An Analysis of On-Farm Feed and Fuel from Dryland Camelina

By Thomas Foulke, Milton E. Geiger, and Bret Hess

Abstract

Concern over rising and volatile energy prices, the desire for personal energy independence, and the promotion of cleaner energy sources has led many farmers to consider oilseed crops as a source of biodiesel. Analysis of the economics of on-farm biodiesel from dryland camelina (*Camelina sativa*) shows that camelina meal is the primary product. The cost savings of using meal as livestock feed accounts for most of the value. Both individual and group ownership perspectives are addressed. Combining resources to achieve maximum output results in a more efficient process and allows each producer to have less capital outlay.

Introduction

Concern over rising and volatile energy prices, the desire for personal energy independence and the promotion of cleaner energy sources has led many farmers to consider oilseed crops as a source of biodiesel with its concomitant feed and fuel components. Most recently, the "Arab spring" has brought with it social unrest in a region crucial to world oil supplies. In this environment, it makes sense to revisit the potential for on-farm biodiesel production to understand when and if it can be economically viable for dry land farmers to consider investment in the process. Additionally, previous research has shown that the scale of operations may also be an important factor in profitability.

Evidence of camelina (*Camelina sativa*) a brassica, cultivation in Europe has been found from 5,000 years ago (Putnam et al, 1993). However, it is a new crop for the western United States where cultivation began in the 1980s (McVay & Lamb, 2008). More recently, there has been increased interest in camelina as an input for biodiesel production and supplemental feeding of the meal to livestock. This paper investigates the economics of on-farm biodiesel production from the oilseed, camelina, at two different on-farm scales: the individual producer; and a multiple-ownership or "neighbor" level (three producers in local proximity). We also address some of the barriers that arise from an attempt to move to the "community" production level. This paper is an outgrowth of a Western Sustainable Agriculture Research and Education (W-SARE) grant to evaluate camelina as a suitable crop for fallow replacement in a dryland cropping system and to evaluate camelina for feeding and biodiesel applications.

The authors are a Senior Research Scientist, Extension Energy Coordinator, and a Professor respectively at the University of Wyoming in the College of Agriculture & Natural Resources, Laramie, Wyoming.

The economics of on-farm biodiesel have been investigated by Sawyer (2007), who found that on-farm biodiesel was uneconomic at current petroleum diesel prices. Kingwell and Plunkett (2006) also addressed on-farm production in western Australia. They also found that on-farm biodiesel was currently uneconomical to produce. Their work showed that the key driver of potential profitability was having an inexpensive feedstock for production. Bender's (1999) review of 12 feasibility studies showed that production costs for biodiesel were greater than pre-tax diesel prices in the U.S. His paper focused mainly on community and industrial scale production.

Although these papers investigated the economics of biodiesel production, they treat meal production as a by- or "co-product," with transportation costs incurred and without regard to its utilization. If the meal is truly a "co-product," then some thought should be given to the disposition of the meal prior to sizing a biodiesel facility. Camelina was previously evaluated by Foulke and Hess (2010) for an on-farm biodiesel production system. The authors take the view that producers should consider oil seed (in this case, camelina) meal and biodiesel production as a complete system and size their operation accordingly. This means having the land resource to grow the crop and the animals to consume the meal on-farm. This minimizes meal transportation costs. Indeed, as we will show later, the cost savings of not having to purchase and transport livestock feed accounts for most of the economic value in the production system.

Methods

The systems approach begins with defining the parameters of the system. A spreadsheet-based "calculator" developed by Foulke and Hess (2010) for camelina has been refined for a more detailed comparison between different levels of operation. Whereas previously, the authors were only concerned with profitability on an individual basis and with experimentally derived yields, here we use a yield more comparable to the average yield for the state of Montana (NASS, 2010). We also expand the use of the highest cost capital component of the system, i.e., the press, to its maximum sustainable capacity in order to increase efficiency; and share the capital cost among a number of neighbor investors.

Figure 1 shows a schematic of how the system is structured. Traditional economic analyses of agricultural enterprises often consist of enterprise budgets to analyze the costs and returns from specific activities. Our approach is similar to a "whole farm" approach in that parts of this enterprise are dependent on other enterprises. The system starts with planting camelina, followed by harvesting and crushing the seed. This results in two products: camelina meal and oil. Since the majority of the output of the process is meal (in terms of weight and volume), meal becomes the primary constituent and should be consumed as close to the point of production as possible to avoid transportation costs. Therefore, having enough animals locally to consume all the meal annually produced is essential and should be an investor's first concern.

It should be noted that until November, 2009, FDA regulations restricted camelina meal supplemental feeding to two percent of a dry matter ration for cattle. Camelina contains a naturally high level of erucic acid (4-5%) (Pilgeram et al, 2007). That restriction has now been raised to 10 percent for ruminants, based on further research (FDA, 2009).

Costs and returns of growing camelina are estimated on a model 4,400 acre dryland farm, hypothetically located in the state of Montana. The farm consists mainly of wheat/fallow dryland crop land. Cropping costs and returns are evaluated using a spreadsheet program developed by Montana State University Extension (Montana, 2010) which analyzes tillage types and cropping mix. The price of diesel fuel reflects the four-year average (2007-2010) U.S. pre-tax diesel price of $2.62/gallon (EIA, 2010). The camelina yield is set at 600 pounds per acre (lbs/ac) which is slightly above the 2008 Montana average yield of 546 lbs/ac (USDA, 2008). Long-term yield information does not exist. The price of camelina is set at the latest reported average Montana camelina price (2007) of $9.18 per hundred weight (cwt) (USDA, 2008). All other parameters in the spreadsheet remain unaltered.

These estimates are used as an input in the spreadsheet calculator. This model uses economic information and assumptions from the growing and feeding enterprises and combines it with biodiesel production information. The calculator is designed to be adaptable to other types of oilseed crops as well. Production estimates for oil and meal are used in conjunction with prices for other types of comparable meal substitutes to generate a range of alternative feed costs to compare with the costs of growing and feeding camelina. Cost comparisons with camelina are important because the market for this oilseed is not well developed. Comparisons can be made between three different rations: a substitute ration of one-half corn, one-half soybean meal; linseed meal, canola meal, and an estimate of growing; and pressing costs for camelina. Due to a lack of data, we use an estimated value of camelina meal based the average of the price of canola meal and linseed meal. Under this assumption, camelina meal is valued at $0.119/lb. Price data for camelina oil isn't available, so we use an implied price based on the estimated price of the meal and the growing costs for camelina with oil as a residual of the meal production process. Using this method, we estimate the value of the oil to be $2.49/gallon.

The model operates at the capacity of the press. Indeed, the model is built around press capacity, since the press is the most expensive piece of capital equipment in the system ($12,500). Within the model, total costs can be viewed as those costs that a single producer/investor would face. To try and determine if any economic efficiency could be found, a multiple ownership scenario for the capital equipment (press and biodiesel production equipment) has been built into the model. We refer to this as the "three-neighbor" scenario since it is assumed that these investors would use the same press and biodiesel production facility, but grow their own crop, feed their own animals with the meal and store their own seed, oil, and biodiesel. It is assumed that the neighbors are all located in close proximity to each other to minimize transportation costs. The press can easily be transported between the neighbors for crushing, but the oil would have to be brought to a single point for processing. Therefore, one of the neighbors would need to agree to "host" the facility. Different numbers of investors (neighbors) were tried in the model. In the end, the authors chose three as the optimal number. This is because with three investors, each person's share would equate to growing approximately 128 acres of camelina, and more importantly, feeding about 275 head of cattle. This is a number closer to average herd size in the region than the single investor scenario of 830 head. Of course any arrangement among the neighbors that consumes the meal and oil during the year would be acceptable.

The model assumes a 20-year life span for the system. Usage of the press was adjusted so that the press would be used the maximum amount each year in order for its lifespan to be 20 years. Given these assumptions, the press would operate 72 days (24 hours per day) and crush 151,000 pounds per year.

The biodiesel facility is modeled after Kemp (2006) where 66-gallon water heaters are used to process the oil in 50 gallon batches. A batch must settle overnight, so production capacity is limited to 50 gallons per day. At this rate, oil from an entire crop – 7,344 gallons – could potentially be processed into biodiesel in 147 batch/days (additional settling tanks could increase capacity, but were not factored in). Table 1 lists the equipment and costs derived from Kemp (2006).

Pressing costs are estimated by using nameplate data from the press. The press used in this project is a Kern Kraft, KK40F with a nameplate throughput capacity of 88 pounds per hour and a daily capacity of 2,112 pounds. Current electricity costs are estimated at $0.09 kilowatt/hours (kwh). Daily electricity consumption is estimated to be 38.4 kwh (24hrs x 1.6 kwh). Camelina is assumed to have an average oil content of 34 percent and an average meal content of 66 percent. The mechanical pressing process assumes and 80 percent extraction rate. This results in an actual oil yield of 27.2 percent, accounting for 90 percent of planted acres being harvested.

It is important to note that labor costs are not included in this analysis. Labor for this system is assumed to be all operator labor. No hired labor is required. The amount of labor expended in set-up and production is likely to vary significantly depending on the skills of the operator and how comfortable they are with plumbing and electrical work (a 220 volt hookup is required). The authors felt that trying to factor in labor would be purely speculation. Therefore labor is considered to be included in returns to management and capital. This is consistent with the Montana State University crop budget software used (Montana, 2010). However, the authors realize that set-up and operation labor would be a significant input and if valued, would materially alter the results.

Results

Table 2 summarizes the estimated start-up costs investors face to produce biodiesel. This includes production equipment, the press, storage tanks, and testing and safety equipment. The production of biodiesel involves the use of some hazardous and explosive chemicals (caustic soda and methanol). Quality control of the product is also essential for personal safety and to safeguard equipment. Therefore testing and first aid equipment costs are built into the model.

The summary results for the growing, yield, and feeding portions of the model are shown in Table 3. Total output is shown under the "individual" heading as if an individual producer were operating the system. The "three-neighbors" heading lists the one-third share that each of three neighbors might encounter as part of the group. Yield information shows how much meal and oil might be produced from a given acreage. Annual meal usage and oil yield are also shown. Camelina yields in Montana in 2009 ranged from 250 lbs/ac to over

1,000 lbs/ac and averaged 615 lbs/ac. The authors chose to model a 600 lbs/ac yield. Note that the actual percent of oil yielded is different from the amount of oil in the seed. This is because the difference in the percentage of acres harvested over those planted as well as the use of a mechanical press, which leaves some oil in the meal. In this scenario, the breakeven operating yield for growing camelina would be 517 lb/ac.

The model assumes camelina meal is fed to cattle at a rate of two pounds per day for 90 days (winter feeding). In order for all the meal produced in a given year to be consumed, 830 cattle would need to be fed this ration. Many producers in the region do not have this many cattle, which lends support to the neighbor model used here. The three-neighbor scenario, assumes each neighbor has a third the number of cattle and land area in camelina as in the individual scenario.

When evaluating the biodiesel production system, the authors found it helpful to present the costs in two different ways: total costs, including ownership costs and operating costs; and operating costs alone. Operating costs are analogous to cash costs, which many producers use to evaluate the performance of their operations. However, from an economic perspective, ownership costs must be taken into account since they include depreciation and the opportunity cost of capital. Some sources present only operating costs as a compelling reason to invest in biodiesel. The authors feel that this misrepresents the true costs of the enterprise. By showing these two values side by side, producers can make more informed investment decisions.

Table 4 shows the summary financial results for both the individual and the three-neighbors scenarios. Avoided costs are the amount of feed and petroleum diesel that the farmer does not have to buy. Using the four-year average pre-tax diesel fuel price of $2.62/gallon investors would *not* have to buy 7,344 gallons of diesel fuel. The larger savings comes from the cost savings for feed. Investors are estimated to save $36,018 from feeding camelina meal, assuming an alternate two pound ration of one-half corn, one-half soybean meal at $0.24/pound. These two values added together result in total estimated savings of $55,259. The higher value in the process with the current price structure is from the avoided costs of livestock feed. In other words, from a production standpoint, it is more accurate think of this system as being centered on feed production with biodiesel as a by-product.

Total annual costs are estimated by adding growing costs ($36,267) and biodiesel production costs ($21,912) for a total cost of $58,179. Subtracting the avoided costs of fuel and feed ($55,259) results in the net annual overall savings/cost of the production system (-$2,920). This number (not including labor) shows that the biodiesel production system from an economic perspective is not economically feasible at the four-year average price of petroleum diesel. However, when evaluated from an "operating costs only" perspective, the overall savings/cost is $34,034. This is because the ownership costs of growing and processing camelina are not accounted for in this perspective. The three-neighbors scenario results follow a similar pattern, but are not quite one-third of the individual scenario cost due to the assumption that each of the investors must purchase their own storage tanks.

Unit production costs are shown in Table 5. Camelina oil feedstock is the primary constituent, followed by chemicals. Depreciation and annual maintenance are both estimated at five percent of start-up costs (see Table 2). The "operating costs only" columns differ from the "total costs" columns in that camelina oil costs do not include the ownership costs associated with growing the crop, nor is depreciation included. The cost of producing on-farm biodiesel from camelina is estimated to be $2.98/gallon. From the three-neighbors scenario the cost is a bit higher, $3.04/gallon due to the assumption that each investor would have their own set of storage and blending tanks.

Subsidy values required to break even and break even per unit prices were also calculated from the total cost columns for each scenario. In the individual scenario, a per-gallon subsidy of $0.40 would be required to break even, and equate to a $3.38/gallon price of fuel. In the three-neighbors scenario, these prices rise to $0.45/gallon and $3.49/gallon respectively. Remember that these values are based on a pre-tax petroleum diesel price of $2.62/gallon. Given the uncertainty surrounding the future price of petroleum fuel and the future cost of growing camelina and producing biodiesel, the price at which producers would find biodiesel production attractive is likely to be higher than the breakeven price.

There are currently no farm-level subsidies for biodiesel. Subsidies in general came under increasing pressure from Congress in 2011. The one dollar per gallon biodiesel subsidy for blenders expired at the end of 2011 (it also expired at the end of 2010 but was reinstated). So the outlook for future subsidies is clouded. The only potential government support for on-farm biodiesel production is the USDA

Rural Energy for America Program. This is a competitive grant program that could provide up to 25 percent of the cost of equipment (USDA Rural, 2011).

Glycerol is another by-product of the biodiesel production process. Glycerol, methanol, and catalyst are the residuals to biodiesel production. The process outlined by Kemp (2006) and used here includes a methanol recovery unit to reclaim and reuse as much methanol as possible. Kemp estimates that three pints per batch can be recovered using this method. Yet even with a methanol recovery unit the glycerol is not "refined" and has very little, if any, value unless the producers are close to a processing facility that can refine this product. Some internet sites promote glycerol from biodiesel production as a livestock feed. But here again the authors caution that even with a methanol recovery unit, the amount of methanol in the glycerol by-product is likely too high for livestock and toxic. In order to be fed, the catalyst (either potassium or sodium hydroxide) must also be neutralized with vinegar and the glycerol left to stand for several days until any residual methanol has evaporated. The authors assign no value to glycerol in the model; instead, to avoid disposal issues, the glycerol is treated as described and fed. This process is estimated to produce 1,322 gallons per year (see Table 3).

Discussion

This paper investigates the costs and returns of a biodiesel production system from camelina in a western U.S., dryland crop setting. Important insight has been gained in several areas. The original intent was to investigate economies of scale of moving from the individual scale to a three local investor, "neighbors," multi-ownership model and to address the issues of moving to the community scale.

Economies of scale are achieved when long-run average total costs decrease as output increases. As our results show, the assumption that each investor has their own set of tanks leads to marginally *increasing* the unit cost of production in spite of the shared press and production facility. Since production does not increase with multiple-ownership, there are no economies of scale. However, what has been achieved is an increase in efficiency for an average sized producer, since the press and production facility are used to near capacity. Additionally, each investor gains through reduced capital outlay. Therefore, the reduced opportunity cost of capital can be considered a gain in efficiency over a single investor scenario.

The per gallon (operating only) cost of $0.40 could lead some to think that biodiesel production is profitable given today's diesel price. However, when ownership costs are included, the resulting $3.04/gallon production cost shows the enterprise is not profitable. Producers who normally only consider cash costs in production decisions would be wise to take a closer look at the ownership costs involved. Additionally, we assigned labor costs to returns to management and capital. A significant amount of operator time would likely be required to produce the amount of fuel estimated here and these costs would likely add a considerable amount to per unit production costs, if factored in.

Perhaps the greatest challenge to biodiesel profitability is the opportunity cost of putting land into camelina when prices for other crops (especially wheat in our region) are above historic levels. It makes it hard to justify growing a marginal crop like camelina when profitability of more mainstream crops provides greater economic returns. Of course crop prices do fluctuate and there may come a time when this difference is negligible. In general, however, camelina is probably best suited for marginal cropland where yields of camelina may be expected to be better than other competing crops.

Since the current market for camelina is thin (low trading volumes and few trading hubs), it is important to have sufficient livestock resources (or access to them) to consume the meal, although this could change if the market matures. Our calculations show that at current meal and diesel fuel prices, camelina meal, and the role it plays in the capital flows of the system, plays a more central role than that of the oil.

The capital costs of setting up even a modest biodiesel production system are relatively large. The system designed for our project requires a significant investment of financial resources ($19,443). Much of this cost is associated with the press. Informal conversations with a rural banker indicate that this type of enterprise would be difficult to finance under traditional terms. Therefore having sufficient financial resources on hand would be required.

To understand economies of scale, the authors wanted to investigate a multiple-press, multiple-ownership scenario with the model. This was intended to be a "community" level model on the order of 9 to 12 investors and 3 or 4 presses. However, as work on this model progressed, it became clear that this was a larger undertaking than first thought and represents an order of magnitude higher than multiple-ownership. A number of questions came up that would necessitate a rethinking of the whole model. For instance, a multiple-press model would not be mobile and would require some sort of building (and heat and light). And the quantities of oil and meal produced would require more extensive storage facilities. The biodiesel processing facility would need to be scaled up and would no longer fit with what had been originally designed for on-farm use. With additional investors, some sort of more formal business arrangement seems to be more appropriate than the "neighbor" model proposed here. This could potentially be some sort of cooperative structure. Some provision for liability, insurance and financing would likely be necessary to move to this higher scale. More administration would be required to monitor operations and some hired labor would likely be necessary. Transportation costs would also become more of an issue as farmers would need to transport seed, oil and meal to a central processing facility and haul the products back to the farm. The amount of meal and glycerol produced from a larger facility would be more difficult to dispose of locally, unless there is already a robust livestock industry in the region. For these reasons, the authors felt that the number of assumptions about a larger scale facility would make comparison with the work already done problematic and beyond the scope of the current work.

The question remains, "Under what conditions would on-farm biodiesel become economically viable?" The authors support Kingwell & Plunkett (2006) in their contention that there is no one "trigger price" for economic viability. Rather, different producers will face different scenarios based on their production practices and prices that they face. Some preliminary work with our calculator model shows that when holding all costs static except the pre-tax petroleum diesel price of \$2.62/gallon, on-farm biodiesel would break even at \$3.38/gallon. However, it is not unreasonable to think that if petroleum diesel prices were to rise, other input prices would follow suite, shifting the production price structure upwards. In other words, there is significant price risk to achieving a breakeven price for small producers. A break-even price for on-farm biodiesel likely converges at some point, but the price level at which producers would be willing to commit to investment is also likely significantly higher than the \$3.38/gallon price provided by the calculator. This is especially true given the current prices for crops such as wheat and corn.

The authors' model also supports Kingwell and Plunkett in their contention that the key driver in the system is the price of the feedstock. The amount of meal produced makes it the primary component of the system. Lower price (cost) feedstocks increase the attractiveness of on-farm production. But opportunity costs of capital and depreciation in the production system, in most cases, would keep these costs from going low enough to support economically viable on-farm biodiesel production.

From a purely economic perspective, on-farm biodiesel production from camelina is not economically feasible. This research serves to illustrate the premium producers would need to achieve their goals. However, the authors understand that economics is only one variable (albeit quite important) in the decision-making process. Those farmers concerned about access to fuel, volatile fuel prices, and the impact of petroleum diesel on the environment do have a choice. Biodiesel may have a place in farmer's production system, but it will not come without a price.

References

Bender, Martin. 1999. Economic Feasibility Review for Community-Scale Farmer Cooperatives for Biodiesel. *Bioresource Technology* 70 (81-87).

Foulke, Thomas and Bret Hess. 2011. *Dryland Camelina, A Systems Approach to On-Farm Feed and Fuel: Preliminary Results*. In the proceedings of the 18th International Farm Management Congress, ChristChurch, NZ. Will be available from: http://www.ifmaonline.org/pages/congress.php

Kemp, William H. 2006. *Biodiesel: Basics and Beyond, A Comprehensive Guide to Production and Use for the Home and Farm*. Aztext Press. Tamworth, Ontario, Canada.

Kingwell, Ross and Brad Plunkett. 2006. *Economics of On-farm Biofuel Production*. Invited paper presented at the conference, Bioenergy and Biofuels. February 2006. Perth, Australia. Available from: http://wwwtest.agric.wa.gov.au/objtwr/imported_assets/content/sust/biofuel/200603_bfonfarmeconomics.pdf (accessed, January, 2011).

McVay, K.A. and P.F. Lamb. 2008. *Camelina Production in Montana*. Montana State University Extension. Bozeman, Montana. MT200701Ag revised 3/08. Available from: http://msuextension.org/publications/AgandNaturalResources/MT200701AG.pdf . (accessed June, 2010).

Montana State University Extension. *Analyze the Economics of Tillage Systems and Crop Mix*. An Excel workbook. Available from www.montana.edu/extensionecon/software/EnergyImpactOnAg.swf (accessed May, 2010).

Pilgeram, Alice L.,David C. Sands, Darrin Boss, Nick Dale, David Wichman, Peggy Lamb, Chaofu Lu, Rick Barrows, Matthew Kirkpatrick, Brian Thompson, and Duane L. Johnson. 2007. *Camelina Sativa, A Montana Omega-3 and Fuel Crop*. Reprinted from: Issues in new crops and new uses. J. Janick and A. Whipkey (eds). ASHS Press, Alexandria, VA. Available from: http://www.hort.purdue.edu/newcrop/ncnu07/pdfs/pilgeram129-131.pdf . (accessed: June, 2010).

Putnam, D.H., J.T. Budin, L.A. Field, and W.M. Breene. 1993. *Camelina: A promising low-input oilseed*. p. 314-322. In: J. Janick and J.E. Simon (eds.), New crops. Wiley, New York. Available from: http://www.hort.purdue.edu/newcrop/proceedings1993/v2-314.html (accessed: June, 2010).

Sawyer, Erin. 2007. *The Feasibility of On-farm Biodiesel Production*. University of Saskatchewan Department of Economics Project on Organic Agriculture. Available from: http://organic.usask.ca/reports/Biodiesel%20draft.pdf . (accessed: January, 2011).

United State Department of Agriculture, National Agricultural Statistics Service. 2010 . *Camelina Acreage, Yield and Production, Montana, USA*. http://www.nass.usda.gov/Statistics_by_State/Montana/Publications/crops/camelayp.htm Last updated: April 8, 2010. (accessed: June, 2010).

United States Department of Agriculture. National Agricultural Statistics Service. 2009. *The 2007 Census of Agriculture. Table 11 inventory of Cattle and Calves, 2002 and 2007*. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_US_State_Level/st99_2_011_011.pdf . (accessed: January, 2011).

United States Department of Agriculture. Rural Development. Business and Cooperative Assistance. *Section 9007: Rural Energy for America Program*. http://www.rurdev.usda.gov/BCP_ReapResEei.html. (accessed December, 2011)

United States Department of Energy, Energy Information Administration. Diesel fuel price. Website: http://www.eia.doe.gov/emeu/ebr/ebrcop.html (accessed February, 2010).

United States Department of Health and Human Services, Food and Drug Administration, Division of Animal Feeds, Center for Veterinary Medicine. 2009. Personal communication from Director Sharon A. Benz, Ph.D. to Ms. Vickie Forster, Principal, Forster and Associates Consulting, LLC. Dated November 9, 2009.

Table 1. Biodiesel production facility equipment list and costs

A. Production equipment

Qty	Item	price/ea	Cost
3	66 gallon electric hot water heaters (@ $467 ea)	$467.65	$1,402.95
1	30 gallon mixing tank and stand (conical base)	$149.00	$149.00
1	60 gallon wash tank and stand (conical base)	$175.00	$175.00
1	300 gallon raw oil storage tank	$249.00	$249.00
1	300 gallon biodiesel storage tank	$249.00	$249.00
1	40 gallon treated water storage tank	$70.00	$70.00
4	liquid pumps, 1/2 hp @600gpm	$40.00	$160.00
1	reverse osmosis water purifying system (GE Merlin)	$390.00	$390.00
1	air/liquid condenser unit (estimated)	$200.00	$200.00
1	ventilator fan (Broan 701 cfm fan)	$159.00	$159.00
1	chemical mixer (Talboys lab stirrer explosion proof)	$231.00	$231.00
1	water tank heater (1,000 watt)	$19.80	$19.80
1	small compressor (airbrush compressor like below)	$80.00	$80.00
1	air blower (airbrush compressor with variable speed)	$80.00	$80.00
1	chemical hand pump (barrel fuel type pump)	$24.99	$24.99
2	2 inline oil filters (estimate)	$30.00	$60.00
1	1 inline air filter	$7.99	$7.99
16	3/4" ball valves	$12.73	$203.68
1	3/4" re-enforced nylon tubing (per 50 foot box)	$49.49	$49.49
20	3/4" black mild steel pipe (per foot)	$2.50	$50.00
1	14 gauge electrical wire -Romex (per 250' roll)	$43.90	$43.90
1	electrical load center, 100 amp	$49.00	$49.00
1	assorted fasteners and couplings	$100.00	$100.00
1	digital probe thermometer	$42.95	$42.95
			$4,246.75

B. Testing and safety equipment

1	Fire extinguisher	$47.99	$47.99
1	face shield	$13.86	$13.86
1	Nitrile gloves (pkg of 12)	$19.80	$19.80
1	eyewash flush kit	$14.49	$14.49
1	first aid kit	$34.95	$34.95
1	digital laboratory scale	$89.99	$89.99
1	Hydrometer set (includes hydrometer and cylinder)	$36.50	$36.50
2	250 ml beakers	$3.25	$6.50
1	titration burette	$32.00	$32.00
1	titration stand	$13.00	$13.00
1	phenolphthalein reagent (1 oz.)	$3.50	$3.50
1	Glycerol test kit (no price)	$0.00	$0.00
			$312.58

C. Storage and blending tanks

		Capacity/gal	Cost
1	Raw oil storage tank	1,000	$780
1	Biodiesel (finished) storage tank	500	$399
1	Blended biodiesel tank	1,000	$780
1	Petroleum diesel storage tank	1,000	$0
			$1,959

Table 2. Start-up capital summary

Total estimated	Individual	3-neighbor (Per investor)
Biodiesel production equipment	$4,671	$1,557
Press cost	$12,500	$4,167
Storage tanks	$1,959	$1,959
Testing and Safety equipment	$313	$104
Total estimated start-up costs	**$19,443**	**$7,787**

Table 2. Start-up capital summary

Total estimated	Individual	3-neighbor (Per investor)
Biodiesel production equipment	$4,671	$1,557
Press cost	$12,500	$4,167
Storage tanks	$1,959	$1,959
Testing and Safety equipment	$313	$104
Total estimated start-up costs	**$19,443**	**$7,787**

Table 3. Camelina calculator annual growing, yield, and feeding results

	Individual	3-Neighbors
Growing costs ($/ac)		
Gross revenue (@ $0.0918lbs/ac)	$55.08	$55.08
Total operating costs	-$47.47	-$47.47
Total ownership costs	-$46.73	-$46.73
Total growing costs	-$94.20	-$94.20
Returns over operating costs	$7.61	$7.61
Returns over total costs	-$39.12	-$39.12
Yield		
Area of camelina planted	346.5	115
Area harvested (90%)	367	122
Yield	600lbs/ac	600lbs/ac
Total harvest		
Percent oil	34	34
Percent meal	66	66
Percent of oil extracted	80	80
Actual percent oil yield	27.2	27.2
Total weight of oil	56,549lbs	18,850lbs
Total weight of meal	151,351lbs	50,450lbs
Total volume of oil (@7.7lbs/gal)	7,344gal	2,443gal
Total weight of meal	75.6 tons	25.2 tons
Total glycerol production	1,322gal	441gal
Feeding		
Feeding rate	2lbs/day	2lbs/day
Number of days on feed	90	90
Number of head on feed	830	277
Total consumption of meal	149,400lbs	49,800
Residual meal	1,951lbs	650lbs

Table 4. Camelina calculator summary financial results

	Individual*		3-neighbors*	
	Total costs	Operating costs only	Total costs	Operating costs only
Fuel costs avoided	$19,241	$19,241	$6,414	$6,414
Feed costs avoided	$36,018	$36,018	$12,006	$12,006
	$55,259	$55,259	$18,420	$18,420
Growing costs	$36,267	$18,276	$12,089	$6,092
Biodiesel production costs	$21,912	$2,949	$7,435	$1,048
	$58,179	$21,225	$19,524	$7,140
Total est. cost or savings	**-$2,920**	**$34,034**	**-$1,104**	**$11,279**

**Assumes labor is included in returns to management and capital*

Table 5. Camelina biodiesel unit costs of production

A. Individual scenario

	Total costs		Operating costs only	
	Per per gallon	Per batch*	Per per gallon	Per batch*
Camelina oil	$2.49	$124.35	$0.04	$1.87
Chemicals	$0.20	$9.91	$0.20	$9.91
Annual operating cost	$0.03	$1.69	$0.03	$1.69
Capital depreciation (5% of startup)	$0.13	$6.62	$0.00	$0.00
Annual maintenance costs (5% of startup)	$0.13	$6.62	$0.13	$6.62
Total	**$2.98**	**$149.18**	**$0.40**	**$20.08**
Per per gallon subsidy required to breakeven	**$0.40**			
Per per gallon breakeven price	**$3.38**			

B. 3-neighbor scenario

	Total costs		Operating costs only	
	Per per gallon	Per batch*	Per per gallon	Per batch*
Camelina oil	$2.49	$124.35	$0.04	$1.87
Chemicals	$0.20	$9.91	$0.20	$9.91
Annual operating cost	$0.03	$1.69	$0.03	$1.69
Capital depreciation (5% of startup)	$0.16	$7.95	$0.00	$0.00
Annual maintenance costs (5% of startup)	$0.16	$7.95	$0.16	$7.95
Total	**$3.04**	**$151.85**	**$0.43**	**$21.41**
Per per gallon subsidy required to breakeven	**$0.45**			
Per per gallon breakeven	**$3.49**			

**1 batch equals 50 per gallons*

Figure 1. Camelina systems approach diagram