FNE03-453

HEATING YOUR GREENHOUSE WITH FARM-MADE BIO-DIESEL

We have been growing certified organic produce on our small farm in northern Vermont for ten years. We currently grow about forty types of vegetables on about three acres and market our produce at several farmer's markets, grocery stores, and restaurants. Being located on the line between zone 3 and 4 means that greenhouses and cold frames are essential to our success. We currently have three heated greenhouses and two unheated steel cold frames.

One small 1000 square foot greenhouse is used, primarily, to produce transplant plugs for field production. The other two heated structures provide a little over 1300 square feet of growing space each, which is devoted exclusively to tomatoes, our farm's most important source of income. The importance of these growing structures cannot be overstated. We get a big jump on the growing season by starting over half of our crops in the seedling house. We also grow a few plugs for early income as nursery stock.
Greenhouse tomatoes also bring in customers to our stand at the farmers markets who will buy additional items while they are there. The tomatoes are started in the seedling house and transplanted into the ground in the tomato houses, spending their entire productive lives in the greenhouses. We start getting red ripe tomatoes for sale by the third week in June and continue selling them until other growers start bringing in field fruit in late August. At that point we remove the plants, amend the soil with compost, and seed salad greens ingredients for harvest through late fall when hard frost and the occasional snow, and generally cold weather render poor quality greens. Salad Mix is a close second source of income, and the last to succumb to winter.

Over the years we have fueled different greenhouses with a variety of fuels including propane, heating oil, and wood. All fuels have various advantages and drawbacks. Our fuel concerns center around three issues: environmental cost, financial cost, and our time.
Our farm has a nearly limitless supply of firewood. Most of the 44 acres we live on is forested, so wood seems a logical choice as a fuel and, from a financial standpoint it makes sense. On the positive side wood is renewable but the time spent cutting, splitting, not to mention getting up at 2 or 3 in the morning, heading out to the greenhouse through the snow to stoke the fire in April left us feeling less enthusiastic about using wood as a fuel for greenhouses.
Heating oil left me feeling more frisky in the mornings…plenty of sleep and hey, with the fuel company delivering the stuff…it was pretty much hassle free! But there was the expense, both in terms of money and in terms of environmental cost.
As our customers reminded us at our stand, " We love these tomatoes, they're so tasty and we love your commitment to growing them organically, but how do you get them so early, how do you heat your greenhouses? Oh, oil furnaces…hmmm…how about that fuel oil spill off the coast of Spain last week isn't that awful"?
And it is. A quick check of inter-net sources reveals hundreds of spills all over the world in just the last 20 years. There is also the looming issue of global warming. Taking fuel from a carbon sink where it has been safely out of the way for millions of years and throwing it into the atmosphere, eventually making us all feel like we are under doubled 6 mil poly for the rest of our lives is not a smart move.
Propane, a reliable fuel, tends to be less efficient to heat with and so ends up costing more than oil heat. Though it does not create the same havoc as spilled oil it is also environmentally costly when one considers that it is still part of the larger energy infrastructure and its CO_2 emissions are as damaging as those of oil.

Bio-diesel, on the other hand hasn't been implicated in any spills, and if spilled, is biodegradable; Nor is it lying in vast reserves under wildlife refuges. And no one is invading countries for access to their vast reserves of used fry oil. Not yet in any case. Additionally, it is carbon neutral. The CO2 that is released upon burning bio-diesel was taken out of the atmosphere in the recent past by the plants that produced the oil this fuel is made from. In other words it is part of the present atmospheric carbon load unlike petroleum products whose carbon has been effectively out of circulation for the last several million years. Additionally bio-diesel doesn't add any sulfur dioxide, or lead to the atmosphere.
So Bio-diesel is an environmentally benign alternative fuel. But we still had questions regarding cost and could we use it to heat our greenhouses?

About the time these questions were on our minds I had the opportunity to work on an organic farm for a winter in Hawaii where I did the tractor work. We weren't heating any greenhouses there, but using and maintaining the Kubota tractor, and running it with purchased bio-diesel made it seem like a pretty reliable fuel alternative. However the cost, at $2.50 a gallon, was pretty steep compared to diesel unless you are growing ginger with a return of $8 a bed foot. Since we wouldn't be growing ginger in northern Vermont until global warming really took off, it looked like buying bio-diesel would be a little out of our reach.

An article on using bio-diesel to heat campus buildings at the Chewonki Foundation in Wiscasset, Maine captured our attention- the fact that home-made bio-diesel could be used for producing heat, not just to run tractors and vehicles, really made an impression on us.

Following our return to the chilly northeast we applied for and received a grant from the Sustainable Agriculture Research and Education Farmer/Grower grant program to look at the economics of producing and using bio-diesel for our greenhouses over the 2003-growing season. We already knew that bio-diesel was a cleaner burning fuel than diesel or heating oil. We wanted to find out whether it made financial sense to make it ourselves. And of course would we have the time to produce this fuel? Armed with Joshua Tickell's book, "From the Fryer to the Fuel Tank, The Complete Guide to Using Vegetable Oil as an Alternative Fuel" and our SARE grant, we dug in and got to work!

At the time that we began producing bio-diesel the cost of heating oil in our neck of the woods was $1.40 a gallon. From our records of growing tomatoes under plastic we knew that we would be using about 350 gallons of fuel oil to keep each 1300 square foot house at 70-75 degrees from the middle of April to the middle of September. Some simple math reveals that we would spend almost $1000 to heat both our houses. How much would it cost us to make 700 gallons of bio-diesel, and could we, as busy growers, handle the extra time it would surely involve?

First of all how is bio-diesel produced? Basically bio-diesel is made from vegetable oil either new or used. It is heated and a mixture of methanol and lye is added to the oil. This combination is mixed for an hour. It is then allowed to sit for 8 to 12 hours allowing the byproduct, glycerin, to settle to the bottom of the mixing tank. After all the glycerin settles out it is drained off leaving the ready to use fuel, which is then transferred to the furnace fuel tank.

Equipment Costs:

(1) 110 gallon plastic mix tank w/valve drain----------$135.08

(1) Corrosion resistant pump----------$162.50

(1) Steel Tank stand for mix tank----------$ 85.71

(1) Digital Scale----------$122.00

(1) ¾ hp electric motor and mixing shaft w/clamp mount------$258.00

(1) 2 burner propane hotplate for heating oil----------$ 80.00

(2) 20 gallon plastic totes (mixing and lye storage)--------$ 20.00

(1) ½ inch electric drill----------$135.00

(1) dry wall mix blade for mixing methoxide----------$ 15.49

(2) 55-gallon steel drums----------$ 10.00

(1) Dial Thermometer Compost type 36inch----------$ 89.90

(1) 20 foot length 1 ¾ inch reinforced plastic tubing-------$ 40.00

(4-5) plastic 5 gallon buckets----------$ 20.00

(1) squeeze hand pump----------$ 4.29

(1) Hydrometer----------$ 10.60

(1) Rotary style heavy duty hand fuel pump----------$100.00

(1) digital pH meter----------$ 44.00

(1) electric kitchen blender----------$ 80.00

(1) Case of 12 20ml beakers----------$ 26.95

(2) 500ml beakers----------$ 6.10

(3) 2000ml plastic beakers----------$ 17.05

(1) 1000ml graduated cylinder----------$ 12.90

(1) case of graduated droppers----------$ 19.10

TOTAL EQUIPMENT COSTS----------$1494.67

SUPPLIES AND INGREDIENT COSTS

10 pair Pantyhose for filtering oil and bio-diesel----------$ 30.00

10 pair dishwashing gloves----------$ 15.00

1 set of raingear (protective clothing multi-purpose)-------$ 45.00

6 rolls paper towels---------- $ 8.50

Gas to pick up used vegetable oil----------$ 30.00

Used Vegetable oil----------$ 0.00

165 gallons methanol----------$265.50

50 pounds Sodium Hydroxide (lye)----------$ 43.73

TOTAL SUPPLY AND INGREDIENT COSTS----------$437.73

TOTAL COST FIRST YEAR----------$1932.40

COST PER GALLON FIRST YEAR----------$ 2.76

EQUIP COSTS EXTRAPOLATED OVER 10 YEARS----------$ 149.47

TOTAL COST PER YEAR W/EXTRAPOLATED COST----------$ 587.20

COST PER GALLON W/EXTRAPOLATED COSTS----------$ .84

Average cost of heating oil April-September, 2003*----------$ 1.38

Total cost for 700 gallons heating oil 2003 season---------$ 966.00

Savings using Bio-diesel----------$ 378.80

From a simple economic standpoint it would seem to make sense to produce your own fuel for your greenhouses as we would have spent 40% more for heating oil for the same period*.

However, as anybody in farming is aware, the outright costs are only part of the equation. There is never enough time to do everything that needs to be done. Using commercially available heating oil is expensive and environmentally costly, but it is EASY, and the farmer may well decide that they cannot take on one more time consuming task. Growers considering making and using bio-diesel must weigh the advantages…cost, environmental soundness, and marketing to an environmentally aware consumer against the time it takes to process this fuel.

* Data on home heating oil for the 2003 growing season from Fred's Propane and Heating Oil, Lyndonville, Vermont. Personal communication.

I've broken down the time spent in making bio-diesel into 4 categories.

1) Collection of waste vegetable oil
2) Titration and making test batches
3) Processing large batches
4) Transfer of fuel to tanks

1 COLLECTION OF WASTE VEGETABLE OIL

I collect waste vegetable oil (wvo) from two local diners. These two places are preferred because they filter their used fry oil and store it in the plastic 5- gallon containers the vegetable oil originally came in. It is easy for me to pick up these containers on a weekly basis in the back of my pickup truck. I have received offers of wvo from other sources that I ended up turning down because of poor quality product…ie: water in the oil or unfiltered oil with a lot of solids in it. I have two other recent sources that are joining forces to actually deliver the oil to our farm! I have not charged for picking up wvo as some other bio-diesel producers have suggested, since we are already benefiting from the product they are providing. Normally diners and restaurants pay a substantial fee to a waste removal service to take the wvo.
Since it is an hour round trip for me to pick up the oil once a week, I almost never make the trip just for the oil. I combine any other town chores to make the trip more efficient. This is why the cost for gas in picking up the wvo listed under supplies and ingredients is so low. Additionally one of the diners is conveniently located directly behind one of the farmer's markets we attend so pick up there during the market season doesn't involve an extra trip at all. We just toss the jugs in the truck before we leave the market. We receive about 30 gallons of wvo from our two main sources each week. Although we combine wvo pickup with other chores lets allocate a full one-hour to this category.

2 TITRATION AND TEST BATCHES

Doing the titration is necessary to determine the amount of NaOH (Lye) to use in the test batch and during the actual processing later.
Doing a test batch or mini batch is simply a way to test the results of the titration without committing to a 50- gallon error.
The titration is accomplished by dropping NaOH solution in one ml increments into a solution of wvo and isopropyl alcohol. The pH of the solution is checked after each 1 ml is added. When pH jumps to around 8 or 9 the titration is considered finished. A simple calculation reveals how much lye to use in the mini batch. The titration usually takes me about 30 minutes, including cleanup time.
Doing a test or mini batch involves blending a liter of wvo with a mixture of methanol and lye. The methanol and lye are mixed first yielding methoxide. The methoxide is then blended with the wvo for 15 minutes. The whole blending process and cleanup takes about another 30 minutes. I pour a liter of the mixture into a large graduated cylinder for settling. Most of the settling occurs in the first 90 minutes so you have a pretty good idea of how the process went well before the

full 8 hours of settling time are over. Making the test batch takes about 30 minutes not counting the settling time.

3 PROCESSING LARGE BATCHES

Doing the big batch goes like this: I fill a steel 55 gallon drum with 50 gallons of wvo, filtering it through a pair of pantyhose to remove any solids that are in the oil. The steel drum is set up on three cinder blocks above a two- burner propane hotplate. After filling the drum the oil is heated to 120 degrees F. This takes about 1 1/2 hours. While the oil is heating put 10 gallons of methanol and the appropriate amount of lye into the 20 gallon mixing tote. The amount of lye will vary depending on the results of the titration, and test batch. You may end up using between 30 and 50 ounces of lye for a 50- gallon batch. Exercise great caution when handling the methanol and lye. Methanol is highly toxic, and lye is extremely caustic. You don't want this stuff on your skin!

I drilled a hole in the center of the lid that fits onto the tote so that I could pass the drywall mixing rod through the lid and into the ½ inch drill. Using the drill and mixing blade I mix the methanol lye solution for about 5 minutes until there is no unmixed lye left. Note that the lid stays on the mixing tote…the methoxide fumes are caustic and very bad to breathe. A respirator *is recommended!*

When the wvo is up to temperature I pump it into the mix tank where it is combined with the 10 gallons of methoxide, and mixed with the electric motor and mixing rod combo. The mixing takes about an hour and I always use this time to clean up or work on some other task. Once the mixture has been agitated for an hour the mix motor is turned off and the reaction is allowed to go to completion and settle for 8 to 12 hours. As soon as the mixer is turned off I immediately take a one-liter sample so I can see how well the reaction went. My mix tank is opaque which I thought would allow me to see the glycerin settling out but the plastic is just too thick to see through. Instead, we just take the sample and put it into a 1 liter graduated cylinder which is *easy* to see through! Not only is this sample handy as a visual indicator of how your batch has turned out you can also test the viscosity or specific gravity with a hydrometer. Bio-diesel has a specific gravity of around 0.88 at room temperature.

I usually get about 10 gallons of glycerin as a byproduct. The rest is bio-diesel! We have a stopcock type valve on the bottom of the mixing vessel, which is handy for draining off the liquids from the bottom as opposed to having to pump or siphon from the top. I drain the dark thicker glycerin into the same 5- gallon jugs that the vegetable oil came in when I picked it up at the diners. As I am drawing off the byproduct we watch for the color and viscosity change to a thinner golden colored liquid typical of bio-diesel fuel. At this point I draw off the fuel into clean 5 gallon buckets and empty them into a 55 gallon drum that is already stationed on the 3 point hitch platform that attaches to the back of the tractor.

The heating, mixing and drawing off into the transportable drum take about 3 hours.

4 TRANSFER OF FUEL TO TANKS

Now that I've made 50 gallons of bio-diesel I can put it directly into the fuel tanks that I have inside the greenhouses. My fuel storage consists of standard 275- gallon oil/kerosene fuel tanks that are available new through most fuel companies and used just about anywhere.

With the new fuel in our transport drum and the lid clamped down tight we are ready to move the fuel to the greenhouse. It is a simple matter to back the tractor up, attach the platform, and bring the fuel around to the back of the greenhouse. I pass the delivery end of the rotary hand pump hose through a flap in the end wall plastic and into

the fuel tank, and start pumping. It takes me about 15 minutes to get the fuel from the barn and into the fuel tank.

All together it takes about 5 ¼ hours of actual work time to make and move a 50 - gallon batch of bio-diesel. Making larger batches seems the logical way to cut down on the time involved.

LOCATING THE FUEL TANKS

I locate the tanks inside the greenhouses because it is best to keep this fuel warmer than heating oil. Bio-diesel has a higher cloud point than does heating oil/diesel. This means that bio-diesel will cloud up, eventually gelling at warmer temperatures than heating oil/diesel. Standard heating oil/diesel will cloud at 20 degrees F. Bio-diesel cloud points are highly variable depending on the oil they are made from. Bio-diesel fuel made from used vegetable oil will cloud at higher temps than that made from unused vegetable oil. Since clouding and gelling will negatively affect furnace performance a couple of strategies are recommended.

As most people who live in the north and heat with oil are aware fuel companies will blend kerosene with their product as winter approaches. The kerosene lowers the gel point of the oil it is blended with. Likewise, bio-diesel can be blended in any ratio with fuel oil or kerosene with no ill effects. Or one might choose to use standard heating oil early in the season and go back to bio-diesel when warmer weather arrives.

I decided to move our fuel tanks inside the greenhouses to keep the fuel at a nice warm temperature so I would not have to rely on blends to keep my fuel liquid. We have tomato plants in the ground in the houses in April when there is still plenty of seriously cold weather and snow on the ground outside. I don't want to risk the nightmare of having the furnaces quit on a frigid night just when we need them the most! Of course we are changing our seeding house over to a bio-diesel fueled furnace this year. That house is up and running by the first of March when it is not unusual to see nighttime temperatures below zero here in the northeastern part of Vermont. So moving the tanks inside is a logical step.

There are regulations for distance between fuel tanks and furnaces. This distance is 60 inches. However it should be noted that diesel heating oil has a flash point of 125 degrees F while bio-diesel's flash point is much higher, 301 degrees F so while diesel is listed as explosive bio-diesel is not considered explosive under normal circumstances. Still we try to maintain some distance between the fuel tanks and the furnaces.

PROBLEMS WE ENCOUNTERED

We ran into a problem after we became over confident and stopped doing test batches. One day the furnace in one of the houses just quit! Although this was toward the end of the summer when we were just taking the edge off the nighttime lows it certainly caught our attention!

We removed the fuel filter between the tank and the furnace and found it was completely clogged with a jellylike substance. We had, over the course of the summer, become so confident in our basic "recipe" that we started eliminating the titrations and test batches…BAD MOVE! We had made <u>soap</u>, which actually burns quite poorly (surprise), and clogs fuel filters. In the system we had in the other greenhouse there was no fuel filter at all! This furnace also stopped working. The pores in the fuel nozzle on the "gun" were clogged, and the nozzle had to be replaced. At this point I learned not just a little lesson on oil furnace mechanics but also…DON'T SKIP THE TITRATIONS, DON'T SKIP THE

TEST BATCHES! If this had happened early in the season when we needed those furnaces for severely low temperatures we would have been looking at some severely reduced farm income! Fortunately this wasn't the case and the cost for a new filter cartridge and a new nozzle put us back by less than $8.

The only other hurdle we would like to overcome is the issue of the amount of time it takes us to produce the fuel we need for our greenhouses. If it takes us over 5 person hours to make a 50 gallon batch, and if we value that time at $10 per hour, that adds a steep dollar per gallon to our costs! OUCH! The only way to get around this, we believe is to make larger batches. It would take very little extra time to double or triple our batch size, effectively reducing time per gallon by ½ or2/3.

In any case, knowing that we can produce a bumper crop of early tomatoes for our customers at our markets and not have to depend on petroleum fuels to do it feels pretty good. Saving 25 to 40% on our fuel bills just makes it that much sweeter.

Recommended reading: From the Fryer to the Fuel Tank, The complete guide to using vegetable oil as an alternative fuel. By Joshua Tickell, published by Tickell Energy Consultants, Covington, LA 2000