VERMONT BIOENERGY INITIATIVE

A program of the Vermont Sustainable Jobs Fund

OILSEEDS

U.S. DOE Award #DE-FG36-08GO88182

ABOUT THE VERMONT BIOENERGY INITIATIVE

The purpose of the **Vermont Bioenergy Initiative** (VBI) was to foster the development of sustainable, distributed, small-scale biodiesel from oilseeds and algae and grass/mixed fiber industries in Vermont that would enable the production and use of bioenergy for local transportation, agricultural, and thermal applications. Our investments in feasibility analyses, research and development, and demonstration projects for various bioenergy feedstocks were intended to lead to their commercialization over 7 year time horizon. This initiative was a statewide market building approach to sustainable development that may be replicated in other rural states around the country.

As a grant-making entity, project manager, and technical assistance provider, the Vermont Sustainable Jobs Fund (VSJF) solicited and selected the best sub-recipient proposals for bioenergy related projects through a competitive Request for Proposal process and conducted a number of staff directed investigations, all designed to support the four key priorities of the U.S. Department of Energy's EERE Strategic Plan:

1.) Dramatically reduce dependence on foreign oil;
2.) Promote the use of diverse, domestic and sustainable energy resources;
3.) Reduce carbon emissions from energy production and consumption;
4.) Establish a domestic bio-industry.

Thank you to the office of U.S. Senator Patrick Leahy for securing three U.S. Department of Energy congressionally directed awards (FY08, FY09, FY10) to financially support the Vermont Bioenergy Initiative.

Learn more at

VERMONT BIOENERGY INITIATIVE

http://vermontbioenergy.com

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OILSEEDS SUMMARY

Energy costs are often one of the most significant farm expenses. On farms—where tractors and other engine-powered equipment are common—diesel fuel costs dominate total energy costs. From 1997 to 2012, the amount of money Vermont farmers spent on fuel increased 132%, from $19.7 million to $45.8 million. Fuel expenses increased from 3.5% of total expenses in 1997 to 6.4% of total purchases in 2012.

With support from the Vermont Bioenergy Initiative, Vermont farmers have experimented with producing their own biodiesel made from vegetable oil as a replacement or blended supplement for diesel fuel. **The intent was to replace imported fuel on farms with home-grown fuel.** Although ASTM D6751 quality certification was a goal, since farm use is generally off-road use, this was not an absolute requirement.

The oilseed biodiesel work was accomplished through five main activities:

1) Crop Production and Agronomic Research
2) Crop Processing Research and Development
3) Biodiesel Production Research and Development
4) Integrated Economic, Energy and Environmental Analysis
5) Education and Outreach

These efforts have produced the following results:

Crop Production and Agronomic Research

Sunflowers in bloom at Ekolott Farm in Newbury, Vermont.

- Oilseed crops can be successfully grown in the Vermont and the Northeast US. Researchers and growers in Vermont have successfully grown sunflower, canola, winter rapeseed, flax, safflower and camelina. At the height of VBI activities in 2010, about 320 acres were specifically devoted to oilseed crops for biodiesel production.
- Production guidance from other, high-volume production areas is generally not well-aligned with Vermont's growing region due to soil fertility, pest management and weather differences.
- Researchers in Vermont have compiled and published regionally-specific production guidance based on the crop research done locally.
- Crop production costs are generally stable on a per-acre basis, varying mainly based on management practice.
- Yields are highly variable from year to year with the main depressive pressure being from pests and disease.
- As a result of variable yields, crop production costs on a unit output basis are highly variable.

Crop Processing Research and Development

- Harvester (combine), drying, cleaning, and storing capacity are critical barriers to entry and adoption of oilseeds as a revitalized crop in the Northeast.
- Oilseed presses, though commercially available, are not well specified by manufacturers and require nuanced expertise to operate.
- Researchers in Vermont and Pennsylvania compiled and published oilseed press best practices and reviews to assist with more expedient adoption of the practice.

Bill Mordasky runs Rainbow Valley Farm with his son, Mark, in Orwell, Vermont.

Biodiesel Production Research and Development

- Multiple scales of biodiesel production from seed oil have been demonstrated on farms in Vermont including self-built and commercially available systems.
- The feasibility of mobile seed processing and biodiesel production was explored and summarized in a report.
- Alcohol recovery from the production process has been demonstrated using post-process distillation.
- The use of glycerin as a heating fuel for the biodiesel production process has been demonstrated using a waste oil boiler to make hot water.

John Williamson (Shaftsbury) draws a sample of fuel from a 300-gallon batch of biodiesel made in his self-built processor.

Roger Rainville (Alburgh) uses a 50-gallon Springboard Biodiesel BioPro 190 to make fuel at Borderview Farm.

Integrated Economic, Energy and Environmental Analysis

- Researchers have documented the financial cost of production for various oilseed crops and associated co-products. An associated calculator was developed to allow others to perform early-stage enterprise budgeting and forecasting. A fuel cost of $2.30—2.50 per gallon was estimated based on current practice.
- Researchers have documented the Energy Return on Energy Investment associated with biodiesel production from oilseeds grown on the farm. A net energy return ratio of between 3.6 and 5.9 to 1 was estimated.
- Researchers have documented the net carbon benefit of oilseed-based biodiesel produced on the farm. Net carbon avoidance of 1,984 to 3,227 pounds per acre per year was estimated for sunflowers.
- Renewable Fuel Identification Numbers (RINS) were explored for relevance to on-farm production and deemed difficult to advance due to the scale of production and necessary consolidated record keeping of production and sale.
- A regulatory review of on-farm biodiesel production was conducted by researchers at Vermont Law School which explored a wide range of regulatory hurdles and requirements that farm-based fuel enterprises can face.

Education and Outreach Programming

- A mix of large-group field days, focused grower meetings, and one-on-on direct consulting enabled a diverse set of early adopters to grow and process oilseed crops. **Over 1,300 people attended field days and producer meetings.**
- The Vermont Bioenergy Initiative website serves as a clearinghouse of VBI related information and publications.
- The Bioenergy Now! Video series captures the above work and findings in a viewer-friendly and accessible manner enabling outreach to a broader audience.
- Outputs from research and development efforts have been integrated into undergraduate education programs at the University of Vermont and Vermont Technical College.

- Outputs from research and development efforts have been published as part of the new college textbook, "Bioenergy: Biomass to Biofuels."
- Interest in oilseed-based biodiesel is highly dependent upon the cost of petroleum based fuels.
- Although there is interest in oilseed-based biodiesel among larger, institutional and fleet customers, the cost of fuel and variability of quality is a limiting factor for near-term adoption.

Dr. Heather Darby led crop trials and agronomic studies throughout Vermont. Here, she hosts over 200 farmers at a field day at Borderview Farm in Alburgh.

In summary, oilseed crops can be produced and processed in the region. Even at relatively moderate yields and at small scales of production, farm-based biodiesel enterprises can produce fuel from these crops:

- At a cost of $2.30-2.50 per gallon
- With a net energy return ratio of between 3.6 and 5.9 to 1, and
- With net carbon avoidance of 1,984 to 3,227 pounds per acre per year.

U.S.Senator Patrick Leahy speaks at a gathering of VBI sub-recipients at North Hardwick Dairy.

THE OPPORTUNITY

Vermont consumes the least amount of petroleum of any state in America, but ranks 15th in petroleum consumption on a per capita basis. Liquid fuel consumption in Vermont increased by about 74% from 1960 to 2013. However, Vermonters have reduced total petroleum consumption by about 108 million gallons from the highest year of consumption on record, 2004 (749,868,000 gallons), to 2013 (641,886,000 gallons). Gasoline consumption increased 127% from 1960 to 2013 and is equal to 50% of total petroleum consumption. The majority of the gasoline consumed in Vermont is for transportation (98%). Billions of gallons of ethanol are produced in the U.S. and the Energy Information Administration reports that almost all U.S. gasoline is now blended with 10% ethanol. Distillate consumption in Vermont increased 48% from 1960 to 2013 and is equal to 29% of petroleum consumption. About 28% of distillate consumption in Vermont is for transportation, with the rest used for heating.

Energy costs are often one of the most significant farm expenses. On farms—where tractors and other engine-powered equipment are common—diesel fuel costs dominate total energy costs. Vermont farms consume about 6 million gallons of diesel fuel per year. From 1997 to 2012, the amount of money Vermont farmers spent on fuel increased 132%, from $19.7 million to $45.8 million. Fuel expenses increased from 3.5% of total expenses in 1997 to 6.4% of total purchases in 2012.

The VBI marked the first strategic effort to reduce Vermont's dependency on petroleum through the development of homegrown alternatives. With billions of gallons of ethanol produced and blended with gasoline each year—and very little possibility of corn-based ethanol development in Vermont—we focused on a specific subset of bioenergy alternatives. We worked with interested farmers to develop **on-farm oilseed production, processing, and biodiesel production capacity for farm and local community use**, and we worked with researchers to develop the agronomics and economics of oilseed crop and biodiesel production in Vermont.

The model can be summarized as **"local production for local use."** In this case, "local" is really about being local to the farm. The crops, practices, equipment and overall production and processing models were always selected to favor on-farm feasibility. This approach manifests

> "When my grandfather came to our farm back in the 1930s he came with horses and he grew oats to feed those horses. Those horses were his power that took him to town and pulled his plow. And now we're growing an oil crop, which is our power. It's just a different time, a different technology, but it's the same thing all over again."
>
> — **John Williamson, State Line Biofuels**

itself in two key ways. First, the scale of the production and processing methods is generally small compared to national-level production plants, but larger than do-it-yourself "home brewers." Secondly, the model supported farm ownership and control of the biomass and bioenergy from planting and harvest of the seed to combustion in the tractor engine. Lastly, the work also sought to fully capitalize on the co-products of the overall process, the meal and glycerin, by demonstrating their on-farm use and value.

Oilseed crops are grown in rotation with grains and grasses and can yield high quantities of oil. These replacement fuels can be produced at lower cost than diesel fuel, depending on crop yield and market price of diesel fuel. Since replacement fuels can be sourced from crops grown on the farm in rotation with other existing crops, biodiesel produced on the farm can result in greater energy security and more predictable costs. Vegetable oil and biodiesel can also be produced with a positive net energy return (meaning more fuel is produced than is used in its manufacture).

Along with high diesel fuel costs, farms also experience high feed and fertilizer costs. The costs of these three inputs are highly correlative. Farms supported by the VBI explored the use of oilseed meal to displace imported feed. Oilseed meal was also trialed as a combustion fuel in pelletized form and as a soil amendment or fertilizer. Use of meal as a fertilizer was especially attractive to organic vegetable growers due to the high nitrogen content.

Oilseed crops provide an alternative means of producing feed, fuel and food in a more local model which can minimize cost and maximize benefit.

Taylor (left) and Nick (right) Meyer in a field of sunflowers at North Hardwick Dairy.

STATEMENT OF PROJECT OBJECTIVES

The Vermont Bioenergy Initiative made a series of grants to sub-recipients for oilseed-based biodiesel that were focused on research and development, systems feasibility, and education and outreach (Task F). The work funded by the VBI in the area of oilseeds has included agronomic research and development, crop processing research and development, fuel production research and development, technical assistance, and education and outreach.

Task F: Oilseed Crops — Feedstock Analysis & Production Techniques

SUB-TASK F.1 AGRONOMICS / RESEARCH

The objective of this sub-task was to provide funding to researchers, entrepreneurs, and farmers to experiment with the development of oilseed feedstocks and companion crops, such as sweet sorghum, that are suitable for Vermont soils and climate. Agronomic research involved replicated field trials and analysis on appropriate varieties (e.g., oil content, sugar content and meal quality), seeding rates, nutrient management, weed, disease, and pest control.

- **University of Vermont Extension's Northwest Crops and Soils Team (Dr. Heather Darby):** The objective of the NWCS Team project was to develop regionally appropriate oilseed crop production guidance for farmer adoption (e.g., crops and varieties, plant density, fertilization, harvesting maturity).

- **Borderview Farm:** The objective of the Borderview farm project was to explore oilseed drying, cleaning and pressing options along with commercially available biodiesel production options for small scale operations. Borderview also hosted farm-level variety trials in addition to the agronomic trials done by UVM Extension NWCS.

- **State Line Biofuels:** The objective of this State Line Biofuels project was to improve operational capacity and efficiency in order to expand the scale of oilseed and biodiesel processing in the Bennington County area.

- **Otter Creek Biodiesel:** The objective of the Otter Creek Biofuels project was to gather comparative agronomic and economic data on organic and conventional methods of oilseed crop production and processing on two Vermont farms at the partner's farms (Lawes Ag and Wood's Market Garden). In this project the team purchased a new combine, combine head, no-till grain drill, cover crop roller, and an oilseed press.

- **Clear Brook Farm:** The objective of the Clear Brook Farm project was to explore organic production methods for oilseeds and to host farm-level variety trials.
- **Ekolott Farm:** The objective of the Ekolott Farm project was to gather comparative agronomic and economic data on organic and conventional methods of oilseed crop production and processing.
- **North Hardwick Dairy:** The objective of the North Hardwick Dairy project was to research the production and processing of oilseed crops for the dual benefit of making fuel and dairy feed.

SUB-TASK F.2 LOGISTICS / PRODUCTION

The objective of this sub-task was to provide sub-recipient award funding for oilseed crop and sweet sorghum feedstock logistics and production techniques that fit the scale of Vermont farms and communities, including harvesting and drying techniques, pressing, optimal storage, expelling (to optimize oil extraction) and/or pelletization of co-products (oilseed meal).

- **Farm Fresh Fuel:** The objective of the Farm Fresh Fuel project—managed by UVM NWCS and Borderview Farm—was to improve oilseed crop yields through targeted efforts within one Vermont County to increase farmer adoption of oilseed and farm-scale biodiesel production.

SUB-TASK F.3 PROCESSING / CONVERSION / DEMONSTRATION

The objective of this sub-task was to provide sub-recipient award funding for biodiesel conversion, processing, and demonstration projects (e.g., developing small-scale or on-farm facilities for biodiesel and ethanol production).

- **Rainbow Valley Biodiesel:** The objective of the Rainbow Valley Biodiesel project was to increase grain storage and oilseed pressing capacity in order to expand the scale of oilseed production in Addison and Rutland counties.

- **State Line Biofuels:** The objective of the State Line Biofuels project was to explore the feasibility of using a waste oil boiler to burn glycerin as a biodiesel byproduct and heat the production process.

Chris Callahan provides an overview of the biodiesel production process during a field day at Borderview Farm in Alburgh.

TABLE 1: VBI OILSEEDS AND BIODIESEL PROJECTS

Fiscal Year(s)	Sub-Recipient	DOE Funds	Total Cost Share	Total Project Cost
FY08-FY10	**University of Vermont Extension:** Crop Production, Agronomic Research, Education and Outreach	$233,512	$77,188	$310,700
FY08-FY10	**Borderview Farm:** Crop Production and Processing, Biodiesel Production	$108,103	$31,998	$140,101
FY08-FY10	**Stateline Biofuels:** Crop Production and Processing, Biodiesel Production	$64,861	$60,340	$125,201
FY08-FY10	**Otter Creek Biofuels:** Crop Production and Processing, Biodiesel Production	$80,000	$107,684	$187,684
FY08-FY09	**Ekolott Farm:** Crop Production and Processing	$49,200	$18,641	$67,841
FY08	**North Hardwick Dairy:** Crop Production and Processing	$13,000	$32,396	$45,396
FY08	**Clearbrook Farm:** Crop Production and Processing	$20,000	$3,700	$23,700
FY08	**Rainbow Valley Biodiesel:** Crop Production and Processing, Biodiesel Production	$65,000	$98,819	$163,819
	SUB-RECIPIENT SUBTOTAL	**$633,676**	**$430,766**	**$1,064,442**
Fiscal Year(s)	**Staff Directed Projects**	**DOE Funds**	**Total Cost Share**	**Total Project Cost**
FY08-FY10	**Chris Callahan:** Technical Assistance/Project Management	$171,694	$36,295	$207,984
FY08	**Chris Callahan:** Mobile Oilseed Unit Cost / Benefit		$20,549	$20,549
FY08	**Eleanor Campbell:** Oilseed to Biodiesel Greenhouse Gas Calculator		$28,050	$28,050
FY08	**Eric Garza:** On-Farm Biodiesel EROEI analysis	$5,063		$5,063
FY08	**Shearwater Energy Partners:** On-Farm Biodiesel RINS analysis	$4,850		$4,850
FY10	**Vermont Law School:** On-Farm Biodiesel Regulatory Review	$25,000		$25,000
	STAFF DIRECTED PROJECTS SUBTOTAL	**$206,607**	**$84,894**	**$291,501**
	TOTAL OILSEED BIOENERGY PROGRAM	**$840,283**	**$515,660**	**$1,355,943**

LOCAL PRODUCTION FOR LOCAL USE

The work of the VBI related to oilseed-based biodiesel was focused on a replacement model for farm diesel. The model can be summarized as "local production for local use." In this case, "local" is really about being local to the farm. The crops, practices, equipment and overall production and processing models were always selected to favor on-farm feasibility. This approach manifests itself in two key ways. First, the scale of the production and processing methods is generally small compared to national-level production plants, but larger than do-it-yourself "home brewers." Secondly, the model supported farm ownership and control of the biomass and bioenergy from planting and harvest of the seed to combustion in the tractor engine. Lastly, the work also sought to fully capitalize on the co-products of the overall process, the meal and glycerin, by demonstrating their on-farm use and value.

Parts of the System	-Seed -Soil Prep. -Fertilizer -Planting -Cultivation -Harvesting -Hauling	-Grain -Cleaning -Grain -Drying -Grain -Storage	-Pressing oil -Primary filtration & settling	-Raw oil storage -Meal storage -Secondary filtration	-Catalyst & alcohol produce biodiesel	-Glycerin settling -Fuel washing -Biodiesel storage & filtration
Equipment Needed	-Tractors -Seed drill -Planter -Cultivator -Sprayer -Combine -Wagons	-Seed cleaner -Grain bin -Drying fan	-Trailer -Truck -Press & filter -Receiving tank -Pump	-Oil storage tanks -Meal bins -Pelletizer -Filters	-Trailer -Truck -Receiving tank -Catalyst tank -Proc. tank	-Settling tank -Proc. tank -Fuel washing equip. -Fuel tank

Crop Production and Agronomic Research

Although the Northeast region of the United States has a history of growing a variety of crops including oilseeds, much of the experience and equipment once used for this purpose is long-gone. The farmer sub-recipients supported by the VBI, and even the agronomic researchers, needed to study-up and tool-up early on to become acquainted with the reintroduced crops. For example, planters and seed drills needed to be modified and small combines needed to be purchased.

Crop production and agronomic research improved current practices for producing oilseed crops in Vermont and New England for use as high protein livestock feed (i.e., oilseed meal), and biodiesel for running farm equipment and heating greenhouses. Currently, oilseeds are primarily produced in the northern and western plains of the country. Most production information available for oilseeds is based on research from these areas, where conditions differ markedly from New England. The climate of New England has more precipitation and humidity,

Jon Satz runs Wood's Market Garden (Otter Creek Biofuels), an organic fruit and vegetable farm in Brandon. He explored oilseeds as a rotational crop with vegetables that can also provide fuel (oil) and fertilizer (meal).

soils are generally more acidic and existing cropping systems are based on hay or corn silage production. Researchers found that standard oilseed agronomic practices needed to be modified for New England. There was a need for more specific agronomic data for oilseeds in New England, specifically with regard to varieties, fertility requirements, plant populations and weed control. At the height of VBI activities in 2010, about 320 acres were specifically devoted to oilseed crops for biodiesel production.

Dr. Heather Darby is an agronomist with UVM Extension where she leads crop production trials each year. She and her team helped to develop regionally appropriate guidance for these crops based on work supported by the VBI.

Variety Trials

Each oilseed crop presents variety options to farmers at the time of seed purchase. While agronomic data generally exists for different varieties of oilseeds, none of it existed for production in the Northeast. In response to this need, University of Vermont Extension Northwest Crops and Soils Team (NWCS) led by Dr. Heather Darby performed multi-year, multi-treatment variety trials at the Borderview Research Farm (Alburgh) along with field locations in other parts of the state. These trials were conducted both at small-scale plot level and at farms growing the crops on a demonstration basis such as State Line Biofuels (Shaftsbury), Rainbow Valley Farm (Orwell), North Hardwick Dairy (North Hardwick), Wood's Market Garden (Brandon), Clear Brook Farm (Shaftsbury), Lawe's Ag (Brandon) and Ekolott Farm (Newbury). Each year, an annual Oilseed Growers Meeting was held to share research and farm production findings and plan for the coming season. Farmers shared challenges they faced and worked with researchers to plan for additional trials.

Organic and Conventional Production Comparison

Several partner farms were interested in exploring organic oilseed production and carried out related farm-based trials with support of UVM Extension. North Hardwick Dairy, Wood's Market Garden, Ekolott Farm, and Clear Brook Farm all explored organic production methods in their sponsored activities.

Fertility Requirements

Another area of difference between the Northeast and other common oilseed production regions turned out to be fertility. The soils in the Northeast are relatively fertile and early crop trials demonstrated "lodging" of sunflower attributed to over fertilizing when following standard fertilizer application guidance from other areas. Lodging results from plants growing very tall and thin and being blown down by wind or simply toppling due to gravity. This impacts the consistency of the crop stand and can result in increased challenges in harvesting. This finding resulted in more focused crop research trials aimed at understanding the impact of fertilizer type and amount on the crops and varieties in question.

Plant Populations

Another key agronomic decision related to plant population or density of planting. A higher plant density generally will result in a greater number of smaller plants, while a lower plant density generally will result in a smaller number of larger plants. This is especially evident in sunflowers and can be seen in the size of the sunflower heads which can have a harvesting impact. Plant population studies helped to optimize planting density for Northeast growers and aided in harvest efficiencies as well.

Canola field at Borderview Farm (Alburgh).

Weed Control

As with most crops, oilseeds benefit from strong control of competitive weeds. Some of the growers supported by the VBI desired organic production and even those not seeking certified organic production aimed to minimize inputs and operations for other reasons (e.g., environmental, philosophical, and economic). As a result, weed control in these crops that

Cover cropping at Wood's Market Garden (Brandon).

were new to the region required research and education as well as some fortunate weather. Generally, a combination of herbicide application and mechanical cultivation (e.g., tine weeding) led to adequate weed control. Cultivation requires cooperative weather leading to proper soil conditions which can be hard to find in the Northeast in the spring. Alternative practices such as tine weeding, cover crop rolling, and no-till planting were explored by partner farms such as Woods' Market Garden and Lawes Ag.

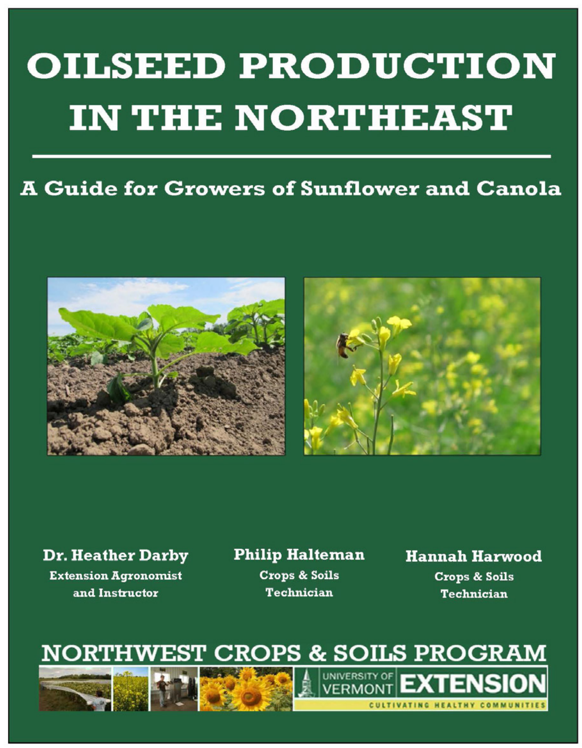
Pest Control

Deer, birds, and bears were continually identified as the main challenges in producing a predictable yield of oilseeds. Deer were to blame for early season loses as seedlings emerged from fall-sown winter canola, or spring sown canola or sunflowers. Crops that survived predation in spring and matured in the fall often faced bird and bear damage. Birds were especially troubling for sunflowers. Some mitigations were trialed including distress calls, visual deterrents, and electric fencing.

Birds in field of sunflowers.

John Williamson surveys a field of sunflowers. On-farm trials were a large part of the VBI funded research into oilseeds. An insect trap is visible in the foreground which helped to quantify the pest pressure in this crop and plan for mitigations.

The overall work of the agronomic production research and development activity has been documented on the [UVM Extension Northwest Crops and Soils Team website](). Additionally, research findings were published in a regionally specific handbook (Darby, Halteman, & Harwood, 2013).



Research findings from the UVM Extension Northwest Crops and Soils Team were published in a regionally specific handbook.

Crop Processing Research and Development

VBI sub-recipient activity also focused on harvesting, handling, and processing of oilseed crops to value-added products. Harvesting small grains is a practice that has history in the region, but not recent history. It was necessary to establish combine capacity for oilseeds and developing an understanding of how to use that capacity effectively. Postharvest handling also required investment in learning and additional infrastructure. Seed dryers and bins were built and installed. Conveyance equipment such as augers and elevators were required.

Harvesting

The harvesting of oilseeds involves combining (combined reaping and threshing) using purpose built machines. These machines were once common in the region when farms harvested seeds for food, feed, or future sowing. However, at the start of the VBI, combines were rare in the region and early effort was needed to procure scale-appropriate machines for use at

A small Massey Harris SP35 combine was resurrected from the hedge row for use by John WIlliamson at State Line Biofuels in Shaftsbury. Jim Williamson (foreground) handles the grain cart while John Williamson combines sunflowers (background).

John Williamson using a "classic" Massey Harris SP35 combine to harvest sunflowers (top) and canola (bottom) early in the days of growing oilseeds at State Line Biofuels.

The VBI supported the joint purchase of a larger scale (and newer) John Deere combine used at State Line Biofuels and Clear Brook Farm in Shaftsbury.

participating farms. Early trials were done using very old and very small machines with the scale and sophistication improving over the years of the project. Additionally, a research scale "plot combine" was purchased by UVM NWCS and used to support their crop trials.

The VBI funded the purchase of three larger scale used combines, one each at Otter Creek Biofuels (Brandon), Ekolott Farm (Newbury) and Clear Brook Farm (Shaftsbury).

Drying, Cleaning, and Storing

Oilseeds benefit from high stability in storage once harvested at maturity and dried to stable storage conditions. The infrastructure required for drying and storing oilseeds was generally lacking in a region most familiar with storing other feeds (e.g., corn silage, haylage, and dry-bailed hay). Early adopters were instrumental in researching, purchasing and demonstrating small grain cleaning, drying and storage systems. Grain bins with false floors were commonly employed, making use of ambient air for low-temperature drying of the oilseeds. Corn driers are not well-suited to this task due to oilseeds being damaged by the high heat their burners generate. Some grantees repurposed existing grain bins while others purchased new bins, allowing for documenting differences in costs and experiences of each practice. One grantee also trialed a solar hot water heated grain dryer funded externally by USDA-REAP (Williamson, Williamson, & Callahan, 2008).

John Williamson checks the performance of a Clipper seed cleaner.

The "Bio Barn" at State Line Biofuels (Shaftsbury) was built "into the hill" to receive oilseeds on the uphill portion and allow the use of gravity as much as possible to flow the seed through the processing. The solar panels in this image were funded separately, but augment the grain drying with low-grade heat.

The VBI supported the construction of a "Bio Building" and a grain drying and storage bin at Borderview Research Farm in Alburgh.

The radiator from a Ford F250 pickup truck was salvaged and attached to the grain drying fan at State Line Biofuels (Shaftsbury) to speed up the drying time of the oilseeds.

The VBI supported the purchase of additional drying bin capacity at Ekolott Farm. Here the bin is shown in mid-winter keeping the harvested and dried crop of sunflower seeds dry and stable.

Pressing

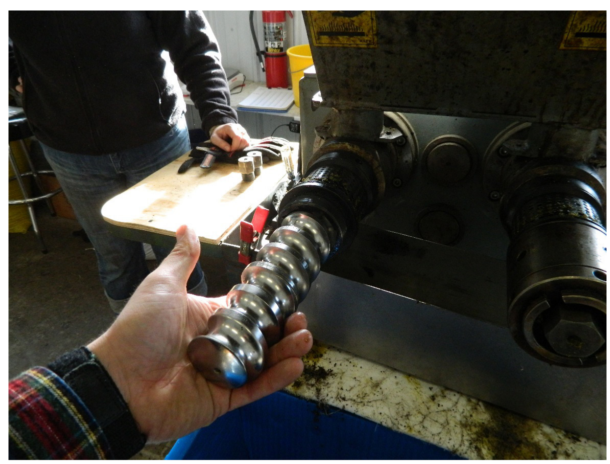
The conversion of oilseeds to meal and oil (as a precursor to biodiesel) requires pressing. This is a mechanical process that applies heat and pressure to burst the seed and split the liquid oil from the solid meal. Generally speaking, there are two categories of oilseed presses with relevance to farm-scale operations; less-expensive ones made for attended operation and more expensive ones made for automated operation. At the start of the VBI there was very little domestic experience with farm-scale presses. Sub-recipients were supported in purchasing different kinds of presses to better understand the pros and cons of each. Borderview Farm purchased a large, attended press from China, while State Line Biofuels purchased an automated press from Sweden, while North Hardwick Dairy purchased a Kern Kraft press from Germany. These early experiences helped to inform future adoption of practices at Rainbow Valley Farm, Ekolott Farm, and Otter Creek Biofuels. Borderview eventually abandoned the attended press for two automated presses used both for fuel production and for research trials.

Borderview Farm originally purchased a large, attended press from China.

Borderview eventually abandoned the attended press for two automated presses used both for fuel production and for research trials.

Oil presses are used to crush the seed and separate oil from the meal. In this picture the oil is seen coming through the wall of the press barrel, seed is coming in from the right via a screw impeller and meal leaves to the left.

Jerrod LaValley demonstrates the Kern Kraft press at Borderview Farm (Alburgh).



Changing screw impellers on the Kern Kraft press at Borderview Farm (Alburgh). Different screws are used for different seeds based on size and hardness.

The positive experiences of John Williamson at State Line Biofuels with this Taby oilseed press informed Larry Scott's decision to install one at Ekolott Farm.

John Williamson cleans up his Taby oilseed press following a day of operation.

An overall evaluation of oilseed presses was conducted in parallel with VBI activity funded by USDA-SARE. A report on this evaluation was published and includes summaries of each press in use and general guidance from operators of those presses to help others accelerate their learning process (Callahan & Harwood, 2013).

Meal Utilization

Uses for oil meal include livestock feed, fertilizer, and as a solid fuel. Oilseed meal, as produced on farms in VBI funded projects remained high in residual fat that made it difficult to use in rumen nutrition (e.g., dairies). Monogastric species such as chickens and pigs are better aligned with oilseed meal as a feed than ruminants such as dairy cows and some sub-recipients have marketed their meal co-product to these other farm customers. In general, the fluctuation of volume and quality of the oilseed meal has limited the access to traditional market channels. Feed dealers need a consistent volume and quality in order to commit to buying the meal. As a result, they

Canola meal as it comes off the oilseed press at Otter Creek Biofuels (Brandon).

tend to depend on regional and national suppliers for their sourcing. Some preliminary work was done to explore the use of oilseed meal as a fertilizer and also as a pelletized fuel for on-farm use. Both Clear Brook Farm (Shaftsbury) and Wood's Market Garden (Brandon) explored the use of meal for fertilizer when other listed organic fertilizers were becoming scare and expensive. Generally, given the nascent nature of these enterprises, the closer to the farm the use was, the more likely it was to be economically feasible. As a result, on-farm uses tended to be favored.

Biodiesel Production Research and Development

Biodiesel Processing Equipment

The conversion of vegetable oil to biodiesel requires heat and chemical inputs (i.e., lye and alcohol). This process is performed in a heated and generally insulated tank. While there are many small-scale options to performing this task, the VBI supported a more rigorous design and evaluation approach to the process. Sub-recipients that had made fuel with less refined designs prior to the VBI were eager to explore improved approaches and systems. State Line Biofuels (Shaftsbury) constructed a 300,000 gal/yr processor using salvaged brewing tanks, dairy piping and an explosion proof pump. Borderview Farm (Alburgh) purchased a "turn-key" processor from SpringBoard Biodiesel called the "BioPro 190" that is capable of producing 14,000 gal/yr.

Roger Rainville (Alburgh) purchased a BioPro190 biodiesel processor after careful consideration of building his own system. He liked the fact that the machine came all in one piece, "ready to go." Roger also bought a fuel finishing unit (background) that attaches to the BioPro to filter fuel and remove water and glycerin.

Quality Improvement

In addition to fuel processing equipment to enable the primary conversion process, on-farm enterprises also needed post-processing equipment to clean the fuel. This step is often done with water washing in small-scale production, but results in waste water that can have methanol and other contaminants present. The idea of adding water to fuel was also never fully embraced by the farmers in the project. As a result, some VBI sub-recipients received funding support to invest in flow-through cleaning systems that use drying media and ion-exchange media to clean the fuel. These media are replaceable and can be packaged and shipped back to the supplier for proper recharging and disposal.

Chris Callahan and John Williamson explain the nuance of a self-built biodiesel processor at a farmer field day held at State Line Biofuels in Shaftsbury.

John Williamson gives the thumbs-up after checking the settling tank filled with the results of his first "large" batch of fuel (300 gallons) at State Line Biofuels.

Biodiesel storage tanks at State Line Biofuels.

Roger Rainville shows off his methanol recovery system. Removing residual alcohol from the final fuel batch is an important quality hurdle that VBI funding helped to address.

Jerrod LaValley performs a test for water in feedstock oil at Borderview Farm prior to making a batch of fuel. The VBI supported the purchase of simple lab equipment like this to improve fuel quality at the partner farms.

Use of Waste Streams & Co-Products

A guiding principle of VBI oilseed sub-recipients has been to make the most use of the products produced. In the case of oilseed meal, although it is a commodity and is sold in large volumes nationally, local production was of varied quality and volume and its sale into that traditional distribution channel was limited. More often the meal was used on-farm directly to displace imported feed. It was also trialed as a combustion fuel in pelletized form and as a soil amendment or fertilizer. Use of meal as a fertilizer was especially attractive to organic vegetable growers due to the high nitrogen content.

Glycerin from the biodiesel process was trialed as a combustion fuel at State Line Biofuels using a waste oil boiler from EnergyLogic. The boiler was designed to burn waste motor oil, but was shown to be able to burn a mixture of glycerin and biodiesel or 100% glycerin to produce heat for the biodiesel process. Glycerin is separated from biodiesel during the biodiesel production process and accumulates. Again, although it is a commodity valued in some other industries such as soap making and pharmaceuticals, small-scale producers do not produce enough of it at high enough quality to reach those markets.

State Line Biofuels demonstrated a waste oil boiler to heat the biodiesel processor and enable methanol recovery. The waste oil boiler was selected due to the potential to use glycerin, a co-product of the biodiesel process, as a fuel source.

Table 2 summarizes the oilseed processing capacities of VBI sub-recipients.

"There is probably no way I would have built out our BioBarn to the point that it is today, had it not been for the help of the VBI and U.S. DOE. The engineering guidance we received from Chris Callahan in order to make a safe and high quality product and the help from Dr. Heather Darby in growing the best oilseed crop possible was priceless. The collaborations we had with other farmers involved with this same program was also a great help. What I learned mostly through this whole process was the sustainability and fuel independence that we can achieve as farmers. My hope is that the knowledge that I have learned will be carried forward for generations to come." — Roger Rainville, Borderview Farm

TABLE 2: OILSEED PROCESSING CAPACITIES

	Storage Bins		Pressing Capacity		Biodiesel Capacity
Site	**Bushel**	**Tons**	**Gallons / Yr**	**Tons / Yr**	**Gallons / Yr**
State Line Biofuels (sunflower)	1,363	22	26,280	183	312,857
Borderview Farm (sunflower)	2,130	34	179,093	1,679	13,036
Ekolott Farm (sunflower)	9,500	152	26,280	183	N/A
North Hardwick Dairy (sunflower)	1,643	26	23,360	219	13,036
Rainbow Valley Farm (soybean)	30,000	900	155,733	2,920	417,133
TOTALS	**44,636**	**1,134**	**371,813**	**5,183**	**756,071**
Totals with 80% uptime	N/A	N/A	297,451	4,146	604,857

Note: The calculations assume 15% oil content for soybeans and 38% for sunflower as well as an oil density of 7.5 pounds per gallon. In most cases the farms would need to purchase additional oil extraction and storage equipment to match their biodiesel production capabilities. These components are modular and can be added in the future as dedicated acreage is secured.

Integrated Economic, Energy and Environmental Analysis

Crop Production Assistance

Crop production assistance was provided through VBI grant-funded support of seed purchases, on-farm consultation, on-farm research and engagement in farmer-to-farmer educational programming. This technical assistance followed the growing and processing cycle each year. In early spring, a grower's meeting was held to share growers' lessons and researchers' findings from the prior year. Often this served as a workshop or seminar where technical assistance providers could deliver formalized content to a larger group followed by a group discussion. Crop and variety selection, as well as production practices, were commonly discussed in an open, sharing environment which allowed reflection on both successes and failures. In-field educational and consulting support was supported by VBI funding through partnership with UVM Extension Northwest Crops and Soils Team. **The Crops and Soils team planned, organized and facilitated the growers' meeting, coordinated a consolidated seed order, led both research trials and on-farm trials, and provided in-field consultation related to disease and pest management as well as production practices.**

Harvest and Postharvest Engineering Support

Technical assistance and facilitated farmer-to-farmer peer support was commonly used to help with adoption of improved harvesting and postharvest process systems. Some of this coordinated support was arranged at the spring grower's meeting. Often it was coordinated directly among growers who lived nearby each other. Sharing of combines, drying bins and grain wagons was common. Agronomic and engineering support was provided with VBI funding through partnership with UVM Extension Northwest Crops and Soils Team and Chris Callahan. The Crops and Soils team provided direct educational and consultation support related to pest and disease management and harvest timing. Callahan provided sizing, design and operational planning support for on-farm infrastructure such as conveyors, driers, cleaners, and storage bins.

Hannah Harwood (University of Vermont Extension) explains the results of crop trials at an annual farmer field day in Alburgh.

Biodiesel Processing Support

Engineering support was a significant part of the technical assistance provided to the farm-based biodiesel operations. Chris Callahan, a consulting engineer (and later as faculty at University of Vermont Extension), was contracted for this support with VBI funds. He provided direct consultation with VBI sub-recipient farms to help them size, design, build and commission processing infrastructure. This support included process design support and equipment selection, failure mode, and effects analyses (FMEA), development of standard operating procedures (SOP's) and general processing support (Callahan & Williamson, 2009). The FMEA and SOPs, in particular, were noted by the farm processors as being particularly helpful. The value of the FMEA was to allow a methodical "walk-through" of the processing system with an eye towards potential component failures. This enabled consideration of mitigations ahead of the first production batch, and helped to establish safety-related best practices that could be transferred from one

Chris Callahan provided technical assistance to VBI sub-recipients.

"The VBI support I received to support grantees with engineering services helped me develop a strong portfolio of work in the field and led to greater engagement in related projects through-out Vermont and the Northeast. The work of the VBI took place in a very dynamic period of fuel prices and still demonstrated strong technical and economic feasibility for the model. UVM Extension programs will continue to pursue research and education activities in these areas due to continued interest from stakeholders."

— Chris Callahan, University of Vermont

farm to the next even when they had very different looking systems. The SOP's were found to be helpful for the growers since they often have many different daily tasks and might make fuel once per month. The SOP's provided an easy reminder of the process and specific steps to take when making a batch and also provided important safety reminders. One grower printed a copy of their SOP's in poster format and mounted it on the wall above their processor. Schematics of the processors were also developed in support of the FMEA and SOP drafting process, and these have been made available on the VBI website along with the other engineering documents.

Mobile Oilseed Processor

The feasibility of a mobile oilseed processor was studied early in the course of VBI with funding support from the High Meadows Fund (Callahan, 2008). This model was explored as an alternative to centralized, stationary processing infrastructure given the geographic distribution of relatively small-volume producers expected in the buildout phase of the initiative. The study demonstrated a path to economic break-even and profitability and supported the feasibility of mobile oilseed processing (cleaning, drying and pressing) as well as mobile biodiesel processing. Since the completion of the study, several mobile biodiesel processors have been developed, though mainly as educational tools.

Community Scale Models and Farm Fresh Fuel

Given the nascent nature of oilseed enterprises, the risk associated with the new ventures and the capital investment required, farmer discussions continually returned to the concept of shared infrastructure and equipment. At several times during the VBI funding period joint ventures of various forms were explored and attempted.

The first consideration of this model was centered around State Line Biofuels in Shaftsbury. State Line Biofuels already had a biodiesel processor in place along with significant seed handling systems (i.e., dryer, bins, cleaner, press). Several farms within a 20 mile radius had expressed interest in growing oilseeds in order to secure their own fuel and meal. This interest was primarily motivated by historically high fuel prices in 2009. The group met several times, facilitated by Chris Callahan with VBI funding support. These meetings helped to clarify what each grower's expectations, capabilities and capacity were. The oilseed cost and profit calculator was used to estimate fuel and meal costs for each participant. General principles of an operational agreement were drafted that would have allowed increased combine capacity as a result of shared investment. In the end, however, fuel prices eased and the real logistical challenges of shared equipment resulted in reduced interest among the group. State Line continued to process seed for the interested farms, but it was done with existing equipment and on a "fee for service" basis. A larger, used combine was also purchased with VBI funds to improve the harvest capacity and efficiency of both State Line Biofuels and Clear Brook farm.

In 2012, another cooperative initiative was explored on the other end of the state. With funding assistance from the VBI, the UVM Extension Northwest Crops and Soils team instituted a pilot program in order to increase the acreage and visibility of oilseed production in a Grand Isle County (Harwood & Darby, 2012). There were existing farms with sunflower production experience and cropping equipment, a biodiesel processing facility at Borderview Farm, and the technical assistance to provide guidance throughout the season. In fact, the Crops and Soils Team conducts the bulk of their research trials at Borderview Farm in Alburgh. Ten growers participated and over 69 acres of land were planted with oilseed sunflowers. Fields were distributed throughout the county, with at least one grower in each town in the county. Growers received seed and technical assistance and were responsible for all of the crop production, record-keeping, and all other

The Farm Fresh Fuel Project explored collective production and processing in Grand Isle County. Ten farms and 69 acres were involved in sunflower production. Farmers received their fuel and meal after processing at Borderview Farm (Alburgh).

Dr. Heather Darby hosts a farmers' meeting for the Farm Fresh Fuel partners at Borderview Farm.

Oil pressed from Farm Fresh Fuel seeds waits to be made into biodiesel at Borderview Farm. Each farm's seed, oil, meal, and fuel were measured and kept separate to ensure they received their correct share in return.

costs associated with growing and harvesting the sunflowers. Some of the 2012 participants were experienced dairy farmers and crop growers; some were homesteaders who had the means to borrow or hire equipment and arrange the logistics of planting and maintaining the crop.

Results in this pilot year were varied. Due in part to the experimental nature of the project, there were some early obstacles and learning curves to overcome. It was difficult to properly time the termination of a previous crop and the establishment of sunflowers, since many farmers and custom operators were busy getting their first cut of hay in and their corn planted at the same time. Operators' planters and sprayers had to be cleaned and calibrated specifically for sunflowers, and the minimal acreage of the Farm Fresh Fuel project made logistics difficult. Fields that were sprayed, adequately fertilized, and planted properly and at the right time yielded much better than others. In addition, fields with wet soil conditions and poor drainage saw yield drags. There were also issues with pest management; deer and birds wreaked havoc in a number of fields.

Overall, the Farm Fresh Fuel Project's first year was a success. Most growers said they wanted to try again the following year, and maybe attempt winter canola as well. However, challenging growing conditions in the second year resulted in a total crop failure.

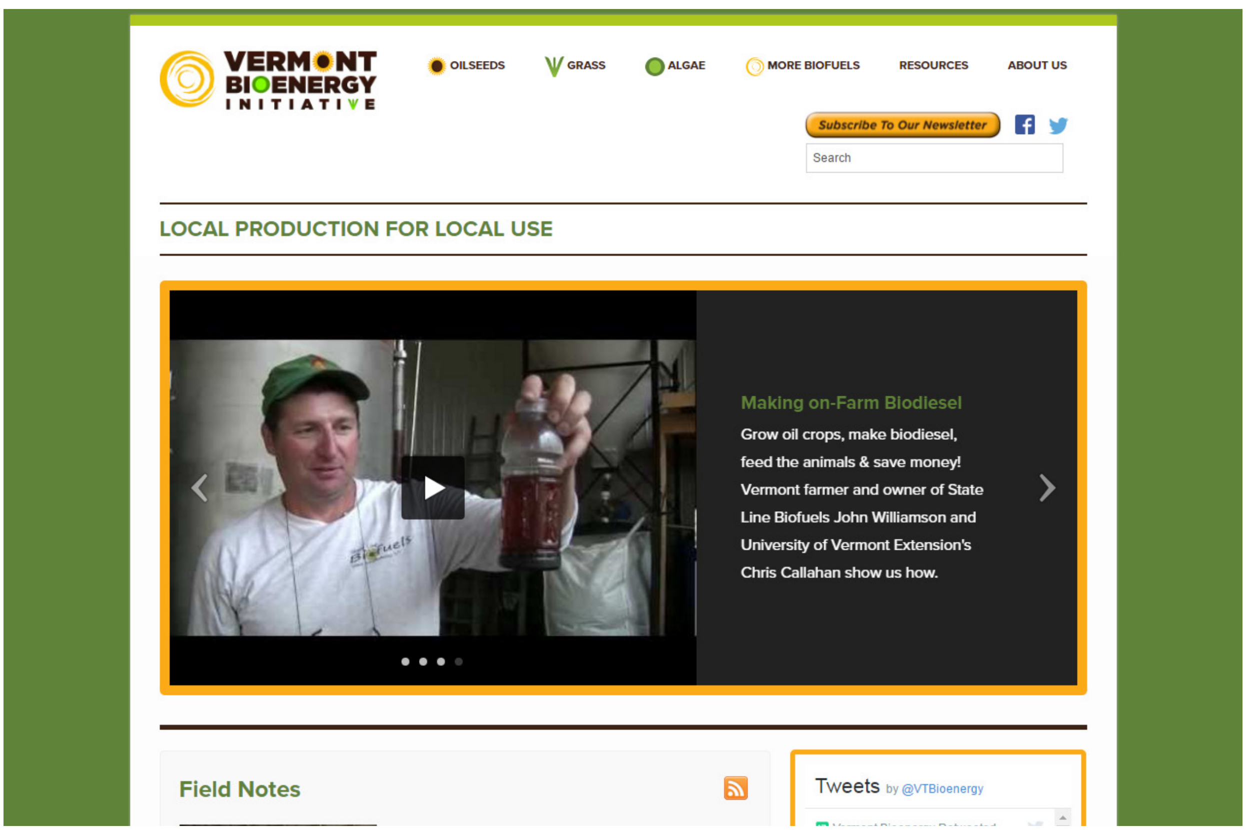
The key lesson learned from both of these VBI projects was that cooperative initiatives require strong leadership and a central champion who will also ensure necessary actions are taken at the right times. The coordination of crop production on distributed property using a mix of shared and owned equipment in the context of distributed production and centralized processing requires significant organization, oversight and expertise. Successful maturation of such an endeavor also requires supportive external economics. **Even with funding support from the VBI, dramatically reduced petroleum fuel prices led many participants to lose interest. It is likely, however, that fuel prices will rise again and farm-based biodiesel using a shared production model will once again be competitive. The structural learning and capital investment resulting from the VBI in this area will likely be put to use again.**

Education and Outreach

Education and outreach was a continual theme of the VBI. This work was integrated into farmer "field days" and several specific "Oilseed" and "Biodiesel" field days were held to provide focused, hands-on review of the developing practice. The work has also been highlighted in both of the formal undergraduate educational projects delivered by the University of Vermont (UVM) and Vermont Technical College. Project outputs have been posted on a variety of websites for long-term use, including the Vermont Bioenergy Initiative website, the UVM Extension Northwest Crops and Soils Program, and the UVM Extension Ag Engineering website.

Vermont Bioenergy Website

The [Vermont Bioenergy website] was established to serve as a clearinghouse of VBI videos, publications, photos, news items, and resources. It also links reports, calculators, and profiles of projects and grantees.

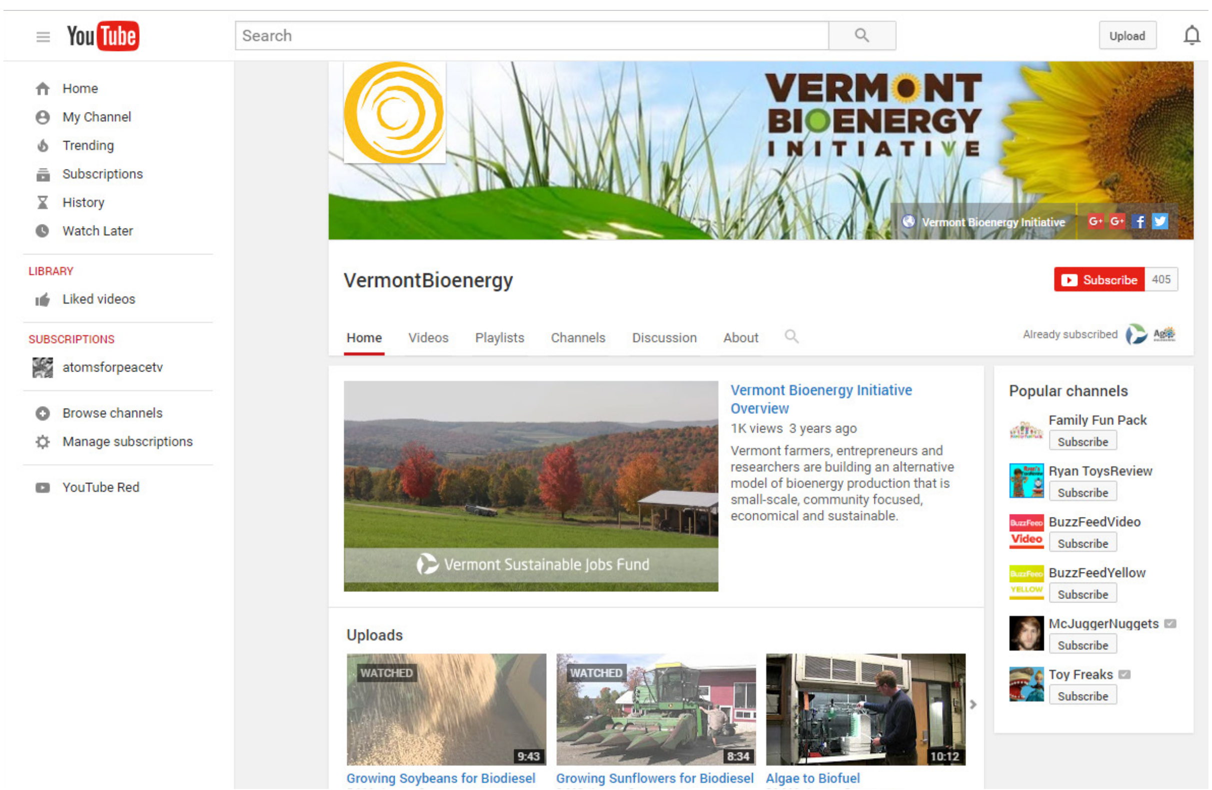


The Vermont Bioenergy Initiative website is a repository of all materials and resources developed by VSJF and subrecipients.

BioenergyNOW Video Series

The projects and results of the Vermont Bioenergy Initiative were documented in a 10-part video series titled Bioenergy Now! under the direction of Netaka White in 2013. The 2 to 10 minute videos are hosted on a VBI YouTube channel have collectively been viewed over 89,000 times and are promoted via the VBI website, associated social media channels, and through project partners' outreach activities. The video segments include:

- The Vermont Bioenergy Initiative Overview
- Homegrown Fuel and Feed
- Growing Canola for Biodiesel
- Growing Soybeans for Biodiesel
- Growing Sunflowers for Biodiesel
- Oil Crop Pest Pressures
- Oil and Meal Extraction
- Making On-Farm Biodiesel
- Grass Fuel, and
- Algae to Biofuel



One of the annual oilseed producer meetings held at Cedar Circle Farm, Thetford, VT.

On-Farm Field Days (Multiple per Year)

A key component of oilseed outreach and education has been UVM Extension led field days at partner farms. Beginning in 2010, oilseeds were a highlight of the UVM Extension Northwest Crops and Soils Team annual field day at Borderview Farm in Alburgh. Additional field days were hosted at State Line Biofuels (Shaftsbury), Wood's Market Garden (Brandon) and Ekolott Farm (Newbury) to demonstrate specific aspects of those site's operations. These field days allowed for hands-on, direct experience with crops, practices, equipment, and products for those showing interest in the emerging industry. They also served as an important networking and outreach mechanism that helped to expand the reach of the VBI funded research and technical assistance in this area. **Over 1,300 people attended these events.**

Oilseed Growers Meetings (Annual)

In addition to the annual field days, the UVM Extension Northwest Crops and Soils Team facilitated annual meetings of growers actively involved in oilseed crop production. These late winter meetings were held centrally in Berlin or White River Junction each year beginning in 2010. The gatherings served as a chance to share lessons learned from the past year, express challenges and research questions, and to sort out the seed order for the coming year.

Farmer to Farmer Education

A somewhat unintended result of investing in on-farm oilseed and biodiesel facilities has been the development of these farms as peer resources for other interested farmers. State Line Biofuels (Shaftsbury), Borderview Farm (Alburgh) and Ekolott Farm (Newbury) all field inquiries from around the nation and the world related to the work they are doing in this area. These farms host school groups, professional tours, and field days each year that help to educate farmers and the general public about the potential for this unique production model.

Bioenergy Class at UVM & Vermont Tech

In addition to farmer meetings, field days and direct technical assistance, two other formal educational programs were supported by the VBI to expand availability of bioenergy curricula. Two separate courses were developed by John Todd and Anju Dahiya Krivov at the University of Vermont (UVM) and John Kidder at Vermont Technical College.

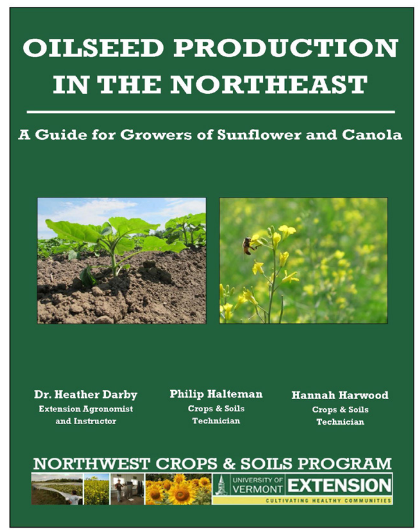
This course provided hands-on experience with various types of bioenergy, including liquid biofuels, solid biomass, and biogas. The course provided the participants—including students, farmers, entrepreneurs, and others—with technical exposure to bioenergy topics. The course involved a) on campus classes; b) field work involving tours to farms/bioenergy facilities; c) presentations by bioeenergy experts; d) bioenergy equipment demonstrations by professionals; e) online supplementary classes/information including video clips; f) service learning projects. The course has been offered 3 times. The development of this course, and increased leadership from Anju Dahiya Krivov led to the development and publication of a textbook, ***Bioenergy: Biomass to Biofuels*** (Krivov, 2014).

The Vermont Technical College course, “Biomass to Biofuels” included course material that was introductory and targeted towards individuals who would benefit from knowledge of how biomass resources (wood, grass, crops, etc.) can be converted and used as fuels for heat and power. The target audience was relatively broad and included educators, managers, farmers, public administrators, community groups, workers, or any others who were interested in producing and/or using biomass for energy. The content was technical in nature and highlighted the opportunities and constraints associated with adopting biomass energy technology. The information drew from several existing resources, including reports produced by the Biomass Energy Resource Center, UVM Extension, the U.S. Department of Energy, and other resources.

Publications

Oilseed Production in the Northeast

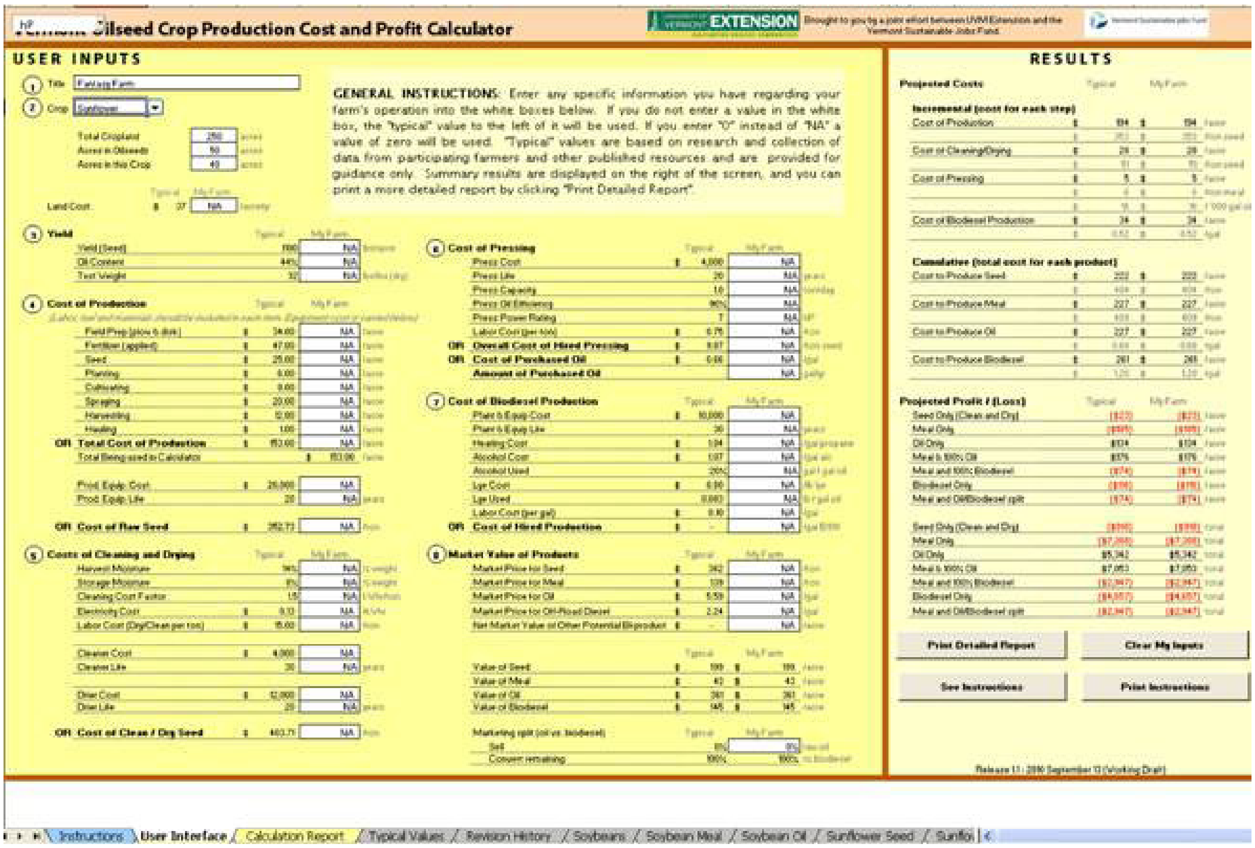
The production of oilseed crops in the region is a relatively new practice and required significant agronomic research. The findings of this research have been delivered through a series of annual meetings and field days and also in the form of a concise production manual. VBI funding, combined with USDA SARE funding, supported the University of Vermont Extension Northwest Crops and Soil Program in the production of a guide that focuses on sunflowers and canola. (Darby et al., 2013). The guide covers crop growth, development, establishment, and production; pest management; harvesting practices; and seed processing and storage.



The University of Vermont Extension Northwest Crops and Soil Program website has become a major resource for all aspects of oilseed crop production and processing. Research results from 2010 to the present are posted on the website.

Oilseed Cost and Profit Calculator

Early in the life of the VBI, a need was noted for an easy, concise calculation of seed, meal, oil and fuel costs based on the unique characteristics of the farm enterprise. A cost of production model was developed and packaged in an easy-to-use Excel format: http://vermontbioenergy.com/oilseed-cost-profit-calculator. This tool—downloaded more than 300 times across the U.S. and other countries, including the Philippines, Germany, and Zambia—enables the

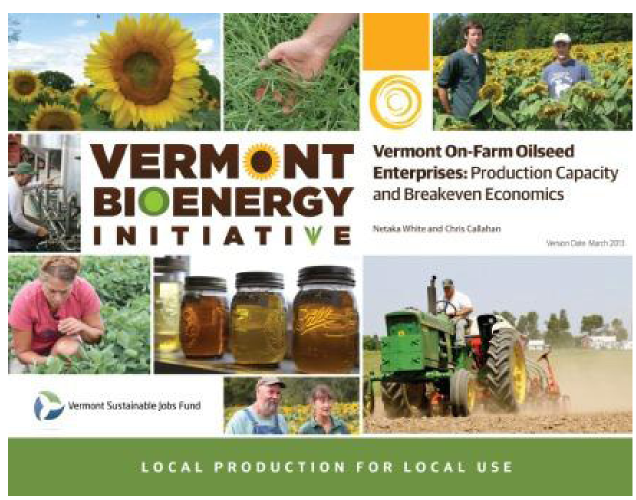


The VBI Oilseed Calculator spreadsheet has been used by people around the world.

calculation of actual unit costs for the primary outputs of the on-farm oilseed enterprises that exist and allows others to assess pro-forma economics using "typical" cost factors included in the input entry page or using parametric sweeps of these parameters (Callahan, 2010).

Oilseed Breakeven Economics Report

To summarize established capacity, document enterprise case studies and demonstrate economic fuel product progress, Netaka White and Chris Callahan prepared a report on VBI associated production capacity and break-even economics in 2012, and updated it in 2013. The findings of this report served as a common message and foundation for outreach and education during the later portion of the funding period. The key



findings noted that even at relatively moderate yields and at small scales of production, farm-based biodiesel enterprises are producing fuel:

- At a cost of $2.30-2.50 per gallon,
- With a net energy return ratio of between 3.6 and 5.9 to 1, and
- With net carbon avoidance of 1,984 to 3,227 pounds per acre per year.

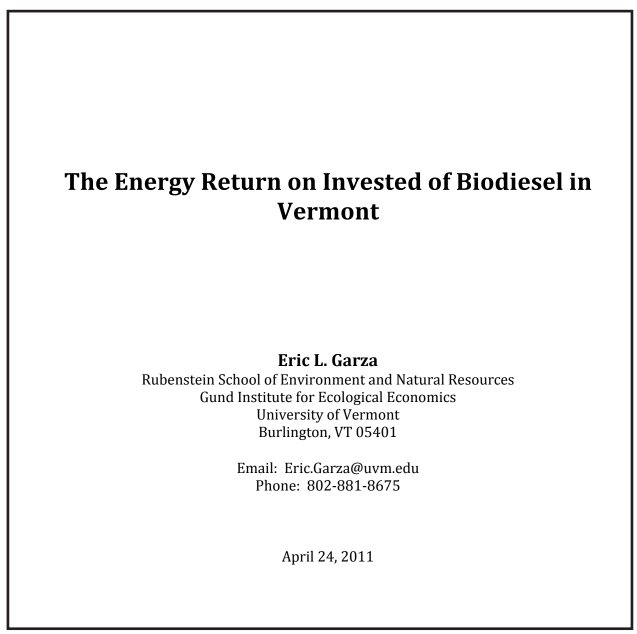
The report explored two scales of production and considered cost of outputs relative to a parametric review of two key parameters: cost per acre of production and yield. (Callahan & White, 2013).

Oilseed Greenhouse Gas Calculator and Report

In addition to financial costs of production and energy return assessments, it was important to determine the net carbon impact of the on-farm oilseed model. Campbell (2009) assessed the carbon equivalent impact of these practices as a graduate thesis and found that, on average, they achieved net carbon avoidance of 1,984 to 3,227 pounds per acre per year (Campbell, 2009).

Oilseed Energy Return on Investment Report

A key question related to the production of biofuels is whether and how well individual pathways deliver net positive energy. The extraction and/or harvesting of feedstocks, their processing and the equipment used in the process all require energy inputs which must be considered when evaluating the fuels. Supported by the VBI, UVM Rubenstein School's Eric Garza reviewed the initiative's farm-based oilseed operations using a life cycle assessment and determined returns of 2.6 to 5.9 with projections to 3.9 to 8.1 based on increases in production (Garza, 2011).


The Energy Return on Invested of Biodiesel in Vermont

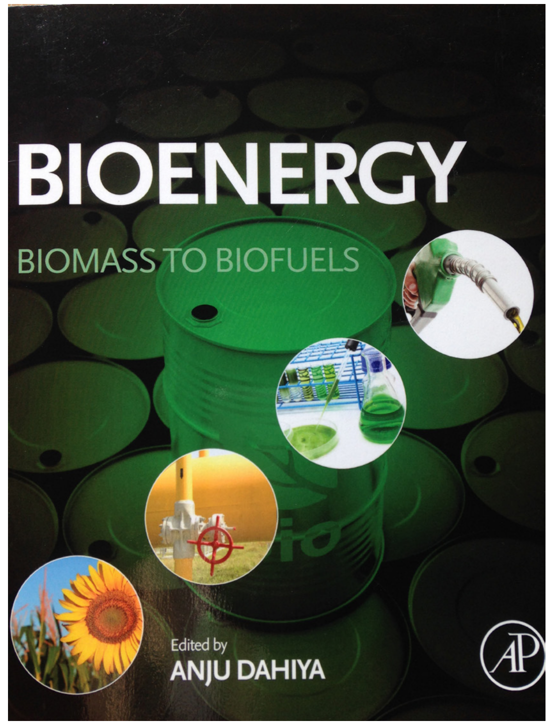
Eric L. Garza
Rubenstein School of Environment and Natural Resources
Gund Institute for Ecological Economics
University of Vermont
Burlington, VT 05401

Email: Eric.Garza@uvm.edu
Phone: 802-881-8675

April 24, 2011

Bioenergy Textbook

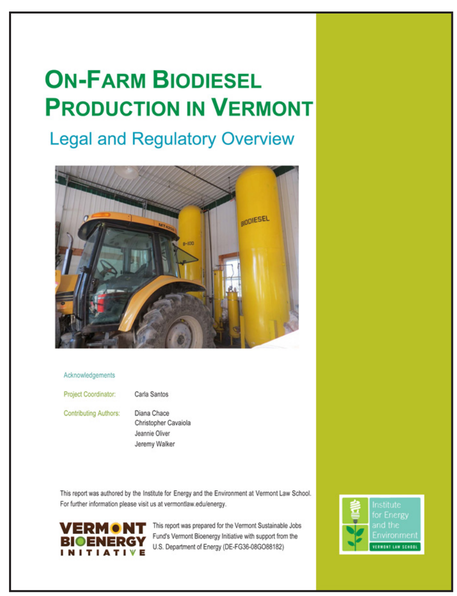
Several VBI supported researchers and educators contributed to the development of a bioenergy textbook led by Anju Dahiya Krivov and resulting in the publication of ***Bioenergy: Biomass to Biofuels*** (Krivov, 2014). The textbook examines current and emerging feedstocks and advanced processes and technologies enabling the development of all possible alternative energy sources: solid (wood energy, grass energy, and other biomass), liquid (biodiesel, algae biofuel, ethanol), and gaseous/electric (biogas, syngas, bioelectricity). Divided into seven parts, Bioenergy gives thorough consideration to topics such as feedstocks, biomass production and utilization, life cycle analysis, Energy Return on Invested (EROI), integrated sustainability assessments, conversions technologies, biofuels economics and policy. In addition, contributions from leading industry professionals and academics, augmented by related service-learning case studies and quizzes, provide readers with a comprehensive resource that connect theory to real-world implementation.



Dr. Krivov edited a Bioenergy textbook.

VT Biofuels Regulatory Review

The development of on-farm biodiesel systems among VBI sub-recipients helped to better articulate regulatory concerns across a number of areas (e.g., siting, environmental, land use, taxation.) In 2015, the VBI initiated a regulatory review by the Vermont Law School Institute for Energy and the Environment (Santos, Chace, Cavaiola, Oliver, & Walker, 2016).



NEXT STEPS

The oilseed and biodiesel infrastructure investments of the VBI has supported the development of an overall capacity of 605,000 gallons per year. For a variety of reasons, actual production volumes have remained well below that with each facility generally producing less than 5,000 gallons per year. Crop production challenges such as disease, weather and pest pressure have prevented more wide-spread adoption of crops and ultimately acceptable yields that would support higher volume production.

Although dips in petroleum prices have made the economics of biodiesel production in Vermont less attractive, the state still has the opportunity to expand the production and use of agriculturally derived bioenergy products to heat homes, offices, and commercial spaces, and for use in transportation and on farms. During the past 15 years, many Vermonters have worked to introduce liquid bioenergy products and develop viable production systems that foster the emergence of new bioenergy technologies and markets. Many of these projects remain active because farmers are interested in environmental sustainability, energy independence, and building capacity for a time when diesel prices may rise.

New private sector oilseed and bioenergy developments have benefited from the work of the VBI. Full Sun Oil Company is a startup venture in Middlebury that is producing high quality culinary oils centered around regionally and locally sourced oilseeds. The company also has long-range plans related to biofuel production via a closed loop supply chain model. Additionally, Green Mountain Power, the state's largest utility, has expressed interest in increasingly fueling their truck fleet with sustainably sourced liquid fuels. They contracted with two VBI grantees to grow sunflowers for making biodiesel in 2015 as a small pilot project and remain interested in the longer term potential of this model.

"Who knew?! That in Vermont you could power up your 180 HP tractor, feed the animals, dress your salad, reduce CO_2 emissions and save money with just a couple small fields of sunflowers?"

— Netaka White, Vermont Sustainable Jobs Fund

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