VERMONT BIOENERGY INITIATIVE

A program of the Vermont Sustainable Jobs Fund

Final Report to the U.S. Department of Energy

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

September 2016

ACKNOWLEDGEMENTS

THANK YOU to the Office of Senator Patrick Leahy and his staff for securing three U.S. Department of Energy congressionally directed awards (FY08, FY09, FY10) to financially support the Vermont Bioenergy Initiative. Without this funding, this initiative would have never happened!

The Vermont Bioenergy Initiative spanned eight years of activity, from 2008 to 2016. Over that time, the Vermont Sustainable Jobs Fund had the pleasure of collaborating with a number of bioenergy innovators and early adopters, talented consultants, and thought partners. We'd like to acknowledge and thank the following individuals and their organizations for being part of this ambitious and first of its kind initiative in the United States.

Staff and Key Consultants: Netaka White, Chris Callahan (Callahan Engineering and UVM Extension), Scott Sawyer, Ellen Kahler, Sarah Galbraith, Anthony Mennona, Mike Brouillette (Vermont Center for Geographic Information), Heather Pipino, Greg (River) Strong (Spring Hill Solutions), Gretchen Stern.

VSJF Biofuels Grants Committee: Ed Kiniry, Nancy Wood, Kelly Launder, David Lane, Bill Murray.

Sub-Recipients: John Williamson – Stateline Biofuels; Roger Rainville – Borderview Farm; Larry Scott and Peggy Hewes – Ekolott Farm; Nick and Taylor Meyers – North Hardwick Dairy; Mark and Bill Mordasky – Rainbow Valley Farm; Jon Satz and Brad Lawes – Otter Creek Biofuels (Woods Market Garden and Lawes Ag); Andrew Knafel – Clearbrook Farm; Dr. Heather Darby and her team at the Northwest Crop & Soils program at University of Vermont Extension; Dr. Sid Bosworth – UVM Extension; John Bootle and Adam Dantzscher – Renewable Energy Resource; Greg Cox – Vermont Farmers Food Center; Dr. Anju Dahiya Krivov – GSR Solutions; Josh Wilkenfeld – Carbon Harvest Energy; Dr. Alexander (Sandy) Wurthmann and Bryan Holmes – Green Mountain Spark; Dr. Jeffrey Marshall – UVM School of Engineering; Gail Busch – Algepower; Peter Bourne – Bournes Energy; Scott Oeschger – D&C Transportation; Winston Sadoo – Nava Bioenergy; Dr. John Todd – University of Vermont; Dr. John Kidder – Vermont Technical College; Renewable Energy Vermont; and Vermont Businesses for Social Responsibility.

Research Consultants: Vermont Law School's Institute for Energy and the Environment; Eric Garza – UVM Rubenstein School; Eleanor Campbell; Dwayne Martin – Shearwater Energy Partners; Biomass Commodities Corp.; Wilson Engineering; Energy Co-op of Vermont; ACORN Renewable Energy Co-op, Sunwood Biomass; VT Wood Pellet Company; Chris Davis - Meach Cove Trust; Mike Dolce - UVM Extension; Emily Stebbins.

Other Key Project Partners: Biomass Energy Resource Center, KSE Partners, Vermont Center for Geographic Information, Fountains Spatial, Renewable Energy Vermont Biofuels Working Group, Vermont Fuel Dealers Association.

Funding Partners: U.S. Department of Energy, High Meadows Fund, Vermont Agency of Agriculture, Food and Markets, Vermont Department of Public Service.

This final report to the US DOE was written by Chris Callahan, Scott Sawyer and Ellen Kahler.

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

TABLE OF CONTENTS

ABOUT THE VERMONT BIOENERGY INITIATIVE

The purpose of the **Vermont Bioenergy Initiative** (VBI) was to foster the development of sustainable, distributed, small-scale biodiesel and grass/mixed fiber industries in Vermont in order to produce bioenergy for local transportation, agricultural, and thermal applications, as a replacement for fossil fuel based energy.

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 in the United States—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.

We worked with interested farmers, entrepreneurs, and researchers to augment Vermont's woody biomass supply with **grass and mixed fiber pellets for thermal applications**.

We worked with interested researchers, entrepreneurs, and farmers to develop **cold climate algae** that could eventually be available for biodiesel production.

We developed **many tools** for understanding Vermont's bioenergy alternatives, including:

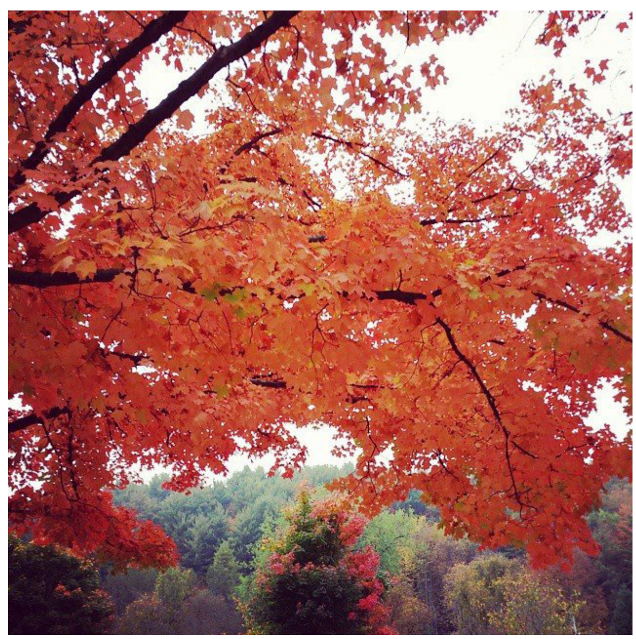
- the Renewable Energy Atlas of Vermont (relaunched in 2016 as the Community Energy Dashboard), a map-based website for visualizing existing and potential renewable energy sites;
- an Oilseed and Biodiesel Production Calculator (downloaded more than 200 times from people in the U.S. and around the world);

- a nine-part video series, Bioenergy Now!— **collectively viewed over 89,000 times—**that highlights oilseed crop and biodiesel production, grass energy production, and algae research;
- the VBI website, a repository for all materials developed by the Initiative; and
- content for biomass-to-bioenergy courses offered at the University of Vermont and Vermont Technical College.

At the beginning of this project, Vermont had very limited experience with the research, feedstocks, production processes, industry networks, and many other factors necessary to develop biodiesel and grass/mixed fiber pellet industries. **Our investments in feasibility analyses, research and development, technology and demonstration projects, and education and outreach resources for various bioenergy feedstocks have created a solid foundation for future efforts to build from.**

The Vermont Landscape

Vermont is a very small New England state with a population of 626,000 and a land area of 9,623 square miles. Forests make up about 78% of Vermont's iconic working landscape, while nearly 8,000 farms—including about 810 dairy farms milking 134,000 cows—are highly visible reminders of the rural character of the state. Not surprisingly, an estimated 37% of Vermont households get some portion of their space and water heat from firewood or wood pellets—and more than 100 institutions such as schools use woody biomass for heating. The waste from Vermont's dairy herd powers 19 anaerobic digesters. Wood bioenergy and methane biogas, then, are readily in use in Vermont's energy system.



Forests make up about 78% of Vermont's landscape.

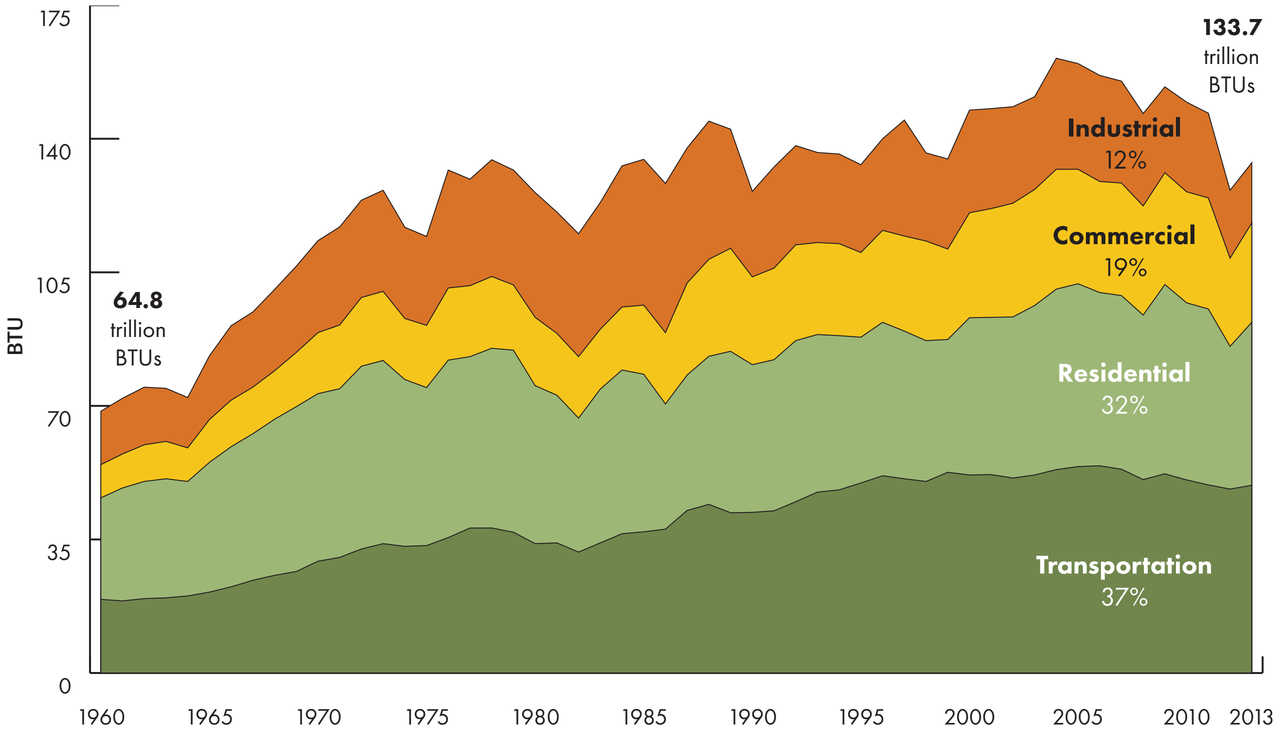
Vermont's hydropower resources have largely been tapped (equal to about 67% of total installed renewable electrical capacity), while four large wind sites have an installed capacity of about 120 megawatts (equal to about 12% of installed renewable electrical capacity), and thousands of solar photovoltaic installations have bloomed across the state. **Liquid bioenergy production and consumption, on the other hand, was virtually nonexistent in Vermont at the start of the VBI.**

Dairy farms and rolling hills are a familiar sight in Vermont.

Vermont Energy Production and Consumption

Vermont produces and consumes a relatively small amount of energy: Vermont ranks 46th in energy production in the United States (84.2 trillion BTUs in 2013), equal to 0.1% of total national energy production. Vermont consumes the least amount of energy of any state (134 trillion BTUs in 2013, Figure 1)—in fact, less than the District of Columbia—equal to 0.15% of total national consumption (Vermont ranks 44th in energy consumption on a per capita basis). Over the past 50 years, energy consumption in Vermont has increased over 100%, from about 65 trillion BTUs to 134 trillion BTUs. Transportation accounted for 36.8% (49.2 trillion BTUs) of total energy consumption in Vermont in 2013, and nonrenewable gasoline makes up 77% of energy consumption in the transportation sector. Homes in Vermont accounted for about 31.9% (42.7 trillion BTUs) of total energy consumption, and over 50% of that amount is for space and water heating from nonrenewable (e.g., distillates) and renewable (e.g., wood) sources. Vermont's commercial sector accounted for about 19.4% (26.0 trillion BTUs) of total energy consumption, and consumption is about evenly split between electricity sales and different fuels for space and water heating. Finally, Vermont's industrial sector consumed about 11.8% (15.8 trillion BTUs) of Vermont's energy from electricity sales and other mostly nonrenewable fuels for space and water heating and transportation.

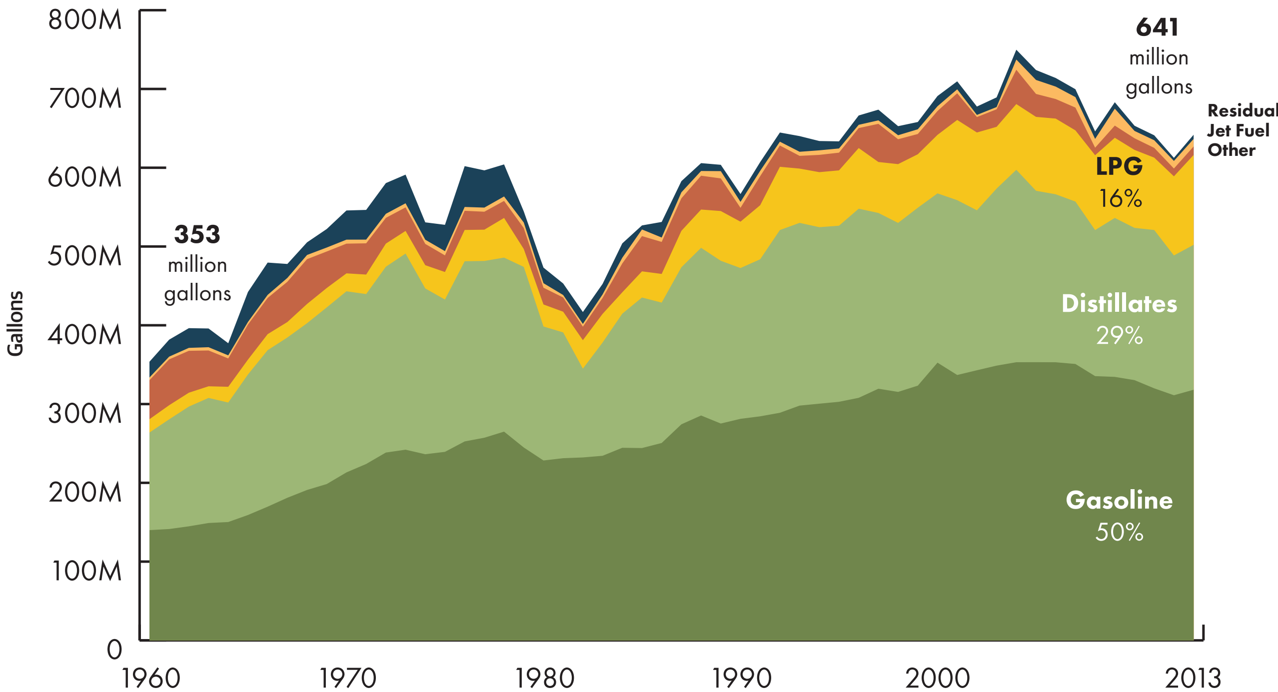
Figure 1: Vermont Energy Consumption by End Sector, 1960-2013



Source: U.S. Energy Information Administration, 2013, www.eia.gov/state/?sid=VT.

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 (Figure 2). 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.

Figure 2: Vermont Liquid Fuel Consumption, 1960-2013



Source: Energy Information Administration, www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/tx/use_tx_VT.html&sid=Vermont

Energy Use and Climate Change

The extraction of energy resources, their conversion into fuel, and their use creates a wide variety of environmental and health problems. With the combustion of fossil fuels to power societal development over the past 100 years, atmospheric concentrations of carbon dioxide have now surpassed **400 parts per million**. From 1990 to 2014, U.S. greenhouse gas emissions generally increased in the electricity, transportation, agricultural, and residential sectors (with a decrease during the Great Recession), while decreasing in the industry and commercial sectors. However, a **recent study** estimates that methane leaks from fracking and the nation's natural gas infrastructure may have increased 30% from 2002 to 2014. In other words, the replacement of coal power plants with natural gas power plants may have increased America's greenhouse gas emisssions. This increase in greenhouse gases is changing the Earth's climate, resulting in melting glaciers and ice sheets, rising ocean levels, altered weather patterns (e.g., increasing the frequency and severity of hurricanes), and changes in the composition of local plants, animals, and insects.

Vermont's emissions are equal to 0.1% of total U.S. emissions. From 1990 to 2012, Vermont's greenhouse gas emissions essentially stayed the same—a little over 8 million metric tons per year. Vermont statute called for a 25% reduction of 1990 emissions by 2012. This mark was clearly not met. Transportation and residential/commercial/industrial activities account for 72% of Vermont's greenhouse gas emissions. When substituted for their petroleum counterparts, bioenergy products like biodiesel and grass pellets can theoretically lead to a reduction in greenhouse gas emissions through the sequestration of carbon during the feedstock growth process as well as the avoidance of fossil fuel-related emissions. In 2009, Eleanor Campbell, a graduate student at the University of Vermont, assessed the carbon equivalent impact of small-scale sunflower and canola crops grown with organic and conventional methods at Borderview Farm (Alburgh, Vermont). **Campbell found that sunflower and canola crops produced with organic and conventional methods can lead to net greenhouse gas reductions when the resulting biodiesel is used in place of diesel, with organic sunflower production resulting in the largest reduction of emissions.**

Agriculture in Vermont

Vermont's small size, relatively short growing season, and hilly topography (which is more suited to small-scales of production) are generally considered to be barriers to generating large volumes of crops. According to the 2012 Census of Agriculture, 92% of Vermont's cropland is devoted to hay and corn production (428,984 acres), while oilseed crops like soybeans (4,500 acres, up from 2,011 acres in 2007) and sunflowers (68 acres) make up less than 1% of cropland. Soybean production in Vermont is mainly for animal feed.

LAND IN AGRICULTURE (2012)

Land	Acres
Vermont Land Area:	6,154,240
Land in Forest	4,591,281
Land in Agriculture:	1,251,713
Woodland	498,975
Cropland	470,403
Forage	337,694
Corn for silage	80,231
Corn for grain	11,059
Soybeans	4,478
Sunflowers	68
Pastureland	195,000

The VBI drew a connection between diversified agriculture and local renewable energy production for on-farm and community use. Namely, oilseed crops could be grown in rotation with grains (i.e., corn) and grasses and can yield high quantities of oil. At the height of VBI activities in 2010, about 320 acres were specifically devoted to oilseed crops for biodiesel production. Additionally, thousands of acres of former farmland is either unused or underutilized and this could potentially be used for growing herbaceous biomass crops such as perennial grasses. The use of grass biomass buffer strips at field edges and near waterways could help to improve water quality. **The VBI aimed to supply farm inputs (e.g., fuel and animal feed) and reduce fossil fuel consumption through research, technical assistance, infrastructure development, and education and outreach.**

Looking west from Mt. Philo across Addison County and Lake Champlain, with New York state in the background. Vermont's landscape is covered in forests, hills, mountains, and many small farms.

ABOUT THE VERMONT SUSTAINABLE JOBS FUND

As a grant-making entity, project manager, and technical assistance provider, the **Vermont Sustainable Jobs Fund (VSJF)** selected the best sub-recipient proposals for bioenergy projects through a competitive Request for Proposal (RFP) process.

Netaka White was the VBI Program Director from 2008 to 2013.

VSJF provided all grant management and administration over the course of the award period (FY08-FY16). Sub-recipients were required to provide the requisite statutory cost share as determined by the DOE and comply with all pertinent state and federal regulations and/or conditions.

VSJF also conducted a number of staff directed investigations, all designed to support the four key priorities of the U.S. Department of Energy's Multi-year Biomass 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.

Vermont Sustainable Jobs Fund

WWW.VSJF.ORG

The Vermont Sustainable Jobs Fund is a 501(c)(3) nonprofit based in Montpelier, Vermont. VSJF was created by the Vermont Legislature in 1995 to nurture the sustainable development of Vermont's economy.

VSJF provides business assistance, network development, research, and financing in food system, forest product, waste management, renewable energy, and environmental technology sectors.

STATEMENT OF PROJECT OBJECTIVES

VSJF developed objectives in six areas to nurture the development of Vermont's bioenergy sector, with the goal of reaching early stage commercialization of these oilseed, grass, and algae feedstocks over 7 years. We utilized U.S. DOE funds to deploy grants and administer projects intended to:

- Provide ongoing education, networking, outreach and technical assistance to farmers, entrepreneurs, municipalities, and others interested in expanding the production and use of bioenergy (Task A)
- Create and fund updates to the Renewable Energy Atlas of Vermont—later dubbed the **Community Energy Dashboard**—a GIS-based website for identifying, analyzing, and visualizing renewable energy sites (Task C)
- Support early-stage research and development in algal biodiesel (Task D)
- Support early-stage research and development for grass/mixed fiber pellet feedstocks and equipment (Task E)
- Expand the physical infrastructure, knowledge, outreach, and technical assistance available for on-farm biodiesel production using oilseed feedstocks (Task F)
- Develop the commercial availability of biodiesel in Vermont (Task G)

Task A: Education, Outreach, Network Development, Technical Assistance

Sub-Task A.1: Analysis, Education & Outreach

The objective of this sub-task was to organize conferences, workshops, peer learning, and networking opportunities for bioenergy entrepreneurs, farmers, academics, state officials, service providers, and consumers to share knowledge and experience. This sub-task also supported the development of educational curriculum at Vermont Technical College and the University of Vermont in bioenergy related research, technology, and production application.

Sub-Task A.2: Technical Assistance

The objective of this sub-task was to provide technical assistance to entrepreneurs and farmers for feedstock development, agronomic species and biological analysis, business planning and business model development, systems optimization, economic analysis, greenhouse gas assessments, and energy returned on energy invested calculations.

Task B: Project Management & Solicitation Administration

VSJF managed all aspects of DOE pre-award paperwork; conducted sub-award solicitations; coordinated and managed grant making; identified and secured co-funding opportunities; monitored funded projects; submitted quarterly reports to the U.S. DOE; and tracked outcomes.

Task C: Community Energy Dashboard (formerly Renewable Energy Atlas of Vermont)

The objective of Task C was to develop a GIS-based website of existing and potential bioenergy and other renewable energy locations that could spur future development statewide.

Task D: Algae Feedstock Analysis and Production Techniques

Sub-Task D.1: Research

The objective of this sub-task was to provide sub-recipient award funding to researchers, entrepreneurs, and others to experiment with the development of algae feedstocks that are adaptable to nutrient-rich waste streams and suitable for Vermont's colder climate. Research included how algae could interface with other Vermont-scale agricultural activities (e.g., anaerobic digesters, nutrient management).

Sub-Task D.2: Logistics / Production

The objective of this sub-task was to provide sub-recipient award funding for algae feedstock logistics and new methods for optimizing production processes that fit the scale of Vermont farms and communities. Funding supported lipid optimization, harvest, dewatering, oil extraction, and refined oil and algal biomass research.

Sub-Task D.3: Processing / Demonstration

The objective of this sub-task was to provide sub-recipient award funding for demonstration projects (e.g., analysis of prototype for algal biodiesel production facility.)

Task E: Biomass – Feedstock Analysis and Production Techniques

Sub-Task E.1: Agronomics / Research

The objective of this sub-task was to provide sub-recipient award funding to researchers, entrepreneurs, and farmers to experiment with the development of perennial grass and biomass feedstocks that are suitable for Vermont soils and climate. Agronomic research for biomass crops involved replicated field trials and analysis on appropriate varieties (e.g., yield, vigor, ash content), soil impacts, seeding rates, nutrient management, weed, disease, and pest control. Research included grass varieties that can be pelletized or potentially be used for cellulosic ethanol production. Research evaluated cost and reliability of supply, potential volume available, and distribution considerations.

Sub-Task E.2: Logistics / Production

The objective of this sub-task was to provide sub-recipient award funding to find new methods for optimizing production processes, including harvesting and drying techniques, optimal storage moisture, and managing ash content. Logistics trials included fiber processing and pellet production testing (i.e., grass and grass-wood combinations) using stationary and/or mobile equipment; identification of appropriate fiber processing and pelletizing machinery to meet the needs of a single farm, group of farms, or a surrounding community.

Sub-Task E.3: Processing / Demonstration

The objective of this sub-task was to provide sub-recipient award funding for demonstration projects (e.g., analysis of grass pellet heating plant in a small commercial business).

Task F: Oilseed Crops – Feedstock Analysis & Production Techniques

Sub-Task F.1: Agronomics / Research

The objective of this sub-task was to provide sub-recipient award 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 of appropriate varieties (e.g., oil content, sugar content, and meal quality), seeding rates, nutrient management, weed, disease, and pest control.

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).

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 potentially ethanol production as a methanol replacement for biodiesel production).

Task G: Expansion of Commercial Biofuels Availability

Sub-Task G.1: Research and Development

The objective of this sub-task was to provide sub-recipient award funding to Vermont fuel dealers to complete land use and/or engineering feasibility studies and/or analyze financing options for new or improved capacity (e.g., to comply with new EPA rules, to provide biodiesel and bioheat in underserved areas of the state) or to expand into other renewable fuels.

Sub-Task G.2: Demonstration / Biodiesel

The objective of this sub-task was to provide sub-recipient award funding to enhance biodiesel blending capacity in the state.

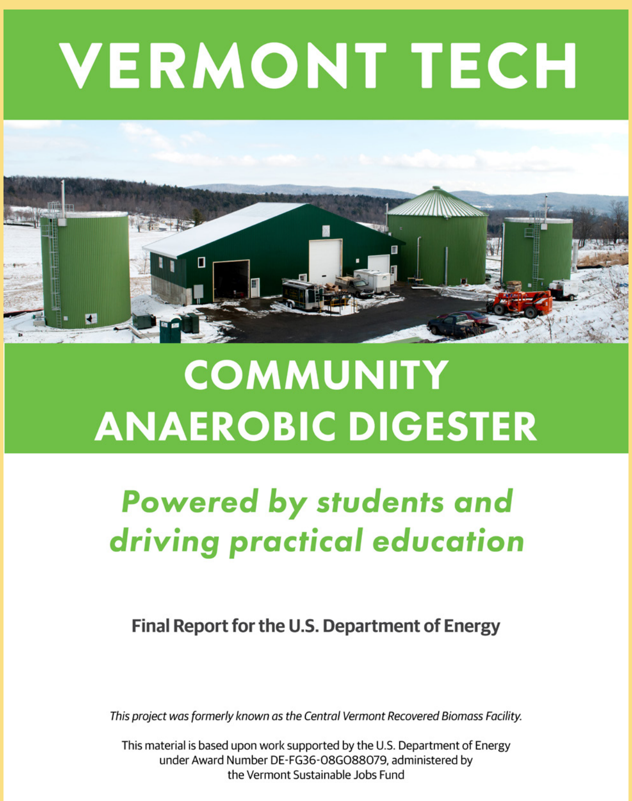
Sub-Task G.3: Demonstration / Biomass fuel

The objective of this sub-task was to provide sub-recipient award funding to enhance bulk distribution of biomass heating fuel in the state.

Report Outline

The rest of this overview provides a summary of VBI tasks. It starts by describing the market development approach that VSJF used to deploy sub-recipient funding and staff-directed projects. It then summarizes tasks based on the stage of development of each bioenergy topic (e.g., number of participants, level of sub-recipient readiness, availability of technical assistance and research expertise), starting with oilseed crops and biodiesel (Task F), grass energy (Task E), algae research (Task D), and commercial biodiesel (Task G). The overview ends by describing the Renewable Energy Atlas of Vermont—renamed the Community Energy Dashboard in 2016—(Task C), and VBI education and outreach activities (Task A).

RELATED PROJECT


VERMONT TECH

COMMUNITY ANAEROBIC DIGESTER

Powered by students and driving practical education

Final Report for the U.S. Department of Energy

This project was formerly known as the Central Vermont Recovered Biomass Facility.

This material is based upon work supported by the U.S. Department of Energy under Award Number DE-FG36-08GO88079, administered by the Vermont Sustainable Jobs Fund

"Big Bertha," the anaerobic digester at Vermont Technical College, is operating at full capacity and successfully putting electricity onto the grid. With a carefully formulated diet of cow manure and organic matter from Vermont farms and brewery waste from the Alchemist and Long Trail Brewing Co., at full power Big Bertha transforms 16,000 gallons of waste to 8,800 kilowatt hours of electricity daily—equivalent to about 200 gallons of heating oil, or the amount of electricity consumed by about 70 houses on a cold day.

VSJF acted as fiscal sponsor for this project (DOE Award Number DE-FG36-08GO88079).

VSJF'S MARKET DEVELOPMENT APPROACH

The components of Vermont's bioenergy supply chain for oilseed crops. grasses, and algae were virtually nonexistent in Vermont when the VBI started. VSJF uses a market development approach to nurture the sustainable development of Vermont's economy for food systems, forest products, and, through the VBI, energy systems. We ask several questions: Where is a particular market in its development trajectory? What does a particular market's supply chain currently look like? By meeting a set of ten market development needs across a supply chain—from feedstock production, feedstock logistics, and biomass conversion, to bioenergy distribution and end use—the intention is to highlight and address specific market development needs that could strengthen Vermont's renewable energy system.

Market Development Needs

- **Research** (e.g., oilseed and perennial grass agronomics)
- **Natural Resource, Physical Infrastructure, and Technology** (e.g., land use issues, using new equipment, infrastructure development and optimization)
- **Sales and Distribution** (e.g., matching bioenergy supply and demand, gaining familiarity with bioenergy products and distribution methods)
- **Marketing and Public Outreach** (e.g., building consumer awareness about bioenergy products)
- **Business Planning and Technical Assistance** (e.g., agronomic advice to farmers for oilseed production, engineering advice for biodiesel processing facilities)
- **Financing** (e.g., identifying additional sources of funding for businesses at different stages of development)
- **Network Development** (e.g., support for existing networks and trade associations, creation of peer learning opportunities)
- **Education** (e.g., technical exposure to bioenergy topics at institutions of higher education)

- **Workforce Development** (e.g., identifying workforce needs)
- **Regulation and Public Policy** (e.g., identifying state or federal regulations that impact bioenergy production in Vermont).

Matrix Key:

- Oilseed and/or biodiesel production projects (yellow)
- Grass energy projects (light green)
- Algae projects (dark green)
- Cross-cutting projects (e.g., education and technical assistance) (orange)

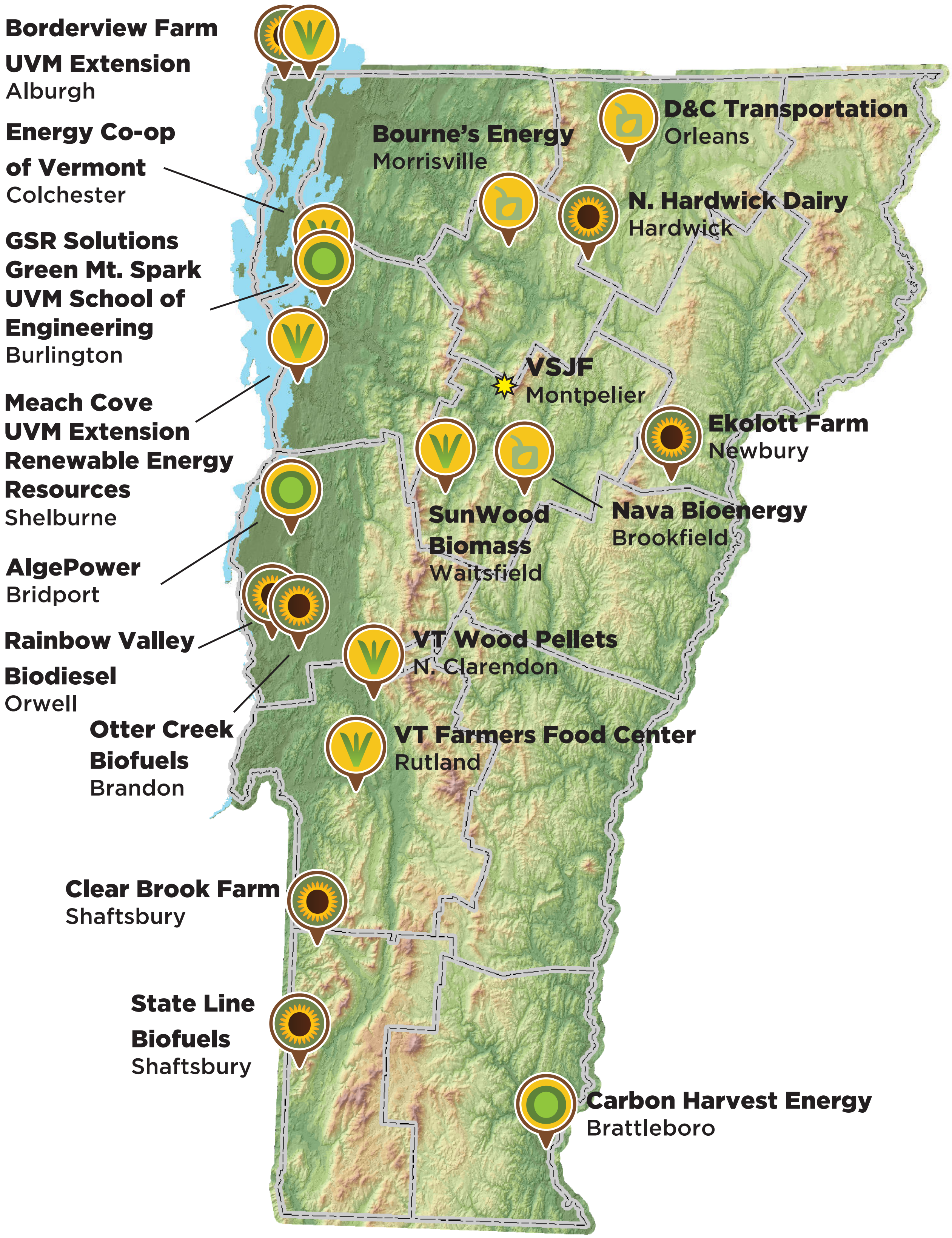
VBI MARKET DEVELOPMENT MATRIX

<table>
<tr><th>Market Development Needs</th><th>Feedstock Production</th><th>Feedstock Logistics</th><th>Bioenergy Conversion</th><th>Bioenergy Distribution</th><th>Bioenergy End Use</th></tr>
<tr><td rowspan="7">Research</td><td colspan="2">UVM Extension: oilseed production and processing research</td><td>Eric Garza: On-Farm Biodiesel EROEI analysis</td><td></td><td>Eleanor Campbell: GHG emission calculator</td></tr>
<tr><td colspan="2">UVM Extension: perennial grass production and processing research</td><td></td><td></td><td>Biomass Commodities Corp and VSJF: Air Emission Profile Testing</td></tr>
<tr><td colspan="5">Wilson Engineering: Grass Energy in Vermont and the Northeast report</td></tr>
<tr><td colspan="2">GSR Solutions: algae feedstock development</td><td>Green Mountain Spark: photochemical reactor</td><td></td><td></td></tr>
<tr><td>UVM School of Engineering: algae mixing test facility</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Algepower: production system</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Carbon Harvest Energy: production system</td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th>Market Development Needs</th><th>Feedstock Production</th><th>Feedstock Logistics</th><th>Bioenergy Conversion</th><th>Bioenergy Distribution</th><th>Bioenergy End Use</th></tr>
<tr><td rowspan="10">Natural Resource / Technology / Infrastructure</td><td colspan="5">State Line Biofuels: oilseed production, processing, and biodiesel production</td></tr>
<tr><td colspan="5">Borderview Farm: oilseed production, processing, and biodiesel production</td></tr>
<tr><td colspan="5">Rainbow Valley Farm: oilseed production, processing, and biodiesel production</td></tr>
<tr><td colspan="3">North Hardwick Dairy: oilseed production and processing, and biodiesel production</td><td></td><td></td></tr>
<tr><td colspan="2">Otter Creek Biofuels: oilseed production and processing</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Clearbrook Farm: oilseed production and processing</td><td>Nava Bioenergy: biodiesel production</td><td>Bourne’s Energy biodiesel blending facilities</td><td></td></tr>
<tr><td colspan="2">Ekolott Farm: oilseed production and processing</td><td></td><td>D&C Transp.: biodiesel blending facilities</td><td></td></tr>
<tr><td></td><td>Energy Co-op of Vermont: bulk bins</td><td>Vermont Farmers Food Center: Thermal Conversion & Economic Feasibility Research</td><td>Acorn Renewable Energy Co-op: delivery system</td><td></td></tr>
<tr><td></td><td colspan="2">Renewable Energy Resources: Densification and Transportation</td><td>SunWood Biomass: delivery system</td><td></td></tr>
<tr><td></td><td></td><td></td><td>VT Wood Pellet Company: delivery system</td><td></td></tr>
<tr><td>Financing</td><td colspan="5">VSJF, Vermont Department of Public Service, Vermont Agency of Agriculture, High Meadows Fund</td></tr>
<tr><td rowspan="4">Technical Assistance</td><td colspan="2">Dr. Heather Darby (UVM Extension): oilseed production and processing research</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Dr. Sid Bosworth (UVM Extension): perennial grass technical assistance</td></tr>
<tr><td colspan="5">Chris Callahan (UVM Extension): engineering technical assistance; project management</td></tr>
<tr><td></td><td></td><td></td><td></td><td>VBSR: Business Energy Action program</td></tr>
</table>

<table>
<tr><th>Market Development Needs</th><th>Feedstock Production</th><th>Feedstock Logistics</th><th>Bioenergy Conversion</th><th>Bioenergy Distribution</th><th>Bioenergy End Use</th></tr>
<tr><td rowspan="3">Network Development</td><td colspan="5">Field Days, Peer Learning Events: networking events for oilseed farmers</td></tr>
<tr><td colspan="5">Grass Energy Collaborative: networking events</td></tr>
<tr><td colspan="5">Renewable Energy Vermont: Biofuels Working Group</td></tr>
<tr><td rowspan="9">Education / Outreach</td><td colspan="5">UVM Extension: Field Days, peer learning events, and networking events for oilseed farmers</td></tr>
<tr><td colspan="5">UVM Extension: Field Days, peer learning events, and networking events for grass farmers</td></tr>
<tr><td colspan="5">UVM: Biomass to Biofuels course</td></tr>
<tr><td colspan="5">Vermont Tech: Biomass to Biofuels course</td></tr>
<tr><td colspan="5">Grass Energy Symposium</td></tr>
<tr><td colspan="5">Algae Symposium</td></tr>
<tr><td>Community Energy Dashboard: energy analysis and mapping</td><td></td><td></td><td></td><td>Community Energy Dashboard: energy analysis and mapping</td></tr>
<tr><td colspan="5">Bioenergy Now!: 10-part video series that explores the Vermont Bioenergy Initiative</td></tr>
<tr><td colspan="5">Vermont Bioenergy Initiative website: online platform for all Vermont Bioenergy Initiative resources</td></tr>
<tr><td rowspan="2">Workforce Development</td><td colspan="5">UVM: Biomass to Biofuels course</td></tr>
<tr><td colspan="5">Vermont Tech: Biomass to Biofuels course</td></tr>
<tr><td rowspan="2">Sales and Distribution</td><td></td><td></td><td></td><td>Bourne's Energy biodiesel blending facilities</td><td></td></tr>
<tr><td></td><td></td><td></td><td>D&C Transp.: biodiesel blending facilities</td><td></td></tr>
<tr><td rowspan="2">Regulatory / Public Policy</td><td></td><td></td><td colspan="2">Vermont Law School: on-farm biodiesel production legal and regulatory review</td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Shearwater Energy Partners: On-Farm Biodiesel RINS analysis</td></tr>
</table>

MAP OF VBI RESEARCH AND DEMONSTRATION SITES



TASK F: OILSEED CROPS AND BIODIESEL

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).

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 and agronomic researcher sub-recipients supported by the VBI needed to study-up and tool-up in order to become acquainted with the reintroduced crops. For example, planters and seed drills needed to be modified and small combines needed to be purchased. 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.

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. These activities have been in pursuit of objectives outlined in multiple Statement of Project Objectives among a variety of sub-recipients.

Our original intention was to develop sufficient on-farm capacity to replace at least 12.5% (750,000 gallons) of the 6 million gallons of imported diesel and at least 12,500 tons of the over 100,000 tons of livestock meal consumed each year on Vermont farms with homegrown biodiesel and feed. This was informed by actions taken by farmers and researchers responding to high prices for diesel—$5 a gallon—at the pump in 2008. At the height of the VBI in 2010, about 320 acres were specifically devoted to oilseed crops in Vermont. While biodiesel production in Vermont is relatively low, the vision of producing a percentage of our liquid fuel needs with local alternatives remains relevant, and the agronomic and technical knowledge now exists to do so.

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	$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	$207,989
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**
	TASK TOTAL	**$840,283**	**$515,660**	**$1,355,943**

These efforts have produced the following findings:

Crop Production and Agronomic Research

- Oilseed crops can be successfully grown in the Vermont and the Northeast US. Researchers and growers in Vermont have successfully produced sunflower, canola, winter rapeseed, flax, safflower, and camelina.
- Production guidance from other, high-volume production regions 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 in 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.

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.

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 would 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.

- The Vermont Bioenergy 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 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.

Lessons Learned

1.) Oilseed crops such as sunflower, canola, winter rapeseed, flax, safflower and camelina can be successfully grown in the Vermont and the Northeast with relatively stable annual per-acre cost of production, albeit with lower and more variable yields than traditional production regions. VBI supported research helped to provide regionally specific crop production guidance to address the regional differences noted in these crops.

2.) System-wide infrastructure is a barrier to entry for farms in the Northeast to grow and process oilseed crops. VBI funded projects have helped to demonstrate equipment, practice and technologies that are appropriate for small to medium sized farms. Research and Extension work has helped to collect and develop best practices for this infrastructure to make further adoption and replication easier.

3.) Farm-scale biodiesel production has been demonstrated with several different systems and at several different scales and various models of shared infrastructure. This work focused on self-built, farm systems and integrated safety as a key design element.

4.) Based on an integrated economic and environmental assessment, the projects have demonstrated local crop-based, fuel production at a cost of $2.30-2.50 per gallon, with a positive energy return on investment ranging from 3.6 to 5.9 to 1, and with a net carbon avoidance of 1,984 to 3,277 pounds per acre.

"The VBI arrived at the right time to help diversified farm and energy pioneers with the tools they needed to break the cycle of fossil fuel dependence."

— Netaka White, Vermont Sustainable Jobs Fund

Larry Scott and Peggy Hewes, Ekolott Farm (Newbury, Vermont) were VBI sub-recipients for oilseed crop production.

TASK E: GRASS AND MIXED FIBER BIOENERGY

Almost a third of Vermont's total energy demand is for heating purposes. Nearly 60% of the heating fuel used in the state is No. 2 heating oil, while propane makes up 14%. Both of these are nonrenewable sources of energy, prone to extreme price fluctuations, and they contribute to carbon dioxide emissions.

Grass pucks being fed into an EvoWorld HC100 Eco boiler at Meach Cove Trust in Shelburne, VT.

Prior to the VBI's research and demonstration investigations, there had been little information on grass production for biomass purposes in Vermont, including suitable species and cultivars, agronomic practices, and economic viability. The goal of this task was to assess potential grasses and evaluate potential economic viability of direct combustion grass energy systems for Vermont and the Northeast region.

These efforts have produced the following findings:

Crop Production and Agronomic Research

- Grass biomass crops trials have demonstrated 3 to 6 tons per acre yields with annual production costs averaged over 10 years—including prorated establishment costs of $250 to $300 per acre per year—resulting in farm gate biomass costs of $50 to $80 per ton depending on annual biomass yield.
- The key factors supporting success of grass biomass crops in the region are species and variety selection, soil fertility, successful establishment including weed management, and soil productivity class.

- Grass biomass crops are aligned with the region's historical production and use of hay and other grass forages.
- Grass biomass crops can be harvested using equipment that already exists in the region.

GRASS AND MIXED FIBER BIOENERGY 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	$151,080	$40,933	$192,013
FY09-FY10	**Renewable Energy Resources:** Densification and Transportation	$117,104	$120,606	$237,710
FY10	**Vermont Farmers Food Center:** Thermal Conversion and Economic Feasibility Research	$41,000	$78,481	$119,481
	SUB-RECIPIENT SUBTOTAL	**$309,184**	**$240,020**	**$549,204**
Fiscal Year(s)	**Staff Directed Projects**	**DOE Funds**	**Total Cost Share**	**Total Project Cost**
FY10	**Wilson Engineering:** Grass Energy in Vermont and the Northeast report	$17,640		$17,640
FY08	**Biomass Commodities Corp and VSJF:** Air Emission Profile Testing	$22,468		$22,468
FY08	**VSJF and Partners:** Grass Energy Symposium	$3,738	$4,612	$8,350
FY08-FY10	**Chris Callahan:** Technical Assistance/Project Management	$1,458		$1,458
FY09	Bulk Wood Pellet Delivery Investigation	$50,000	$29,194	$79,194
	STAFF DIRECTED PROJECTS SUBTOTAL	**$95,304**	**$33,8060**	**$129,110**
	TASK TOTAL	**$404,488**	**$273,826**	**$678,314**

Densification and Transportation Research and Development

- Grass biomass crops can be densified in forms more suitable for storage, transportation, delivery and combustion in appropriately-sized heating appliances for on-farm heating at a conversion cost of $49 to $148 per ton.
- Grass biomass fuels can be delivered with production cost of $85 to $228 per ton ($5.2 to $14.4 per million BTU.).

Thermal Conversion and Economic Feasibility Research

- Grass biomass fuels can be combusted in small commercial boilers intended for wood chips with a 3 to 5 year simple payback period and emissions comparable to wood pellets.
- Recent advances in boiler design such as improved combustion air controls and automated ash removal have helped address earlier issues with the use of these newer, high-ash fuels.

Educational and Outreach

Education and outreach was a continual theme throughout the project. Several specific "Grass Energy" field days were held to provide focused, hands-on review of the developing practice. This work was integrated into other farmer "field days." The results of our research and demonstration projects have also been highlighted in undergraduate bioenergy survey courses at the University of Vermont (UVM) and Vermont Technical College. Project outputs have been posted on a variety of websites for longer-term use, including the Vermont Bioenergy Initiative website, the UVM Grass Biomass Energy website, and the UVM Extension Ag Engineering website.

Lessons Learned

1.) Grass biomass crops aligned with the region's historical production and use of hay and other grass forages and VBI supported trials have demonstrated 3 to 6 tons per acre yields with annual production costs averaged over 10 years—including prorated establishment costs of $250 to $300 per acre per year—resulting in farm gate biomass costs of $50 to $80 per ton depending on annual biomass yield. The key factors supporting success of grass biomass crops in the region are species and variety selection, soil fertility, successful establishment including weed management, and soil productivity class.

2.) Grass biomass crops can be densified in forms more suitable for storage, transportation, delivery and combustion in appropriately-sized heating appliances for on-farm heating at a conversion cost of $49 to $148 per ton leading to fuels with total production costs of $85 to $228 per ton ($5.2 to $14.4 per million BTU.)

3.) Recent advances in biomass boiler design such as improved combustion air controls and automated ash removal have helped address earlier issues with the use of these newer, high-ash fuels. Grass biomass fuels can be combusted in small commercial boilers intended for wood chips with a 3 to 5 year simple payback period and emissions comparable to wood pellets.

4.) An analysis conducted for the VBI found several barriers that make it unlikely that grass pellets will gain widespread acceptance in the residential pellet fuel market without a significant price advantage over wood, which does not currently exist. These barriers are: significantly higher ash content compared to wood, clinkering (i.e., the fusion of ash into hard chunks) caused by lower ash fusion temperatures, lower heat energy content of grass compared to wood, and increased processing costs in producing a grass pellet compared to wood pellets due to increased wear on processing equipment. Ash content and composition can be controlled by managing soils, nutrients applied, and harvest practices. There are pellet stoves, furnaces and boilers available that can burn grass pellets but the high ash content compared to wood requires more robust ash handling equipment.

5.) Larger boilers and equipment are commercially available that can burn grass from bale form to briquettes, cubes and pellets however; there are very few biomass-burning appliances of this large size currently installed in Vermont or the Northeast.

TASK D: ALGAE

As described in the National Algal Biofuels Technology Roadmap, algal biofuel production is attractive due to the possibility of 1) high per-acre productivity, 2) non-food based feedstock resources, 3) use of otherwise non-productive, non-arable land, 4) utilization of a wide variety of water sources (fresh, brackish, saline, marine, produced, and wastewater), 5) production of both biofuels and valuable co-products, and 6) potential recycling of CO_2 and other nutrient waste streams.

A view of the Carbon Harvest Energy prototype algae raceway.

The development of algal bioenergy feedstocks was pursued with VBI funding due to the potentially high yields of this approach and the possible nutrient and carbon conversion opportunities present when co-located with anaerobic digesters or landfills.

The early stage results of this body of work include:

Feedstock Development

- A curated collection of one hundred (100) oil-rich native Vermont algal strains for commercial oil production and nutrient recovery were isolated and are being maintained in a purpose-built facility with ten (10) of these strains being classified as best performers.
- Several Vermont strains that were isolated were transferred to pilot research demonstrations at a closed landfill and at a dairy farm with an anaerobic digester.
- Isolated, regional algae strains will be leveraged in projects aimed to scale up production through integration with waste streams such as new community biodigesters.

ALGAE PROJECTS

Fiscal Year(s)	Sub-Recipient	DOE Funds	Total Cost Share	Total Project Cost
FY08	**Algepower:** Production Systems	$20,000	$5,606	$25,606
FY08-FY10	**Carbon Harvest Energy:** Production Systems	$233,349	$66,225	$299,574
FY08-FY10	**GSR Solutions:** Feedstock Development	$133,833	$106,244	$240,077
FY09	**Green Mountain Spark:** Conversion Technologies	$65,000	$33,651	$98,651
FY09	**University of Vermont School of Engineering:** Production Systems	$44,828	$24,673	$69,501
	TASK TOTAL	**$497,010**	**$236,399**	**$733,409**

Production Systems

- The integration of a pilot-scale algal biomass production system with an anaerobic digester demonstrated the use of waste CO_2 and nutrient (N and P) rich digester effluent.
- The integration of a pilot-scale algal biomass production system with a landfill power plant demonstrated the use of waste CO_2 sources and tolerance of algae production to potential exhaust contamination (i.e., flue gas).
- An experimental platform was established to study the fluid dynamics of mixing and flow related to optimal algal biomass production systems at the University of Vermont School of Engineering.

Harvest and Conversion Technology

- A bench-scale photochemical algal fuel processing system was developed that is capable of producing biofuel more cost effectively and with less energy investment compared to standard oil extraction and transesterification.

- A bench-scale photochemical algal fuel processing system was developed that demonstrated production of a fuel with superior cloud point, pour point, cold filter plugging point, and heat of combustion when compared to fuel produced using transesterification.
- With the granting of a U.S. Patent for their system, Green Mountain Spark intends to pursue commercialization and scaling activities to further develop their photoreactor.

Educational and Outreach Programming

- Educational materials related to algal bioenergy production specific to Vermont have been developed and published.
- A conference focused on algal bioenergy production in the Northeast was held to share research findings and strengthen the research network.
- A Vermont network of stakeholders with interest in algal bioenergy has been established.

Lessons Learned

1.) A collection of regionally specific algae strains with high potential for oil production have been evaluated, selected and curated to provide for future development.

2.) Algal biofuels systems that are integrated with existing agricultural and food system infrastructure have been explored and demonstrated indicating potential for symbiotic solutions of waste management, carbon emission reduction and fuel production.

TASK G: COMMERCIAL BIODIESEL

The VBI provided funding support to two commercial fuel dealers for the development of blending infrastructure. Blending systems enable the proper mixing of 100% biodiesel (B100) with petroleum diesel that provides important technical and economic benefits for the early adoption of biodiesel. At the time of these projects, a blending tax credit was being provided to distributors of fuel to incentivize biodiesel purchase and use while also not exposing the market to increased risk from a complete switch. The use of a blended fuel helps to minimize technical risk that comes along with the use of 100% biodiesel (e.g., engine fuel system issues, suspension of sediment in old tanks, cold-weather performance challenges).

Bourne's Energy biodiesel blending facility.

COMMERCIAL BIODIESEL PROJECTS

Fiscal Year(s)	Sub-Recipient	DOE Funds	Total Cost Share	Total Project Cost
FY08	Bourne's Energy	$45,000	$49,077	$94,077
FY08	D&C Transportation	$32,500	$98,370	$143,370
FY08-09	Nava Bioenergy	$45,000	$126,911	$159,411
	TASK TOTAL	**$122,500**	**$274,358**	**$396,858**

These efforts have produced the following findings:

- The commercial biodiesel infrastructure supported by the VBI has helped to orient two large fuel dealers in Vermont to the handling and mixing of this biofuel. This improved integration of a new fuel into the distribution channel—about 1 million gallons over five years—sets the stage for future growth in the use of biodiesel.

Lessons Learned

- A federal tax credit was important to early adopters of biodiesel, but was removed too quickly to maintain stable use.
- There is a market for bioheat among consumers but more, and consistent, education is needed by fuel dealers to market the environmental benefits of the fuel.
- Housing biodiesel in a temperature controlled building mitigates cold weather issues likely to occur in Vermont and New England.

Further work is needed to increase production of biodiesel in the state and region to supply these enterprises with high quality fuel from sustainable sources with a reliable volume of production.

TASK C: RENEWABLE ENERGY ATLAS OF VERMONT

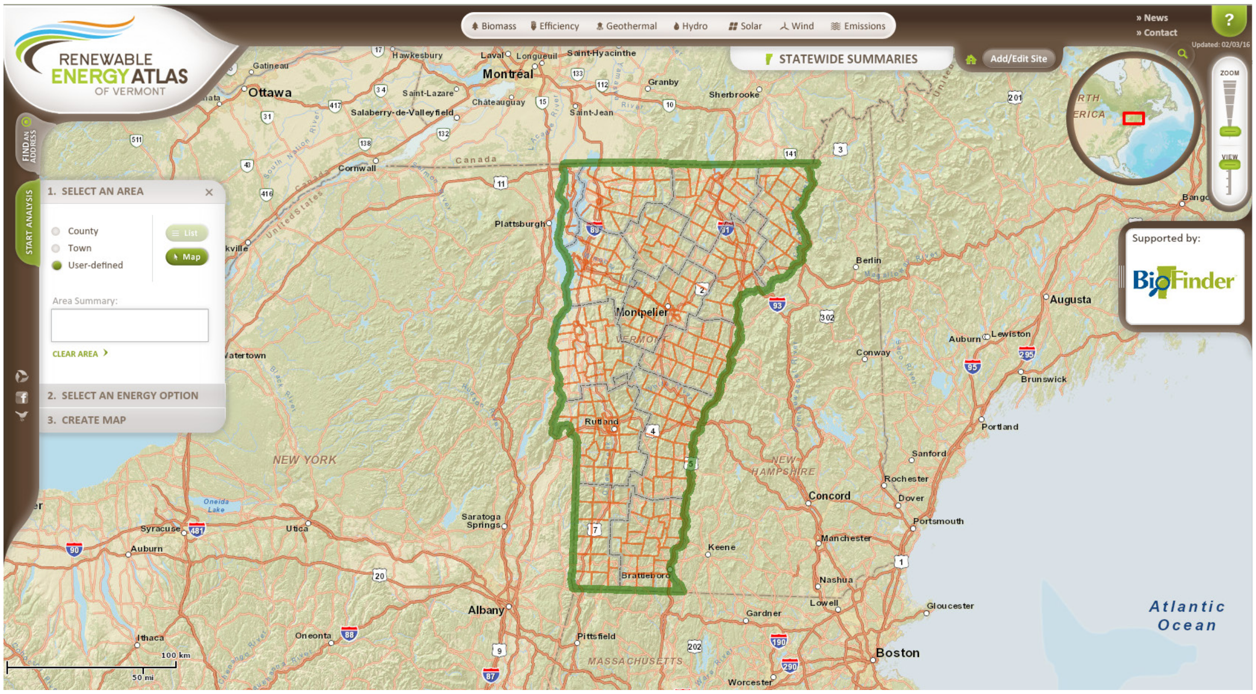
The Renewable Energy Atlas of Vermont was developed as a GIS-based website for identifying, analyzing, and visualizing existing and promising locations for renewable energy projects. The Atlas was created to assist town energy committees, Vermont's Clean Energy Development Fund and other funders, farmers, educators, planners, policy-makers, and businesses in making informed decisions about the planning and implementation of renewable energy in their communities—decisions that ultimately lead to successful projects, greater energy security, a cleaner and healthier environment. The state-of-the-art Atlas was the first tool of its kind in the United States that enabled end users to click on their town (or several towns or county/counties) and select from a thorough suite of renewable energy options: biomass, efficiency, geothermal, hydroelectric, solar, and wind.

RENEWABLE ENERGY ATLAS AND COMMUNITY ENERGY DASHBOARD

Fiscal Year(s)	Sub-Recipient	DOE Funds	Total Project Cost
FY08-10	**VSJF:** project management	$82,214	$82,214
FY08-10	**Vermont Center for Geographic Information:** Energy data layer creation	$116,667	$116,667
FY08-10	**Fountains Spatial:** website development and hosting	$114,067	$114,067
FY08-10	**Vermont Design Works:** Community Energy Dashboard data conversion	$32,129	$32,129
	TASK TOTAL	**$345,077**	**$345,077**

The results of this body of work include:

- First of its kind resource assisted Regional Planning Commissions, Vermont Department of Public Service, Vermont Energy and Climate Action Network, and other stakeholders in analyzing renewable energy potential and reporting results.



The Atlas homepage allowed users to select communities and energy layers to create maps.

- ▶ Creation of renewable energy GIS data layers available for download at the [Vermont Center for Geographic Information]() website.

- ▶ Creation of database of all renewable energy installations in Vermont.

Working with the Energy Action Network, VSJF evolved the Energy Atlas into the Community Energy Dashboard released in May 2016. The Dashboard has many more features, including:

- ▶ **Energy Atlas:** The Energy Atlas remains a tool for mapping town, county, and Regional Planning Commission boundaries for existing and potential renewable energy sites. With the tool, users can turn on additional "constraints" (e.g., endangered species habitat) in order to identify new potential sites that take environmental resources into account. Users can also crowdsource their own information.

- ▶ **Statistics:** Energy installations included in the Atlas database aggregate into real-time renewable energy installations, installed capacity, and electrical generation statistics for every town, county, and Regional Planning Commission in Vermont (e.g., Burlington, Franklin County, and Northeastern Vermont Development Association). Statistics allow users to see how their community ranks compared to other communities.

- **Analysis:** Statistics compiled by the Atlas and other official sources can then be turned into data visualizations (e.g., [Renewable Electricity Sites]) that showcase long-term trends.

- **Stories:** The Dashboard is also a central repository for a growing list of Vermont [energy stories], including Bioenergy Now! videos and bioenergy stories.

- **Progress Timeline:** A Progress Timeline for every community in Vermont allows Dashboard users to track community progress towards meeting 90% of local energy needs through efficiency and renewables by 2050. Each Progress Timeline includes heat and transportation calculations.

- **Actions:** [Action "tiles"] provide an interactive way for Dashboard users to add individual, business, municipal, school and farm actions in order to showcase the collective impact of their community.

The Dashboard includes a searchable database of Vermont renewable energy stories, including bioenergy stories.

Lessons Learned

- Use of proprietary programming software (i.e., ESRI's ArcGIS) increasingly constrained our ability to make updates to the Atlas (e.g., bulk upload of renewable energy sites was desired but not possible). Staff changes at website developer also reduced our ability to make Atlas changes. Consequently, when we transitioned from the Renewable Energy Atlas to the Community Energy Dashboard we used open source software.
- The user interface of the Atlas proved to be overly complicated for some users. When we transitioned to the Dashboard we tested all features extensively and made the user interface more intuitive.
- Bioenergy site development using the Atlas was of low interest to users compared to solar energy and wind siting.

TASK A: EDUCATION AND OUTREACH

The objectives of Task A were to develop the network of farmers and entrepreneurs involved in growing and processing oilseed crops and other bioenergy feedstocks (e.g., algae, perennial grasses) and provide peer learning opportunities. Actions included organizing conferences, workshops, and networking sessions for biofuel entrepreneurs, farmers, academics, state officials, service providers, and consumers to share knowledge and experience. VBI funding supported the development of educational curriculum at the University of Vermont and Vermont Technical College in bioenergy related research, technology and production application.

EDUCATION AND OUTREACH PROJECTS

Fiscal Year(s)	Sub-Recipient	DOE Funds	Total Cost Share	Total Project Cost
FY08	**Vermont Technical College:** College course development	$20,000	$14,600	$34,600
FY08	**University of Vermont:** College course development	$19,994	$9,600	$29,594
FY08	**Renewable Energy Vermont:** Biofuels Working Group	$13,800	$2,555	$16,355
FY09-10	**Vermont Businesses for Social Responsibility**: Business Energy Action	$54,406	$11,939	$66,345
	SUB-RECIPIENT SUBTOTAL	**$108,200**	**$38,694**	**$146,894**
Fiscal Year(s)	**Staff Directed Projects**	**DOE Funds**	**Total Cost Share**	**Total Project Cost**
FY08-09	**KSE Partners and VSJF:** Bioenergy Now! Video Production	$80,037		$80,037
FY08-10	**VSJF:** Technical assistance	$64,286	$30,677	$94,964
FY08-10	**Chris Callahan:** Oilseed technical assistance	$171,694	$36,295	$207,989
	STAFF DIRECTED PROJECTS SUBTOTAL	**$316,017**	**$66,972**	**$382,990**
	TASK TOTAL	**$424,217**	**$105,666**	**$529,884**

- **UVM Biomass to Biofuels Course:** This course provided hands-on experience with various types of bioenergy, including liquid biofuels, solid biomass, and biogas to students at the University of Vermont (Burlington, Vermont). 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 bioenergy experts; d) bioenergy equipment demonstrations by professionals; e) online supplementary classes/ information including video clips; and f) service learning projects. The course has been offered 3 times.

- **Vermont Technical College Biomass to Biofuels Course:** This project developed biomass to biofuels course modules at Vermont Technical College that provided hands-on experience and technical exposure to various feedstocks, technologies, production processes, policies, regulations, along the biomass-to-biofuels supply chain. The course was designed as separate modules to be comprised of informational slides for presentation in a classroom or discussion forum, as well as basic plans for activities that demonstrate and engage participants in the subject. The five modules addressed the following topics:
    - Introduction to Biomass and Biofuels
    - Biodiesel: Feedstock and Byproducts
    - Biodiesel: Fuel Production, Standards, and Regulations
    - Solid Biomass Fuel: Resources, Material Handling and Processing
    - Solid Biomass Fuel: Combustion, Emissions, and Byproducts

- **Renewable Energy Vermont Biofuels Working Group:** Renewable Energy Vermont is a trade association of renewable energy businesses. The Renewable Energy Vermont Biofuels Working Group— comprised of a cross-section of key bioenergy players—met regularly to promote the biofuels sector in the state. The goal of the Biofuels Working Group was to address the strategic growth of the Vermont biofuels industry with an emphasis on identifying gaps in marketing, public relations, and public policy. REV served Vermont's biofuels industry—and the renewable energy community at large—by increasing educational activities through their newsletter, conference, newspaper and public awareness efforts, industry support, and their website.

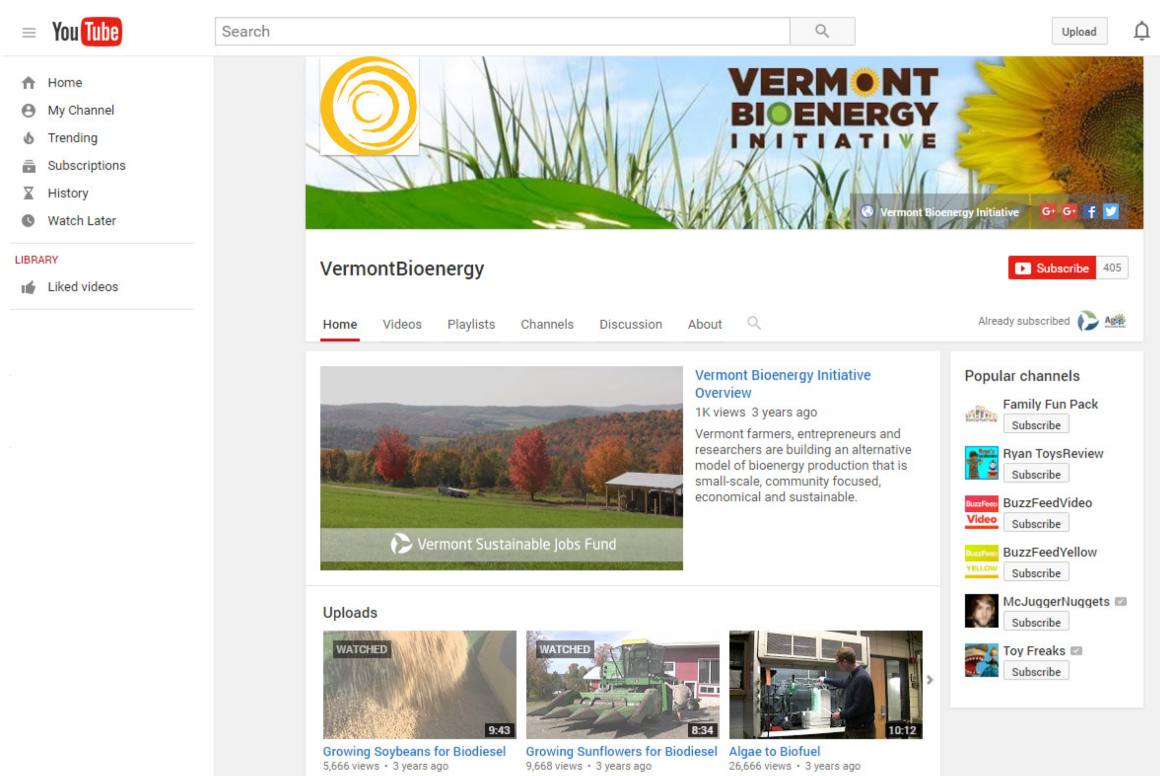
- **Vermont Businesses for Social Responsibility:** In 2012, VBSR created the Business Energy Action demonstration project to help Vermont businesses reduce consumption of electricity and heating fuel by 5% a year for 5 years. Eighty-five (85) businesses signed up to participate. They were required to make a public 5-year commitment to the project. Each business established a baseline level of energy consumption for electricity and heating fuel. Increases or decreases against the baseline were tracked for 2013 and 2014. At the end of the first project implementation year, participants exceeded the 5% savings goal.

B | E | A
Business Energy Action

- **Conferences:** VSJF staff organized numerous conferences and sub-recipient gatherings related to oilseeds, grass, and algae. For example, oilseed farmer meetings were held each spring in advance of planting season.

Question and answer session at the 2008 Grass Energy Symposium, Shelburne Farms, Vermont.

- **Bioenergy Now! 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
    - Algae to Biofuel



Tasks E and F also led to education and outreach components that we summarize here. That is, technical assistance provided through Tasks E and F frequently led to products such as reports with education and outreach relevance. VSJF helped spread these products through various communications channels.

University of Vermont Extension Northwest Crops and Soil Team

As part of her sub-recipient grant awards, Dr. Heather Darby provided extensive agronomic related technical assistance to a large number of oilseed farmers from 2008 to 2015.

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.

Oilseed Growers Meetings (Annual)

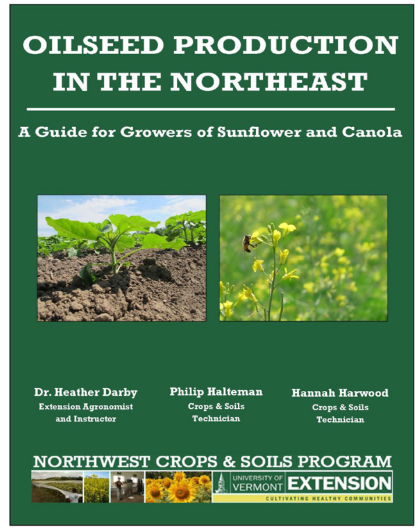
In addition to the annual field days, the UVM Extension Northwest Crops and Soils Team facilitated annual meetings of growers actively involved in oilseed crop production. These late winter meetings were held centrally in Berlin or White River Junction (Vermont) each year beginning in 2010. The gatherings 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.

Oilseed Production in the Northeast

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 the past six years are posted on the website.

University of Vermont Department of Plant and Soil Science

As part of his sub-recipient grant awards, Dr. Sid Bosworth from UVM provided extensive agronomic related technical assistance to grass farmers between 2008 – 2015.

On-Farm Field Days

- Two major field days were held at the Meach Cove and Vermont Tech locations in 2010 and 2011, respectively.
- The Borderview Farm research trials conducted by Dr. Sid Bosworth (UVM Extension) were highlighted at four consecutive Crop Field Days held there from 2009 to 2012.

Grass Energy Symposium

- A Grass Energy Symposium was held in November, 2008 and featured many speakers on topics such as growing and harvesting, processing and pelletizing, and the state of combustion technology.

Perennial Grass Production in the Northeast

- A website dedicated to highlighting Dr. Bosworth's research results was launched (http://pss.uvm.edu/grassenergy).

Chris Callahan, Callahan Engineering PLLC and University of Vermont Extension Ag Engineering

Chris Callahan Engineering (2005-2012) provided engineering assistance (e.g., systems optimization, FMEA safety protocols, economic analysis) as an independent contractor and then through UVM Extension after Callahan joined this organization as their Agricultural Engineer (2012-present). With VSJF's Bioenergy Director, Netaka White, and, later, Sarah Galbraith, Callahan provided guidance in the development of these reports.

- **Oilseeds and Biodiesel Cost of Production 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 by Chris Callahan: 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 calculation of actual unit costs for the primary outputs of the on-farm oilseed enterprises that exist and allow others to assess pro-forma economics using "typical" cost factors included in the input entry page or using parametric sweeps of these parameters.

- **A Feasibility Study of a Mobile Unit for Processing Oilseed Crops and Producing Biodiesel in Vermont:** A feasibility study completed by Chris Callahan (and funded by the High Meadows Fund) reviewed the feasibility of a mobile oilseed processing unit in Vermont. A mobile oilseed processing unit was predicted to be a feasible and profitable opportunity. It is technically feasible to transport appropriately sized equipment with a truck and small trailer to remote locations to provide processing services. It was also estimated that the cost of processing is below the market value of certain outputs (biodiesel and organic meal). A key challenge to such an operation will be establishing a sufficient initial market to breakeven at a reasonable price while also planning on future growth to capitalize on economies of higher volume production. As production volume increases, the breakeven price will decrease and higher profit can be realized at the same market price. A processor charging a price between breakeven and market value can realize a profit while providing some savings to the farmers they serve.

- **An Update on Solid Grass Biomass Fuels in Vermont:** This report documented densification and combustion testing of solid grass biomass fuels from switchgrass, miscanthus, reed canary grass, mulch hay, and "Ag Biomass"/field residue in the fall of 2015. Research identified finished fuel costs for grass and ag biomass solid fuels in Vermont, combustion efficiency of these fuels in an EvoWorld HC100 Eco commercial boiler, and determined the payback period for both the boiler and the delivered fuel.

Additional Research Projects

- **Energy Return on Energy Invested Research:** Research was conducted by Eric Garza, lecturer at the Rubenstein School for Environment and Natural Resources at the University of Vermont which examined the EROEI of small-scale locally produced biodiesel compared to large industrial scale production systems. Garza reviewed the VBI'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.

- **Greenhouse Gas Emissions Research:** Research conducted by Eleanor Campbell examined the GHG impacts of small-scale locally produced biodiesel compared to large industrial-scale production systems. Campbell assessed the carbon equivalent impact of these practices and found that, on average, they achieved net carbon avoidance of 1,984 to 3,227 pounds per acre per year.

- **Renewable Identification Number Research:** An analysis was conducted by Shearwater Energy Partners to explore the feasibility of generating RINs from on-farm biofuels. This investigation explored the economic and practical constraints, and compliance issues associated with small scale biodiesel production and the RINS market. It was determined that this was not an opportunity for Vermont small scale biodiesel producers to explore further at the time. VSJF staff prepared comments that were submitted in April 2013 on Proposed Rulemaking for USEPA 40 CFR Part 80, EPA-HQ-

OAR-2012-0621; FRL-9758-7, RIN 2060-AR72, RFS Renewable Identification Number (RIN) Quality Assurance Program.

- **Legal and Regulatory Overview of On-Farm Biodiesel Production:** This report informs farmers interested in producing biodiesel on their own farm about the potential laws and regulations that may be triggered when adding biodiesel production to their farming activities. While several of the federal regulations are only triggered by high levels of production, there are a number of state laws and regulations that may be triggered by small-scale biodiesel production, such as state air emission provisions that establish lower thresholds when compared to the federal Clean Air Act. In addition, it is critical to understand the role biodiesel production plays in the definition of "farm" and "farming activities" for the purpose of states laws, such as Act 250 and Vermont's Use Value Appraisal Program.

- **Grass Energy in Vermont and the Northeast:** The purpose of this report was to explore whether grass thermal energy can be a viable industry in Vermont. The task included reviewing publications, interviewing people involved in developing aspects of the industry, summarizing the current state of the industry, identifying models for successful projects, and recommending the next steps for moving the industry forward.

LESSONS LEARNED

The VBI pursued a set of ten market development needs for the conversion of oilseed crops, perennial grasses, and algae into bioenergy via sub-recipient awards and staff-directed projects. Over eight years, the VBI yielded many positive results, including new infrastructure and equipment, the steady development of agronomic expertise and technical know-how, and many bioenergy resources used throughout the world, as well as some disappointments.

> "While the approach supported by VBI funding is somewhat unique to Vermont, the basic fundamentals are applicable anywhere. We focused on the resources we had and the methods that were reasonable for the scale and type of farms in our region, allowed the process to be farmer and user driven, and allocated technical and research resources to support that progress. I think, in a nutshell, that was the project approach and it has resulted in a lasting example of progress in sustainable fuels that will support greater production in the future."
> — **Chris Callahan, University of Vermont**

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.

In 2016, the Vermont Department of Public Service released the Vermont Comprehensive Energy Plan, which calls for obtaining 90% of the state's energy from renewable sources by 2050 and reducing greenhouse gas emissions 50% from a 1990 baseline. The plan calls for major decreases in petroleum use through the electrification of vehicle fleets, wider use of heat pumps, and increased use of bioenergy. The VBI set the stage for increasing the production and consumption of biodiesel and grass/mixed fiber bioheat, but Vermont will have to overcome several obstacles to accomplish that state's long-term energy goals:

1.) Early adopters are unlikely to be the ones to make the transition to commercialization of new methods and technologies. The skills and attributes necessary for research and development are rarely combined with the necessity of standardization and marketing and a range of risk tolerance is required at different stages of this process. A sustained focus on recruitment, development, and support of new entrants at different stages of commercialization is important to ensure a continuous development trajectory.

2.) Externalities are significant in the area of bioenergy development. A strong interest in these technologies against a backdrop of high fuel prices is unlikely to be sustained when and if prices drop. A continued focus on future scenario planning may help provide a foundation for planning and adaption that softens the programmatic impact of external factors such as fuel price volatility.

3.) The funding for this project was made possible at a time of Congressionally-Directed Awards. This funding mechanism was instrumental in demonstrating a novel approach to bioenergy systems in Vermont with relevance to rural communities throughout the nation.

VBI REPORT SECTIONS

Five subsequent sections of the VBI report summarize in greater detail tasks related to oilseed crop production and conversion into biodiesel; perennial grass production and conversion into heating fuel; algae research; commercial biodiesel blending facilities; and the Renewable Energy Atlas of Vermont (renamed the Community Energy Dashboard in 2016).