the petroleum grid. My car runs on renewable energy.

Access

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From the Fryer to the Fuel Tank: The Complete Guide to Using Vegetable Oil as an Alternative Fuel, by Joshua Tickell, ISBN 0-9707227-0-2, 176 pages, US$29.95 from BookMasters, PO Box 388, Ashland, OH 44805 800-266-5564 or 419-281-1802 • tickell@veggievan.org www.veggievan.org

Island Earthfair, PO Box 404, Vashon, WA 98070 206-463-1725 • www.islandearthfair.org

Northern Tool & Equipment Co., Inc., PO Box 1499, Burnsville, MN 55337 • 800-556-7885 or 952-8994-9510 • Fax: 952-882-6927 www.northerntool.com • Pump and hoses

Harbor Freight Tools, Inc. • 800-444-3353 or 805-388-3000 • Fax: 800-905-5215 or 805-445-4912 cs@harborfreight.com • www.harborfreight.com

Good biodiesel Web site:
www.journeytoforever.org/biofuel.html