Farm Energy Innovation in Vermont

A Report to the
Vermont Sustainable Agriculture Council

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**EXECUTIVE SUMMARY**

The powerful changes affecting Vermont’s economy over the past ten years have prompted groups of farmers and their allies in the state to innovate a range of energy production options. This strategic analysis of the emerging farm energy sector for the Vermont Sustainable Agriculture Council explores energy production through the lens of *innovation*, which provides valuable perspectives from farmers and their allies into what is taking shape.

This research investigates the notion that by working through *innovation networks* or *hubs*, groups of Vermonters (e.g., farmers, advocates, researchers, utilities, state agencies, community groups, non-profits, etc.) can develop and implement scalable farm energy solutions that will be adopted over time by the majority of interested farmers. To gather information, the author interviewed farmers and organizational leaders involved with farm energy around the state between August and December 2008. Their insights, perspectives, questions and dilemmas offer insights into how farm energy activities such as anaerobic digestion, biodiesel, wind and other farm energy sub-sectors are progressing. The report offers suggestions for Vermont 25 by ’25, a statewide initiative aiming to increase production of renewable energy in the state.

**Energy Innovation on Vermont Farms**

*Innovation* is the introduction of a new idea or an improvement to an existing product or process. *Innovation networks* are groups of people working together to introduce new ideas, products, services, processes or systems to broader audiences. *Innovation hubs* are places, either physical or virtual, where participants in a network share proximity to one another. Identifying existing networks and how farmers share information is a key element to knowing how innovations either spread or stall.

Vermont farms have substantial experience with developing and adopting energy efficiency innovations in the maple sugaring and dairy sectors. Both have networks and professional organizations that connect farmers. They also feature means for developing and introducing new technologies. Progress with energy efficiency highlights how those seeking to advance innovations continually educate and evaluate their strategies as they reach for new segments of a target audience.

To gain insight into how future farm energy production may develop, this report explores examples of anaerobic digestion and biodiesel. These farm energy sub-sectors have moved from concept to implementation over the past ten years or less by following predictable steps and ensuring the build out of key innovation components. Example One reviews the introduction of *anaerobic digesters* into the state beginning with the Blue Spruce Farm in Bridport, a project that helped lay the foundation for subsequent farmers to learn from one another and participants in a farm “biogas” innovation network to create a pathway for others to follow. Example Two entails the development of *oilseed crop and farm biodiesel production*. Biofuel innovation hubs are emerging at the State Line Farm in Shaftsbury and Borderview Farm in Alburgh where farmers are learning directly from one another to understand the dynamics and challenges of growing and processing seed oil crops to make liquid fuels and feed products.
Findings and Discussion
The farm biogas and biodiesel examples provide tangible evidence in support of this paper’s hypothesis that through innovation networks, groups of Vermonter can develop and implement scalable on-farm energy solutions through concept-to-market processes. Conversations with farmers and farm energy stakeholders indicate that certain components appear important to innovation networks. These include:

- Ideas and concepts about products, processes, services and systems
- Learning opportunities including scanning, study tours and discussion groups
- Proto-types, pilot and demonstration projects
- Feasibility studies and strategic analyses
- Communication channels and vehicles
- Public and private financing
- Technical assistance, “circuit riders” and consultants
- Professional associations and peer networks
- Mature technologies from local and non-local vendors

Conclusions
Farm energy production is emerging as a viable option for farmers to pursue thanks to the innovation networks that have developed systems adapted for Vermont. While this report notes substantial progress with anaerobic digestion and biodiesel production, neither of these sub-sectors has gone commercial, so the jury remains out on whether the innovation networks will succeed in moving each to scale.

As anaerobic digestion and biodiesel production mature in Vermont, other kinds of farm energy production are emerging and competing for resources. The state is well positioned to expand production of farm energy in the next five years. Understanding the components of innovation networks may offer clues for those interested in fostering greater participation and achievement of farm energy production.

This research shows that communication among peers plays a pivotal role in advancing innovation. In addition, positive experiences encourage individuals to promote an innovation. Members of innovation networks help to do so by testing assumptions and evaluating performance through deliberate learning, proto-typing, and feasibility stages that condition the pathway toward greater adoption. While this process takes time and resources, success at the front end can increase the rate of penetration at later stages.

Recommendations
The unfolding story of each farm energy sub-sector presents questions about how farmers will generate the levels of energy anticipated by Vermont 25 by ’25. To reach these goals through mostly voluntary approaches, the state would benefit by addressing issues that emerged from conversations with farmers and allies involved with farm energy innovation. These conversations and accompanying research yielded the following recommendations (abridged; see report for full recommendations):

1) **Focus on peer learning for farm energy.**
   Peer learning opportunities can help farmers make decisions and form essential connections with those who can assist them with their projects.
Farm Energy Innovation in Vermont

2) **Improve farmers’ access to good information about farm energy production.**
   Farmers need accurate information from trustworthy sources to gain comfort with innovations appearing in Vermont. The sector would benefit by a deliberate focus on capturing the many ideas that are emerging and making intelligence about the state of farm energy readily available where farmers already seek information.

3) **Provide two or more farm energy technical assistants.**
   There are not enough technical assistance providers focusing on farm energy to go around. Hiring two or more neutral farm energy “circuit riders” to travel among farms on a regular basis would maintain and strengthen farm energy innovation networks.

4) **Help farmers get to nearby demonstrations hubs.**
   Support six geographically distributed farm energy demonstration hubs within easy driving distance for all Vermont farmers. These hubs would include a range of working demonstrations on a variety of farms where farmers can “kick the tires” and get good information from peers.

5) **Identify potential user groups for adoption of new energy technologies.**
   Achieving farm energy production goals would benefit by understanding the characteristics of prospective farm energy producers, what their interests are, and what kinds of energy applications would work in their context.

6) **Fill out each farm energy sub-sector with key innovation components.**
   All the sub-sectors reviewed for this report have at least three components in place with variable depth of activity. To develop emerging sub-sectors, each would benefit by having all components in place. Some components (e.g., public/private funding, professional associations, communication vehicles) serve more than one sub-sector but not necessarily all sub-sectors. Therefore, existing components can be expanded to serve emerging farm energy sub-sectors without creating new components.

7) **Focus on continuous development in a few farm energy sub-sectors.**
   Given the large resource requirements and long development time lines, Vermont should identify options of highest net benefit to the state, and make long-term commitments to select sub-sectors. Potential criteria for determining where to focus could include presence of the innovation components (Table 1), knowledgeable advisors and mentors, greenhouse gas reduction potential, and an economic analysis developed in the context of Vermont resources, policies and regional competition.

8) **Monitor and communicate regarding strategic innovation across sub-sectors.**
   The state has several farm energy innovation networks in action. Vermont’s public and private organizations with experience in driving innovation in one sub-sector have practical skills and knowledge needed to advance other farm energy sub-sectors. However, those with knowledge and skill in one sub-sector do not necessarily interact regularly with their counterparts in other sub-sectors, nor do they necessarily have the mission to do so. Further, knowledge and experience with strategic innovation is patchy across these groupings. The state’s farm innovation networks would benefit by deepening their knowledge of innovation in different sub-sectors, and strengthening a cooperative approach that can help the state reach its renewable farm energy goals.
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INTRODUCTION
This report focuses on innovation to promote farm energy production, which has risen in importance over the past five years. On-farm energy production has the potential to help farms diversify operations, improve profitability, reduce environmental and community impacts, and gain a degree of control over their operations. Farms have the potential to generate a substantial portion of their own and the state’s energy requirements in the future. Energy production as a major focus, however, only emerged as a topic of serious consideration in the past few years as oil prices made a relentless climb towards highs of over $147 a barrel in July 2008, commodity price fluctuations jolted farmers, and concerns about climate change reached a tipping point with the public.

Over the past ten years, the number of farms considering and implementing on-farm energy production systems has risen from a few to dozens. The early pioneers of Vermont’s farm energy sector have gained a great deal of knowledge and insight into what it takes to add energy production to their already full slate of activities on the farm. As more farmers, policy makers and members of the public look to farms as potential sources of energy, questions and examples about how to build this sector in ways that help farms endure as a part of the state’s community and economic fabric are emerging.

This report to the Vermont Sustainable Agriculture Council provides a strategic analysis of farm energy activities through the lens of innovation where economic, social and environmental transformations are taking place. Rather than catalog the rapidly expanding set of farm energy activities, this report offers insights into how farm energy is advancing. The report explores some key questions:

- What farm energy options are farmers exploring?
- How are Vermont’s farmers and their allies building their energy systems?
- What are some of the barriers and challenges to farm energy production? How are these barriers and challenges overcome?
- How do farmers communicate what they are learning?
- What will it take to bring farm energy systems to scale?
- What recommendations would support on-farm energy innovation?

This research investigates the notion that by working through innovation networks or hubs, groups of Vermonters (e.g., farmers, advocates, researchers, utilities, state agencies, community groups, non-profits, etc.) can develop and implement scalable farm energy solutions through concept-to-market processes that will be adopted over time by the majority of farmers with interest in farm energy.

The methodology for this study consists of qualitative data collected via personal and telephone interviews with farmers and leaders in farm energy between August and December 2008, a workshop regarding farm energy innovation in October, and a review of relevant information. The study offers farm energy activities in anaerobic digestion (i.e., “biogas”) and biodiesel production as examples of innovation networks. The report summarizes other farm energy sub-sectors and concludes with recommendations.
This report provides an initial attempt to understand the complex evolution of farm energy in the state. Given the limited resources for this task and the scope of the economic crisis that unfolded in 2008, a few caveats pertain.

- This report reflects a preliminary set of data based on limited interviews and a literature search intended to explore the broad range of activities taking place regarding farm energy. The conclusions and recommendations reflect the author’s best attempt to describe, characterize and organize these innovation activities given the limited data.

- The advent of carbon markets has broad implications for farms, investors, utilities and the public. While directly relevant to farms, evaluating carbon market activities was beyond the scope of this work.

Vermont 25 by ’25, a statewide initiative aiming to increase production of renewable energy in the state by 2025, has begun coordinating a more strategic approach that can move each farm energy sub-sector toward a set of policy goals. This group began its work in 2007 and continued through 2008. This report was developed in the overall context of Vermont 25 by ’25 and offers suggestions to help achieve this goal.

### PART ONE: BACKGROUND

Much work has been done by private and public organizations to build farm energy systems in Vermont. Some of this work began decades ago, such as the Foster Brothers Farm that emerged in 1982 as an early innovator with modern farm methane digester technology. Other activities, such as farm biodiesel production, began in earnest in 2004. Still other areas of exploration, such as algae oil, cellulosic ethanol and grass pellet production remain in the early research and development stage. Currently, there are dozens of farms, non-profit organizations, colleges and universities, businesses and government agencies working to advance farm energy production via wind, solar, hydro, biomass, biogas, geothermal, biofuels and energy conservation.

Vermont’s economy was directly affected by energy price swings this year. No. 2 fuel oil prices rose from $2.68/gal in October 2007 to $3.78 in October 2008 after peaking at $4.70/gal in July. Similarly, other petroleum products rose sharply then fell. The changes prompted Lt. Governor Brain Dubie to declare that the state would face a home heating emergency in the coming winter. Since many Vermonters pre-buy fuel in the summer, the situation led to overvalued contracts in the fall as prices dropped unexpectedly. By December, gasoline was selling for under $1.75 per gallon at the pump providing relief to travelers and farmers, but the summer’s damage remained clearly in mind. With the nation in a recession, credit markets damaged and state government facing a $60 million budget shortfall in the current fiscal year, the financial crisis will require substantial belt tightening. The upshot from the financial mess: many people have lost confidence in the systems that support the economy.
During the year, commodity milk prices paid to dairy farmers continued to languish. David Montagne from the Montagne Farm in Swanton said that his "feed, fuel and fertilizer have increased 40 percent in the last year" while the price of milk paid to farmers has dropped from $24.03 a hundredweight in July to $18.78 in October. He said farmers need $27 a hundredweight to cover their costs. With payments barely reaching $19 a hundredweight, dairies continue their struggle to make ends meet. The farmers with dairy operations interviewed for this study cited the perennial challenge of receiving enough payment for their product amidst factors beyond their control. Farmers cited energy generation as one place where they had some control.

In spite of the recent drop in energy prices, farmers, citizens and state officials remain committed to addressing climate related concerns and stoking the economy. As the Wall Street story unfolds and a new Washington chapter begins, Vermonters continue their efforts to regain control of their future. The story of on-farm energy provides insight into progress over the last year.

**Recent Farm Energy Related Activities**

In addition to specific energy innovations taking place on farms in 2008, Vermont witnessed a range of activities across the public and private realms including the Governor’s Commission on Climate Change, Vermont 25 by ’25, and grant making to support farm energy. Highlights are presented below as context for subsequent sections.

*Governor’s Commission on Climate Change*

In December 2005, Governor Douglas issued Executive Order 07-05 forming the Governor’s Commission on Climate Change. This group released its report and recommendations in October 2007, including suggestions to build on Vermont’s energy efficiency leadership and renewable energy potential; maintain our farms and forests; reduce emissions in transportation systems; educate about climate change; and lead by example. The commission also recommended formation of the Vermont Climate Collaborative intended as a “strategic partnership to conduct and intensify capacity for essential research, innovation, and technology transfer in environmental and sustainable technologies.” Some progress occurred in 2008 but much of the work remains. However, UVM, state agencies and others continue to move pieces of the climate agenda forward.

*Vermont 25 x ’25 Initiative*

In January 2008, the Vermont 25 x ’25 Initiative released its preliminary findings and goals indicating that the state can produce 25 percent of its energy from renewable sources by 2025 if near-term priority is placed on supporting the most promising renewable energy and energy efficiency sectors and technologies. The report concludes that the state could derive 79 percent of this renewable energy from farm and forest resources, thereby creating significant economic opportunities in Vermont’s rural communities and stimulating the state’s agricultural industries. The steering committee and five committees are considering strategies by which Vermont can attain this goal.
The 25 x '25 report states that while its “goals are eminently achievable, they will be difficult to accomplish through standard market forces due to challenges such as financing barriers, siting issues, regulatory hurdles and general lack of public familiarity with the technologies that would make such a goal possible.” The report concludes that only through collaboration, decision-making and deliberate action from an array of stakeholders—state leaders, policy makers, non-profit groups, current and potential energy developers, the agricultural community, financial institutions and the general public—will meaningful progress towards these goals be accomplished. The report catalogs the state of the activities, progress and prospects for production towards the 25 percent goal by energy crops, agricultural waste, wood energy, wind, solar, hydroelectric and geothermal resources.

**Clean Energy Development Fund**

During the year, the Clean Energy Development Fund announced that it would award $2.65 million in grants to applicants seeking funding to advance their renewable energy interests. This fund solicits proposals from individual Vermonters, organizations and farms. Grants from the August 2008 solicitation included large-scale anaerobic digesters at Fillmore Farms, Gebbies’ Maplehurst Farm and the Dubois Farm. The fund also made a grant to Neighborly Farms in Randolph for a digester special demonstration project. The state has now awarded $10.5 million for projects with the potential to add 59 mW of new clean energy to the grid. The state put $500,000 to work in 2006 and 2007 with 125 incentives reserved for small wind, solar electric and solar hot water covering 480 systems since 2003. The CEDF granted $2,058,992 in large awards to seventeen projects including Westminster Farm, Neighborhood Energy LLC and the Gervais Family Farm for methane digesters. The total anticipated energy production is 3,517 kW. The loan program was launched in November 2007 culminating with two loans totaling $350,000.

**Vermont Agency of Agriculture REAP Grants**

The Agency of Agriculture deployed a wide range of grants totaling $310,000 since Fall 2006. The projects include methane digesters, biomass pellets, biofuels, and miscellaneous feasibility studies and development grants. The agency continues to use its resources to help Vermont farmers explore their options. Some of the grants help farmers consider existing technologies, while other grants fund development of projects with innovative applications or untried aspects of technologies, or other limitations that make it difficult to finance the project.

**Renewable Energy Funding for Farms**

In 2008, USDA Rural Development program put approximately $1.8 million in grants and loan guarantees to work on Vermont farms implementing renewable energy technologies. The Biomass Energy Resource Center received $984,000 in Congressionally directed project funds for FY2008 from US Department of Energy. These funds will be used to develop community-scale biomass energy projects and programs that make use of local, sustainable, woody and pelletizable biomass throughout the US. The Vermont Sustainable Jobs Fund received $984,000 in Congressionally directed funds via the Office of Senator Leahy to continue the Vermont Biofuels
Initiative. This effort fosters development of a viable biomass-to-biofuels industry in the state using local resources.

_Vermont Renewable Energy Report_

The Vermont Sustainable Jobs Fund produced a compendium of Vermont’s renewable energy organizations and activities in 2008. This document provides synopses of grassroots activism and educational initiatives, advocacy organizations, renewable energy trade associations and sustainable development groups, and government/quasi-governmental activities in Vermont.10

_Vermont Comprehensive Energy Plan_

Conducted for the Department of Public Service, the results of the Public Engagement Process for Electricity Planning were released along with the draft 2009 Vermont Comprehensive Energy Plan. The plan covers electricity but goes beyond to consider regional issues, efficiency of buildings, transportation and issues related to greenhouse gas reductions, combined heat and power, and farm energy.

_Vermont Grass Energy Symposium_

This event held in November 2008 offered a snapshot of the grass energy market. Organized by the University of Vermont Extension, the Biomass Energy Resource Center and Vermont Sustainable Jobs Fund, the event attracted over 80 participants to hear panelists from around North America describe issues related to grass production, harvesting, processing, pelletizing and combustion technologies.

**PART TWO: INNOVATION AND NETWORKS**

_Innovation_ is the introduction of an idea or improvement to an existing product or process. Organizations that practice innovation typically employ some kind of multi-stage process that begins with an idea followed by proto-typing or a pilot stage leading to commercial launch and culminating ideally with market penetration. This “concept-to-market” process exists in economic and social domains among others. _Innovation networks_ are groups of people working together to introduce new ideas, products, services, processes or systems to broader audiences. _Innovation hubs_ are places, either physical or virtual, where participants in a network share proximity to one another. Farm communities tend to have strong social networks and, within the state, there are examples such as Hardwick that are beginning to emerge as agriculture innovation hubs in general.

Evaluating the role of networks in the spread of agricultural innovation is a complex task. Farmers share information, as do others, through webs of connections. Identifying existing networks and how farmers share information is a key element to knowing how innovations either spread or stall. With the advent of the Internet, farmers now have access to a global array of ideas and people. Understanding how frequently farmers rely on information from new media sources compared with traditional social networks provides insights into ways to spread innovations.

The next section explores the dual aspects of innovation and the networks of players engaged in bringing concepts regarding farm energy production to Vermonters.
**Energy Innovation on Vermont Farms**

Farmers have practiced innovation for decades. Rick Marsh, president of Vermont Maple Sugar Makers Association (VMSMA), noted, “Innovation is trying something new, or taking a piece of equipment and using it in a different way.” Kate Duesterberg, from Cedar Circle Farm in East Thetford observed, “Farmers are always adapting to the situation – adapting to the land base, the weather, varieties of seed that work well for them.” In every sub-sector investigated, some farmer or group of farmers was exploring options for energy production and its potential value as part of the whole farm picture.

The drivers identified for farm energy innovation were fairly consistent: price increases of energy, seed, fertilizers and feed along with the desire to reduce costs and improve profitability. Some recognized the importance of environmental improvements such as water quality; others spoke about reducing green house gases, preserving resources for future generations, self-sufficiency, diversifying their operations, wanting to learn, or “just doing the right thing.”

As a mature sector where people have long sought energy efficiencies, sugaring operations benefit from an array of proven and emerging technologies such as reverse osmosis, efficient motors, evaporators and collection systems. Farm sugaring operations enjoy well-established networks and professional organizations such as the VMSMA, which works with researchers at UVM’s Proctor Maple Research Center to apply new technologies. In the case with sugaring operations, new technologies are introduced through a deliberate R&D process with ideas that emanate from equipment dealers, researchers and producers. Careful vetting of new technologies coupled with strong educational programs offered in accessible regional locations fosters effective adoption.11

There is much about diffusion and adoption of new technologies to be learned from the dairy sector as well as sugaring. By 2004, 650 dairy farms had applied some aspect of energy efficiency to their operations. In 2006, Efficiency Vermont began to note a decrease in the number of installations of efficiency options at dairy farms as this market has benefited from the availability of efficiency services for 15-plus years. In response, the organization crafted a set of responses to reach out to different types of farms in the agricultural community.12 These two examples highlight key aspects of how those seeking to advance innovations continually educate and evaluate their strategies as they reach for new segments of a target audience.

Given this backdrop, what kinds of innovations are taking place in the farm energy sector? What are some possibilities on the horizon? Will the energy innovations lead to achievement of policy goals such as 25 percent of power from renewable sources by 2025, or will the collective dabbling with multiple technologies fail to catch hold? Compared with energy efficiency practices, other farm energy production sub-sectors are in their formative stages. What is appearing on the ground is a combination of individual interest, sector development, market opportunity, and organizational response based on a complex mix of incentives, energy costs, resources, regulations, community support, farm capacity and individual drive.
The examples of biogas and biofuels are instructive for how future farm energy production innovations may develop. These sub-sectors have moved from concept to implementation over the past ten years or less in Vermont, in large part due to application of resources, differences in technological maturity and varying policies. These two sub-sectors offer insights from an innovation perspective into considerations for strategically advancing farm energy production in the state.

**Example One: Farm Methane Digestion**

Over the last 25 years, Vermont has witnessed the emergence of a farm biogas sector. Beginning in 1982, the Foster Brothers Farm built a methane digester that has since operated in various configurations. However, until 2005 this was the only one in operation. That year, the digester installed by the Audet family at their Blue Spruce Farm in Bridport advanced the sub-sector from “idea” to “proto-type” stage. This project charted the terrain for other digester projects that followed. This first substantial test case offers insights when viewed through an innovation lens.

Prior to this project, anaerobic digester technologies did not seem to be catching on in the state. To learn why, the state embarked on a joint venture between the Department of Public Service (DPS) and the Agency of Agriculture, Food and Markets in 1999 with funding from the US Department of Energy. The ensuing *Vermont Methane Pilot Project* began by considering demonstration projects but subsequently moved towards a strategic analysis of obstacles and questions that needed to be answered. Through this initiative, a network of participants gained valuable insights about methane recovery as part of a broad strategy that included comprehensive nutrient management systems, renewable energy sources and greenhouse gas reductions. The project yielded data on the potential volumes of organic resources in the state that could be digested, cash flow scenarios, feasibility analyses on fifteen farms that expressed interest in the technology, barriers to adoption and potential solutions, and a demonstration site.

One important feature of this project was identification of the barriers that needed to be addressed including financial, technological, infrastructure, informational, technical assistance, and other less defined issues. In 2004, a report issued by Dan Scruton, Senior Agricultural Development Coordinator at the Agency of Agriculture, identified key hurdles and possible solutions. Between 2000 and 2004, the Agency of Agriculture and DPS along with utilities, numerous farms and other organizations began to address obstacles to implementation. In 2000, methane digestion technologies were relatively new with few examples from which to learn. As an outcome of this effort, Vermont passed progressive net metering legislation, utilities such as CVPS created Cow Power™, and methane digestion has become more widely implemented in the state (See Figure 4).

The advances in farm methane digestion provide a useful starting point for considering innovation with farm energy in Vermont. Current statistics show about 2.4 mW of installed production capacity at eight farms. The sector is gaining ground with potentially 1.6 mW of added capacity coming on line in 2009. Clearly, the technologies are moving toward greater levels of utility in meeting policy goals.
The Blue Spruce Farm digester began as part of the Vermont Methane Pilot Project. The state approached the Audits with technical assistance and potential resources to help with feasibility planning. Grant funds from the CVPS Renewable Development Fund, US Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS) and the state helped the project move forward. Blue Spruce Farm began planning in 2000. In 2004 following a study tour to Wisconsin where participants had a chance to “kick the tires” of a commercial digester designed by GHD, Inc. the farm made a decision to move forward with a GHD system. At a time when operating costs were rising, farmers were also experiencing additional pressures to address manure management issues that affected water quality. The farm has always done a good job meeting the requirements of their LFO (Large Farm Operation) permit but they wanted to go beyond that to do a better job.\(^{16}\) With dairy operations providing little or no margins to cover waste management innovations, methane digestion presented the opportunity to cover several needs at once.

Upon viewing a unit in operation and calculating the economics, the project team had confidence that the digester would meet the farm’s objectives for nutrient management, energy generation, odor reduction, bedding production and cash flow. The unit was installed in 2004 and operating in 2005, producing 1.3 million kilowatt hours (kWh) of power annually.
The project appears to have succeeded due to a combination of financial incentives (grants & financing, 4¢/kWh CVPS premium from Cow Power™), viable digester technology, sale of electricity to CVPS (at 95 percent of the market price for electricity), technical assistance and legal guidance to meet their farm’s management objectives. After start-up Dr. John Barlow, UVM performed a study at the farm to determine if the manure solids were suitable as bedding for milking cattle. The study was important since there had not been a controlled study on using manure solids as bedding. The outcome was positive and the use of solids for bedding dramatically improves the economics of the system.

Other factors that influenced perception of the technology include maintenance and operating requirements. As a full time farm, the digester operations had to be worked into the Blue Spruce Farm’s schedule. The GHD system performs adequately, according to a family representative, but some components have needed more frequent attention. Fortunately, the unit had a back up generator in place when the main generator experienced mechanical difficulties. In addition, GHD provides technical assistance via phone consultation as needed and visits the site when in the state. Overall, the system worked well enough to meet the farm’s needs and expectations of collaborators.

The Audets recognized their role as innovators in the state since their chosen system was unlike the only other system in operation at the time. Since then, many farmers have visited the facility and built systems based on the Audet family’s activities. As an indicator of the relative youthfulness of the biogas sub-sector, new projects are branching into other areas of methane digestion including small farms, crop digesters, advanced digester technologies and mixed farm and non-farm organic substrate digesters.

**Biogas Through the Innovation Looking Glass**

Manure digestion technologies both in the United States and in Vermont are moving through the early innovation stages towards becoming a widespread element of farms and the power grid. The US Environmental Protection Agency estimates that there were 111 digesters operating at livestock facilities in 2007. In addition to the operating digesters, there are at least 12 under development in Vermont. The advances with farm methane digestion provide a starting point for understanding innovation networks as a strategic approach for advancing farm energy in Vermont.

The Blue Spruce Farm made use of existing technologies in a new setting. Taken by itself the single application of one technology is not taking an innovation to commercial scale—it is only one stop on the line for a company seeking market penetration. However, when looking at the overall adoption of various farm methane digester technologies in Vermont, one company—GHD—is establishing a presence: most of the subsequent projects employed GHD digesters (see Figure 4).

Central to understanding the movement of a product, process or service from idea to commercial market penetration is a well-developed set of questions that must be answered. In the case with manure digestion in Vermont, initial questions and answers emerged during the Vermont Methane Pilot Project indicating that manure digestion
would work in Vermont. Subsequent questions about the specific technology, grid interconnection issues, and permitting all had to be resolved. Each stage had its own set of questions whose answers shape following actions. This kind of innovation assumes that answers can be found relatively quickly to inform movement from ideas to prototypes to commercialization.

Blue Spruce Farm can be considered as a proto-type for methane digestion and farm power production in the state. The project organized the elements that would ultimately be needed for future farmers to integrate into the grid. The development of subsequent digesters using GHD and other digester technologies demonstrates that the sector is moving from protootyping into what could be considered a collective “launch” stage by CVPS. With the entrance of Green Mountain Power into the digester arena, the prospect for greater collective market penetration is coming into view. The companies with successful technologies and support systems in place now have the opportunity to scale up their sales to bring more digesters and energy production into the state.

How did the concepts of manure digester technology take hold? The current advance began with knowledge about methane digestion technology options (e.g., GHD digester), a financial innovation (e.g., CVPS Cow Power™) and availability of resources (e.g., technical assistance and grants). Blue Spruce Farm and allies who visited Wisconsin gained information about one particular system, formed an attitude toward the innovation, made a decision to adopt the innovation then implemented a project. As the system met its performance requirements, this group received confirmation that this was a reasonable decision.

This process of acquiring information and formulating an opinion about an innovation is central to the spread of ideas. The experiences of the primary users provide the basis from which peers that may follow form their opinions. For example, another farm energy innovator, Bill Rowell from Green Mountain Dairy in Sheldon, visited Europe to learn about digester technologies. Rather than adopt a system designed for European standards, his evaluation visits to the Blue Spruce Farm and conversations with GHD at his farm led him to follow that pathway charted by the Audets.

To reach the farm biogas goal of 15 mW set by Vermont 25 by ’25, approximately one-half of the manure in the state will need to go into an anaerobic digester. Crop and other substrate digesters may add another 30 mW of additional capacity. Doing so will require an increasing number of farmers to adopt digester technology (Figure 5). The experiences with adoption of efficiency technologies become directly relevant. With 4,000 customers paying a premium in the voluntary CVPS Cow Power™ program, and a similar program at Green Mountain Power now taking shape, many Vermonters recognize the benefits of methane digestion. Hitting these targets, however, will require continued focus on performance among early adopters.

Initial barriers identified early on were overcome at Blue Spruce Farm and subsequent projects. Are these voluntary programs and current incentives sufficient to drive expansion into the next tiers of adopters including small and medium farms? If not, what
will be needed? The rate of adoption will depend on factors such as continued acceptance of the innovation, promotion of the innovation to others, and ability of others to adopt the innovation. Continued acceptance of any innovation will depend on the complex set of factors farms consider including commodity prices, energy costs, incentives, alternative power production options, regulatory issues, appropriate and effective technology, and technical and financial assistance all in the context of a recession, state budget deficits and a new federal administration.

Ultimate achievement of the production goal will also depend on whether disruptive innovations appear that either accelerate implementation of new projects toward this goal or move farms in a different direction.

Figure 5: Projected Production from Digesters

![Figure 5: Projected Production from Digesters](image)

**Ahead of the Curve**

Blue Spruce Farm proved to be ahead of the curve regarding digester technology in the state. When asked about some of the trends affecting Vermont farms, Marie Audet commented that the run up in prices for energy was having a pronounced effect on the farm. “In 2006, we were paid the same amount for milk that we were paid 25 years ago. But in the past year, our five major input costs have gone up by 40 percent. At the same time, our revenues are decreasing with milk around $20.00 per hundredweight. The forecast for next year is $18.49 with an average for ‘08 predicted to be around $19.00.”

With costs as a major driver, the farm needed to find ways to save money.

Given the economic conditions of dairy farming and the promise of methane digestion to yield cash through power sales, bedding production and fuel savings for using hot water
from the system, the Blue Spruce Farm had identified a set of needs that foreshadowed a growing market trend. Although it is not clear how far ahead of the market they were, the farm would benefit by developing an integrated energy and nutrient management system. The GHD system developed as a part of the CVPS Cow Power™ program combined with the various technical and financial supports made these benefits tangible.

The system used at Blue Spruce Farm paved the way for future projects that used GHD digester technologies at Green Mountain Dairy LLC, Montagne Farm, Berkshire Cow Power LLC, and Neighborhood Energy LLC. The Gervais Farm in Bakersfield developed its own digester, which was later converted to a hybrid GHD design. The operation at the Nordic Farm in Charlotte is considered an “open architecture” public domain model available for use and modification. It is not clear whether anyone has decided to do so, but the potential exists and it would be helpful to learn how the system is used or modified.

If the Role Fits, Wear It
The development of farm methane projects in Vermont benefited by individuals including mavens (people who know a topic deeply and help others learn), connectors (people with a gift for bringing people together) and salespeople (those who drive a message home) roles. These individuals foster the acceptance of a change in an existing system. Individuals such as CVPS’ David Dunn and consultant Mike Raker are examples of people who filled these roles, acting as champions and vendor neutral facilitators to advance the sector. Interviews with other farms pursuing methane digesters mentioned the contributions made by these individuals. Others interviewed for this report identified Robert Foster from Foster Brothers Farm as a pioneer of farm methane digesters in Vermont. Currently, innovators such as the Audets and Bill Rowell play similar roles, hosting thousands of visitors such as a study group from British Columbia that visited these and other farms in October 2008.

CVPS’ Dunn, who helped organize the tour of Canadians to Vermont, continues his maven and connector role. His willingness to share his hard earned knowledge of bringing farm digester projects on-line continues to play a valuable function in building capability and advancing the sector as a whole. Digester projects have not reached the “tipping point” but they have passed the first stage of innovation. With farmers beginning to persuade their peers about anaerobic digesters, more pieces are coming together making the system better poised for projects to emerge more quickly.

CVPS’ Dunn reflected on the process of energy innovation on farms. One challenge is the cost of innovation in the early stages of development. Early prototypes and early commercial offerings are often very costly. For this reason, early adopters are sometimes said to pay the “early adopter tax.” In the Blue Spruce Farm example, the up front costs were higher than subsequent projects. According to Dunn, over time prices will moderate leaving early adopter farmers to pay the highest price.

To balance out the private costs and public benefits from technologies such as manure digestion, Dunn believes that early adopters should be afforded support in the form of
man-hours from organizations like the utilities and state agencies. Also, since there are
environmental and other societal benefits, the infusion of tax dollars in the form of grants
is appropriate. If society benefits, the farm should not be expected to pay all the costs.

**Disruptions on the Horizon?**
The farm methane digester sub-sector appears to be evolving along a continuous,
incremental path. Most of the digesters in the state are some variation on the plug flow
technology developed for large-scale application (> 500 cows). New technologies, such
as continuously stirred tank reactors (CSTR), offer advantages for larger scale operations
and are a more efficient design for converting solids into methane. These systems
appear capable of offering additional marginal benefits for farmers, utilities and
government agencies that have similar objectives. According to the Agency of
Agriculture, a farm in North Troy has received REAP funding to consider a fully
mixed tank system. The visible progress implementing such biogas systems is the result of
nearly ten years of sustained, incremental investment by members of the innovation
network that organized in the late 1990s.

However, there are new innovations appearing in the marketplace that may prove
disruptive (e.g., smaller, cheaper, faster). Small farms with fewer than 200 cows are often
considered uneconomical for digester technology. Vermont has fewer than 1,200
remaining dairy farms, and many of these have less than 200 cows. Since the early
digester work focused on large dairy operations, innovators have been considering how to
include the smaller farms in the digester picture. Part of the small farm equation entails
developing effective technology for small farms. Current research and demonstration at
the Foote Farm in Charlotte is providing evidence that a small, scalable system designed
by Avatar, Inc. may work for small operations. The pilot project is moving forward, and
small farms around the state have expressed interest in this system. Unlike in-ground plug
flow digesters, the Avatar system consists of modular above ground hulls that can be
installed in parallel and easily cleaned.

A second part of the small farm equation entails developing efficiencies that typically
emerge with large operations. One example of what this might look like appears to be
shaping up, potentially to occur in Vermont. The SJH and Company from Boston plans to
develop a new model for methane digesters at small farms. Led by the managing
principal William Jorgenson, the project intends to aggregate a power pool derived from
multiple small farm digesters using investment funding. The roll out includes a pilot
project for small and medium farms that will allow key obstacles to be addressed leading
to rapid commercialization. To achieve success, the proponents identify a collaboration
of public and private partners required to allocate and distribute the legal, financial,
technological, and administrative costs.

This model employs a project finance model meaning no mortgage costs for the farm.
Given the capital requirements for digester projects, this feature may prove to be a key
disruptive innovation. The company is pursuing development of a project in Vermont,
Massachusetts and other states. This approach shifts the burden of development and
operation from farmers with little experience in the energy domain to professionals who
will manage operations. By its nature, this is a network model that links multiple players into a distributed system. With multiple farms in a power pool, this approach appears to spread the risk leaving flexibility should any operation require maintenance.

Lowering the cost to market entrance offers opportunities for smaller farms to participate in manure digestion with its multiple economic and environmental benefits. How would a sustained focus on developing small digester technologies and power systems change the landscape for the larger digesters? What would be the implications for agricultural economic development in the state?

**Conclusion**

The early large-scale digester projects in Vermont moved forward due to a network of players who brought skills, insights, connections and resources to bear. Working collectively and independently, this group addressed barriers and created learning systems needed to introduce methane digester technology to the state. As an example of an innovation network, this group has shifted over time as individuals enter and leave particular roles, but the major organizational players (e.g., first set of farm innovators, utilities, state agencies, farm organizations, financers) remain as key nodes in the network that continues to spawn new projects and draw in new participants. The advance of the farm digester sub-sector in Vermont yields tangible evidence that innovation networks play a strategic role in helping groups of Vermonters to develop and implement scalable farm energy solutions through concept-to-market processes.

The build out of the farm biogas sub-sector included a set of innovation components that appear relevant to its success. These include beginning with an idea or concept, learning opportunities to “kick the tires” of potential technologies developed elsewhere followed by technical assistance that helps farmers finance and develop proto-types or pilot projects to test their concept. From that point, spreading the innovation requires people who champion the innovation and connect with people who want to learn more. These and other innovation components will be discussed in the next example.

**Example Two: Farm Biodiesel**

Since 2002, biodiesel has emerged as a viable farm-based product that can help with a portion of the state’s liquid energy supply. As innovators outside of Vermont developed systems to produce and use biodiesel, questions arose in the state about the appropriate scale for making the fuel. In a similar fashion to corn and cellulosic ethanol, federal subsidies influenced decisions about what to produce, how to make the product, and where to do so.

By 2008, this issue of biofuels versus food blossomed into an international concern as speculators, investors and farm interests in developing countries sought opportunities to gain market share. The tumult showed that skyrocketing energy prices, government mandates and subsides would drive countries to trade off conservation of habitat for the opportunity to increase energy independence or agricultural profits. With oil prices
climbing, Vermonters debated the introduction of biodiesel and other biofuels into the state: should farmlands be dedicated to energy production?

As part of a broad effort to expand options for Vermont farmers and use local resources to supply a portion of the state’s energy needs, the Vermont Sustainable Jobs Fund’s Vermont Biofuels Initiative (VBI) coordinated with an array of public and private partners to develop on-farm biodiesel capacity in the state. The project entails market conditioning, network formation, infrastructure development and biofuels production activities geared toward answering key questions and building confidence that would foster local, economically viable biofuel development.

While there are numerous entrepreneurs and fuel dealers using or selling biodiesel, the VBI focused on two prime centers of farm based biodiesel activity (“biofuel hubs”). The first project is the development of a pilot farm biodiesel production facility operated by John Williamson and family at the State Line Farm in Shaftsbury. In conjunction with UVM Extension and other partners, the Williamson family built a farm-scale biodiesel system geared toward making 300,000 gallons of fuel annually from 187,500 bushels of grain processed at the farm and neighboring farms. Funds for the project were provided by a number of sources including the VSJF’s US Department of Energy funds, the McClure Foundation and the High Meadows Fund.

John Williamson commented on his efforts to innovate with biodiesel at State Line Farm. “The rising cost of fuel and grain has financially hurt Vermont farms in the last few years. Farmers are faced with problems that innovation can sometimes solve. Innovation is a means of survival. There are many examples of this in the state and a lot of them have to do with either conserving or getting the most out of what they have to work with.”

Williamson expressed a sentiment heard among other farmers interviewed for this report. Some barriers for farmers is [sic] having time available to pursue some of these alternative endeavors that would make their farm more viable. There are a lot of opportunities coming down the road but I think farmers need to be open minded and willing to change their way of doing things. A lot of different alternative fuel technologies are being developed that farmers can be a big part of. Helping to fund these types of things is a good start but once they see that something really works and will save them money, they will pursue it on their own. Supplying good information so farmers can make informed decisions would help a lot.30

The second project entails oilseed cropping strategies at the Borderview Farm in Alburgh where Roger Rainville is constructing the second farm-based biodiesel production facility in the state. Rainville worked diligently with UVM Extension to conduct trials from 2005 to 2008 that would identify varieties of oilseeds (sunflower, canola and soybean) and the economic implications for biofuel production. In 2008, he began construction of the biodiesel shed with help from a grant from the VSJF’s US Department of Energy funds. This project’s focus on oilseed planting and harvesting yielded a rich array of insights for those new to seed production in the Northeast. The trial and error with oilseeds entailed a network of farmers intent on developing effective solutions.31
Biodiesel Under the Innovation Scope

The State Line Farm project provides an example of bringing farm-based biodiesel production from concept to launch. State Line Farm began experimenting with oilseed crops such as canola in 2003. Like many other self-taught biodiesel producers, John Williamson and Steve Plummer (John’s initial partner in the operation) began with a small-scale processor in the barn. After learning about the technology and acquiring the materials, they began making 60-gallon batches from waste vegetable oil in 2005. This formed the proto-type stage that helped them figure out the process. At the same time, they undertook their own seed trials to learn what would work on their farm. With additional technical assistance and grant resources, State Line Farm was in position to construct a farm-scale proto-type, which began production in 2008. The 2008 harvests identified new needs and options for seed drying using solar technologies. With their initial success at the pilot scale, the farm is poised to process seeds from neighboring farms.

The Farm Viability & Enhancement Program is playing an important role in helping State Line and Borderview Farms to develop a business plan and enterprise budget for their operations. These financial projections will help determine the economic viability of contract processing or oilseed crops for culinary oil, livestock meal and biodiesel at the facilities. Having this economic data will provide more evidence to other interested farmers about whether or not to invest in their own biodiesel operation or whether to tap the Borderview and State Line operations for their needs.

With the exception of a small number of others that produce biodiesel such as the Cate Farm in Plainfield, the majority of farms appear to be waiting to see how things work out and perhaps an opportunity to access grant funding themselves. Although the two pilot projects and the related studies carried out have demonstrated the viability of farm-based oilseed and biodiesel production, the sector has not taken off. Netaka White, former director of the Vermont Biofuels Association now with VSJF, observed that there is enough economic data for farmers to grow crops, but not enough to convince them that they should switch their cropping strategies. After all, there are now many choices for farmers to consider. The next group to move forward would constitute the early adopters in the state: so far, this wave has not manifested itself.

Why not? Is the local positive message about the reasons to produce biodiesel and grow oilseeds clear and compelling enough? Are the negative messages about the industrial commodity biofuels model overpowering? Or are there other reasons holding farmers back? For example, the prices for seeds such as commodity soybeans rose rapidly this year. Commodity seed prices are one potential factor that may have limited progress. Others include the complex set of agricultural issues (costs for energy, fertilizer, etc.), general uncertainty about implementing the technology, lack of farm capacity, or difficulty obtaining good information. Some of the farmers cited lack of readily available financial resources to help offset costs that so far have only benefited a few. Others noted limited opportunities to travel the distance to speak with the innovating farmers directly,
It’s About Peer Learning

Vermont is in the very early stages of innovation with biodiesel in general and on farms in particular. Both the State Line and Borderview farms serve as the primary farm-based biodiesel innovators in the state. This sub-sector appears to be moving through various iterations through which farmers are communicating with each other. As farmers learn about farm-based biodiesel production, they are seeking additional information from the primary sources. For example, Roger Rainville hosted a “Field Day” in August that attracted 100 visitors including about 75 farmers interested in biodiesel production. Like the Borderview Farm, numerous farmers and others have contacted State Line Farm to learn about their experiences with oilseed crops and biodiesel production, and some are beginning to bring oilseeds to be processed. Both are beginning to serve as regional biofuel hubs through which networks of people are learning directly about this option for farm energy production. This is the crucial stage at which observers gather the information that will help them decide to pursue the innovation or not. Although the recent Agency of Agriculture REAP grants show that some farmers are considering oilseed options, most appear to be sitting on the fence.

For those concerned with helping to achieve the 25 by ’25 target of 3.2 million gallons of crop-based biodiesel, this situation presents a critical moment to investigate what farmers need to move forward with oilseed production. Are there strategies that can propel this sub-sector forward into adopting farm biodiesel production from oilseed crops? As a result of studies conducted to date by UVM, VSJF and others, there is a wealth of information available. Some farmers shared specific strategies that would help them, such as increased access to information. With studies readily available via the Internet, what are they looking for?

Some farmers mentioned that they prefer to learn directly from their peers. Peer learning plays a central role with innovation among farmers, potentially determining how far and how fast any particular innovation progresses. “Farmers learn together often during the winter, during site visits to each other’s farms and when they talk to each other,” said Kate Duesterberg from Cedar Circle Farm. “Farmers are never hesitant to pick up the phone, and many now use email. It’s easier to get advice from someone you know than the Internet.” She noted that the best learning occurs among peers, especially if they are close by and have trust between them. Finding more people to focus on farm energy would be very helpful, she noted. “I’m not sure where the position should be hosted; that’s less important than getting someone on the ground.”

In a similar vein, Green Mountain Dairy’s Bill Rowell commented, “When farmers talk to other farmers, they have their own way of expressing themselves.”

Interviews with Brent and Regina Beidler from the Beidler Farm in Randolph, Roger Marsh with the Vt. Maple Sugar Makers Association, and others reinforced the importance of this farmer-to-farmer interaction. For example, Brent and Regina mentioned the value of discussion groups:

*Discussion groups are a valuable vehicle for disseminating ideas and we feel that it would be a good forum for energy discussions as well. These groups are an efficient way to get information out to farmers and to bring in experts who can bring information to a*
whole group. There is also group accountability to keep projects moving and the ability for the cross pollination of ideas.  

Some interviewees commented that farmers learn best when they have a chance to “kick the tires” of an innovation and talk directly with other farmers about their experiences using the innovation. Given their busy schedules, finding time to visit demonstrations sites can be a challenge. Witnessing the number of farmers that reached out to the Blue Spruce Farm, State Line Farm, Borderview Farm and others that have employed alternative farm energy technologies, it is clear that many farmers are moving deliberatively to acquire the information they need to make an informed decision. For farmers at a distance, it is not practical for them to travel so far. Moving to the next stage of biodiesel development may depend on helping these farmers connect directly with one another.

**Knowing Who to Know**

Asking or encouraging farmers to make the trek to visit others may not always work. Historically, UVM Extension has filled this need with agents who visit farms. Many people noted the valuable service provided by Heather Darby, Sid Bosworth and Vern Grubinger who conveyed useful information between dispersed farms. These individuals play the important maven, connector and salesperson functions in their respective domains offering knowledge and insight gleaned from their experiences and interactions.

During a workshop held in Randolph, the Brent and Regina Beidler commented on the value of a similar connector model used by NRCS through which dedicated staff members, serving as “circuit riders,” transport knowledge between farms. They shared these thoughts how to advance this sector.

*There are several major obstacles for farms considering alternative energy projects - cost, lack of easily available resource people and some farmers who aren’t early adopters of any idea but wait to see how it turns out for other farmers. There are so few working models at the current time that nothing is moving fast. Most farmers don’t have time to investigate options for their own farm so having a resource person willing to work with a farmer from start to finish: discussing what type of system would work well on each individual farm, what resources are available to provide that technology and what financial assistance is available to pay for the project.[sic]*

The idea of a circuit rider that understands the range of farm energy options, can provide accurate and timely information, helps with access to resources and walks farmers through their options resonated in the past and has potential for the future. This extension or “connector” model was once popular but cutbacks have limited the number of agents. While some farmers recognized the importance of Extension, one remarked that it is not what it used to be. However, Extension remains a powerful vehicle for helping farmers learn. **If learning is the central element to helping individuals move from consideration to decision, then this should be a high priority role to fill.**

**Go Slow to Go Slow, or Go Slow to Go Fast?**

Farm biodiesel production seems to be working through a continuous, incremental pathway towards establishment in the state in similar fashion to the biogas sub-sector.
While not as far along, there is now five years worth of concerted effort among a wide network of individuals building key components of a farm biofuels energy sector. Hinged to federal, state and private grant sources and the annual growing cycle, current farm-based biofuel innovations tend to move slowly, however. 25 by ‘25 estimates 3.2 million gallons per year from crop-based systems—a small drop in the state’s oil consumption, although potentially quite important to farmers.

As of this writing, a potential breakthrough technology may alter the picture if an algae oil production system being proto-typed by Algepower, Inc. at the Blue Spruce Farm in Bridport is successful. The company has received a patent pending for farm-based algae production system that is intended to operate year-round in Vermont’s climate. It is designed to yield significant volumes of algae that will be fed hydroponically via a nutrient rich solution as found in the diluted effluent from anaerobic digesters. According to Gail Busch, CEO of the company, algae averages 40 percent oil content and reproduces with vigor. She conservatively estimates that the system is expected to produce 150,000 gallons of oil per year. After extracting the copious volume of oil, the protein and mineral rich meal can be used as livestock feed and/or soil amendments. While her company plans to produce the oil and co-products, others could potentially use the oil for biodiesel production.

How far and how fast the algae technology would spread will depend on the very same factors described previously. If the technology proves effective, affordable and profitable, then it is reasonable to assume that the rate of adoption will jump. If this breakthrough technology were to catch hold and spread to some 300 or 400 farms, then many farms will have the opportunity to vault from small-scale to more commercial scale oil production, perhaps providing a chance to reach the 60 million gallon per year target from algae-biodiesel set by 25 by ’25.

If the state hopes to achieve this goal, it may take a breakthrough technology that spreads rapidly through the farm biofuel network that has taken time to connect. Having a technology alone is no guarantee of success: people have to decide to use it first. Success at the early stage appears to matter. What could be done to encourage effective adoption of a breakthrough technology? How could a set of mavens, connectors and salespersons help position a breakthrough technology to spread quickly?

**Role of Professional Networks**

Both the biogas and biofuels sub-sectors have benefited by the presence of professional associations. With the biogas sub-sector, Renewable Energy Vermont (REV) played a key role in shaping policies and legislation that helped make it possible for the early digester projects to take hold. In the case with biofuels, the Vermont Biofuels Association (VBA) helped build credibility of biodiesel through a set of pilot projects that introduced the fuel to institutions and commercial users. This set of projects identified and answered key questions about how biodiesel would work in existing heating, transportation and other diesel powered equipment. VBA merged with REV in 2008. REV participates actively in discussions regarding development of new farm energy projects through its...
involvement with the Clean Energy Development Fund, CVPS Renewable Development Fund and the state legislature.

**Conclusion**

Like the farm methane digester sub-sector, the build out of farm biodiesel production and oilseed crops provides an example of an innovation network with two incipient network hubs at State Line Farm and Borderview Farm. The progress made with transferring complicated technologies developed for large-scale application to small-scale Vermont farms demonstrates the ability of farmers and their allies to drive innovation in this sub-sector. This second example provides additional tangible evidence in support of this paper’s hypothesis that through innovation networks, groups of Vermonters can develop and implement scalable on-farm energy solutions through concept-to-market processes.

Both biogas and biodiesel examples are still in the early stages of innovation and adoption, and neither sub-sector has gone to scale. Therefore it remains too early to draw final conclusions about the ultimate movement from concept to market penetration. However, it is clear that the state has innovation networks and related components in place that can be drawn upon to support development of other less advanced farm energy sub-sectors. There are also an array of questions about how to move these sub-sectors through the early stages of innovation to broader acceptance and implementation.

**Other Farm Energy Innovations**

This section provides briefs on other innovation activities taking place in farm energy sub-sectors. This abbreviated section includes an initial attempt to characterize activities through the innovation lens.

**Crop and Mixed Substrate Digesters** – Several crop or mixed substrate digesters are under development in the state. Common in Europe, these technologies mix organic matter from a variety of sources. There are crop digesters funded by the Clean Energy Development Fund and USDA Rural Development in Alburgh, Pawlett and Highgate. Vermont Technical College continues to explore a combined manure/mixed substrate digester to be developed in partnership with Central Vermont Solid Waste District, the Vermont Environmental Consortium and Vermont Sustainable Jobs Fund. VTC is requesting qualifications for designers of a system that will turn about 10 ton/day of food waste and 7 tons/day of manure into heat and electricity for the VTC campus.39

Given its focus on technology, farms and business, VTC remains poised to serve as an innovation hub for farm and renewable energy development in the state. Faculty members involved with various farm and energy projects remain available from year to year giving the college a set of individuals with knowledge that cuts across domains and sub-sectors. This could serve as a rich repository for information and knowledge.

**Wind** – Thanks to grants, technical assistance and persistence by dedicated farmers, numerous farms have wind installations. This aspect of farm energy has benefited from resources provided by the Vermont Solar and Small Wind Incentive Program under the
Vermont Clean Energy Fund, which recorded 137.7 kW of installed wind capacity at 52 locations (not all farms) in 2007.\(^4\) John Kidder, Assistant Professor of Mechanical Engineering at Vermont Technical College who administers the Vermont Anemometer Loan Program, identified farms in Milton, Charlotte, Holland, and Shoreham that installed towers to map wind potential this year.

Not all those who purchased turbines previously had their sites evaluated effectively for wind capacity. This service can range from a review of wind maps to erecting an anemometer tower to gather detailed data over a longer time. In one instance, a vendor recommended a product and location based on wind maps estimating 10 mph. The reality was an average of 7 to 8 mph leading to lower power output. The chosen location looked good on the map but in reality had a lower wind profile due to local geography.

Interviews this summer identified technical issues with some wind turbines installed under the Vermont Small-Scale Wind Energy Demonstration Program. Some farmers with wind systems who asked not to be identified have had less than satisfactory experiences with certain wind products and a vendor who failed to follow up on maintenance requests.

The result was that some farmers realized they would not obtain the desired payback for their investment within the time line anticipated—if at all. Poor performance and customer service experienced by a few farmers left a negative perception about wind in some quarters. However, a farmer from Colchester who installed a turbine in 2005 with mixed results, stated, “Putting up the tower was the right thing to do.” He recommended monitoring the site for wind and evaluating prospective vendors prior to making a decision.

While erecting towers to measure wind helps in certain situations, it is not always appropriate. According to VTC’s Kidder, setting up an anemometer tower requires a substantial investment of fuel to haul equipment and time. “This is well justified for a potential installation where large efficient machines could potentially generate lots of energy (e.g., a 100 kW turbine costing $300-400k). In fact it might be justified to place more than one tower at such a site. It makes less sense when you consider the money and carbon spent assessing a site for a 1 kW or even a 2.5kW turbine.”\(^4\)

A middle road between simplistic estimates and towers is emerging at VTC where they are developing a methodology for using the existing wind map data more confidently by confirming with field measurements and correcting accordingly. In the future, Kidder believes that he and his students should be able to make a site visit to evaluate local topography and structures then feed that information into a computer model. This would help eliminate costly and potentially unnecessary wind tower siting as well as helping prospective turbine owners to learn if their site has adequate wind potential.

Part of the challenge for advancing farm wind, as with so many other aspects of life, is lack of funding. While there are still funds being granted for small wind and solar projects via the Vermont Clean Energy Development Fund, there do not appear to be
adequate resources available for technical assistance or an identifiable network where farmers can readily learn what they need to know. John Kidder was cited for his valuable role with farm wind in the state yet given his full time teaching schedule, he finds it is difficult to keep pace with demand.42

As a result some farmers made decisions but felt unprepared for the extra amount of work required by a wind turbine. Farmers face the same challenges as those exploring other energy options: lack of good information and clear pathways for moving forward. This puts the burden on already busy farmers to find the examples of successful operations. Compared with resources available in other sub-sectors, the farm wind sector does not appear as robust. The FY 2009 budget for the Clean Energy Development Fund does not appear to address this imbalance. Of the $11,907,717 allocated for renewable energy development, only $50,000 is identified for the technical assistance program.43

Given the advancing state of farm wind, with many innovators now in place, early adopter farmers in some cases can find what they need on their own. For example, a farmer in St. Albans recently rejected the opportunity to install an anemometer tower noting that there were two turbines at neighbors on either side from whom he could obtain information. This is a concrete example of peer learning where proximity and experience matter during the persuasion stage of innovation adoption: if the local experience is good, and a farm has capacity, it is reasonable to assume that new local adopters will install more wind capacity.

One lesson from this experience is developing cost effective ways to help farms evaluate the options regarding wind. Dedicated technical assistance can help. If small farm-scale wind is to advance through peer interactions, then it becomes imperative for the first adopters to have a positive experience. What would a wind development strategy look like if the first wave of innovators all had positive experiences based on affordable knowledge of wind profiles, effective technical support and positive feedback?

Grass Energy – Grasses such as switchgrass or reed canary grass, which can be combusted or converted to cellulosic ethanol, gained additional attention this year. Sid Bosworth from UVM assisted with pilot grass projects and continues to study the energy value of grass plots. At least one project to densify grass into standard wood-sized pellets for combustion in a pellet furnace was funded by the Agency of Agriculture REAP program in Adamant this year.

The grass energy sub-sector, compared with other farm energy sectors, is mostly undeveloped. While there is some basic information emerging regarding grass energy technologies and cropping strategies based on research conducted at Cornell, the Midwest and in Canada, applications in Vermont are largely unexplored. There are a range of technical issues and challenges for growing, densifying and burning grass amendable to exploration in the state. There are companies building new, small-scale portable grass densifiers such as the “Slugger” developed by BHS, LLC in Pennsylvania that was recently pilot tested in the state. There are also companies working to modify
technologies used for wood pellet combustion to accept the higher ash producing grass with its peculiar combustion characteristics. With many sub-assemblies of a comprehensive system remaining under development, it will take some time before products are ready for commercial launch.

Given the success experienced in examples of technological development in the state and success with innovation in other farm energy sub-sectors, however, Vermont is primed to lead with farm and community scale grass energy innovation. There are groups poised to apply lessons from previous sectors. For example, Shelburne Farms and partners are considering a grass energy initiative. This effort will develop an innovation process for grass cropping strategies, densification technologies and combustion systems appropriate for their own use as well as for residential and institutional users. This project may form an example where the partners are ahead of the general public and are positioned to benefit from developing applications that meet their own particular needs. If so, this may be another example that has the potential to contribute to Vermont's agricultural economic development.

Integrated operations – Many farms now employ a range of energy production systems. These include examples such as the Cate Farm in Plainfield (biodiesel, homemade electric tractor), Cedar Circle Farm in East Thetford (solar, corn stove) and Shelburne Farms in Shelburne (grass energy, solar). These farms provide examples of small-scale innovation network hubs. The interviews revealed that small farms with their own unique blends of farming and energy production offer examples of creativity and inspiration from which many people are already learning.

PART THREE: FINDINGS & DISCUSSION
The farm biogas and biodiesel examples provide tangible evidence in support of this paper’s hypothesis that through innovation networks, groups of Vermonters can develop and implement scalable on-farm energy solutions through concept-to-market processes.

What would the key elements of a robust farm energy innovation network look like? Conversations with farmers and farm energy stakeholders indicate that certain components appear important to innovation networks (see Table 1: Innovation Components). These include:

- Ideas and concepts about products, processes, services and systems
- Learning opportunities including scanning, study tours and discussion groups
- Proto-types, pilot and demonstration projects
- Feasibility studies and strategic analyses
- Communication channels and vehicles
- Public and private financing
- Technical assistance, “circuit riders” and consultants
- Professional associations and peer networks
- Mature technologies from local and non-local vendors
The order these components are listed above appears to correspond to the level of development of the sub-sector. While not all of these components appear essential, the review of several farm energy sub-sectors reveals that the more widespread sub-sectors have most of these components in place. This report only captured a snapshot of the sub-sectors, not a thorough analysis. Further, it is not clear whether there is any causal link between presence or absence of any one of these components and successful diffusion and adoption of innovation.

This initial review raises further research questions. For example, does the presence of all the innovation components necessarily mean that successful adoption of an innovation will take place? Or are these necessary but not sufficient conditions? What would a research and development project that integrates these components look like? How would it compare with other economic development approaches?

**PART FOUR: CONCLUSIONS & RECOMMENDATIONS**

Farm energy production is emerging as a viable option for farmers to pursue thanks to the innovation networks that have developed systems adapted for Vermont. Vermont farmers are creating and adopting innovative solutions that meet their needs for manure management, energy production, profitability, and overall farm viability. While this report notes substantial progress in farm biogas and biodiesel production, neither of these sub-sectors has gone commercial, so the jury remains out on whether the innovation networks will succeed in moving each to scale.

As anaerobic digestion and biodiesel production mature in Vermont, other kinds of farm energy production are emerging and competing for resources. The state is well positioned to expand production of farm energy in the next five years. While the policy and regulatory climates differ for the various sub-sectors, there are commonalities that track from young to more mature sub-sectors. Understanding the components of innovation networks may offer additional clues for those interested in fostering greater participation and achievement of farm energy production.

In addition to components identified as parts of an innovation network, achieving success in each sub-sector also depends on incentives, regulations, energy prices, public perception, farm capacity and interest. This report did not evaluate the effectiveness of policies, impacts of regulations on farms or gaps among these elements. However, the author observed that availability of incentives, public perception, farm capacity and personal interest all played a key role in starting projects.

**While all these factors are no doubt critically important, this research shows that communication among peers plays a pivotal role.** In addition, positive experiences encourage individuals to promote an innovation. Poor experiences at the early stage risks locking in a perception that “it won’t work” whatever “it” is. Members of an innovation network help build beneficial experiences by testing assumptions and evaluating performance through deliberate learning, proto-typing and feasibility stages that condition the pathway toward greater adoption. While this process takes time and
resources, success at the front end can increase the rate of penetration at later stages. The ten years it took for farm biogas to emerge has positioned the sub-sector for more rapid adoption in the state.

**Recommendations**
The unfolding story of each farm energy sub-sector presents questions about how farmers will generate the levels of energy anticipated by Vermont 25 by ’25. To reach these goals through mostly voluntary approaches, the state would benefit by addressing issues that emerged from conversations with farmers and allies involved with farm energy innovation. These conversations and accompanying research yielded the following recommendations:

1) **Focus on peer learning for farm energy.**
Vermont farm energy innovation networks feature many vehicles that already help farmers answer their questions and share knowledge. In addition, the state has rich assembly of study groups, conferences, and gathering places that support the essential peer learning functions of innovation networks. While some of these already provide vehicles for farmers to learn about farm energy, there are opportunities to work with others to share information about farm energy. Peer learning opportunities can help farmers make decisions and form essential connections with those who can assist them with their projects.

2) **Improve farmers’ access to good information about farm energy production.**
Farmers need accurate information from trustworthy sources to gain comfort with innovations appearing in Vermont. Farmers garner information and inspiration via social networks and farmer gatherings, as well as existing publications, radio, TV and the Internet. Good, timely information and knowledge regarding the rapidly changing world of farm energy can be difficult to find. The sector would benefit by a deliberate focus on capturing the many farm energy ideas that are emerging and making intelligence about the state of farm energy readily available where farmers already seek information. For example, *Agriview* can feature a regular column on farm energy in each edition.

3) **Provide two or more farm energy technical assistants.**
While farms currently benefit from programs at the Natural Resource Conservation Service, the Agency of Agriculture and UVM Extension, there are not enough technical assistance providers focusing on farm energy to go around. Hiring two or more neutral farm energy “circuit riders” to travel among farms on a regular basis would maintain and strengthen farm energy innovation networks.

4) **Help farmers get to nearby demonstrations hubs.**
Support six geographically distributed farm energy demonstration hubs within easy driving distance for all Vermont farmers. These demonstration hubs can build around existing farm energy hubs (e.g., St. Albans), other farm hubs (e.g., Hardwick) or education facilities (e.g., Vermont Technical College). Each regional hub would include a range of working demonstrations on a variety of farms where farmers can “kick the tires” and get good information from peers.
5) **Identify potential user groups for adoption of new energy technologies.**
Spreading effective farm energy production systems among more farms will require identification of new audiences that have different levels of interest, resources, specialization, capacity and risk tolerance than the earliest adopters. Achieving farm energy production goals would benefit by understanding the characteristics of prospective farm energy producers, what their interests are, and what kinds of energy applications would work in their context.

6) **Fill out each farm energy sub-sector with key innovation components.**
Farm energy sub-sectors well along the innovation curve (e.g., biogas and biodiesel) tend to have more components of innovation in place (e.g., study tours, pilot and demonstration projects, feasibility studies, communication vehicles) and more activity related to each component (e.g., multiple grant sources for digesters, biodiesel production). All the sub-sectors reviewed for this report have at least three components in place with variable depth of activity. To develop the emerging sub-sectors, each would benefit by having all components in place. Some components (e.g., public/private funding, professional associations, communication vehicles) serve more than one sub-sector but not necessarily all sub-sectors. Therefore, existing components can be expanded to serve emerging farm energy sub-sectors without creating new components.

7) **Focus on continuous development in a few farm energy sub-sectors.**
Focusing on slow, continuous innovation works where there are adequate resources in place and cooperating organizations with the capacity to invest over long time lines. For example, the ten-year development time line made it possible for early adopters to have positive experiences with farm methane digesters. Given long time lines and large resource requirements needed to develop other sub-sectors, Vermont should identify farm energy options of highest economic, environmental and other benefits to the state, and make long-term commitments to select sub-sectors. Potential criteria for determining where to focus could include presence of the innovation components (Table 1), leaders from other successful farm energy sub-sectors willing to advise or mentor, greenhouse gas reduction potential, and an economic analysis developed in the context of Vermont resources, policies and regional competition.

8) **Monitor and communicate regarding strategic innovation across sub-sectors.**
The state has several farm energy innovation networks in action. Vermont’s public and private organizations with experience in driving innovation in one sub-sector have practical skills and knowledge needed to advance other farm energy sub-sectors. However, those with knowledge and skill in one sub-sector do not necessarily interact regularly with their counterparts in other sub-sectors, nor do they necessarily have the mission to do so. Further, knowledge and experience with strategic innovation is patchy across these groupings. The state’s farm innovation networks would benefit by deepening their knowledge of innovation in different sub-sectors, and strengthening a cooperative approach that can help the state reach its renewable farm energy goals.
This analysis is based on partial and preliminary data and professional interpretation of the author, not a comprehensive assessment of on-farm energy in the state: there are gaps in the data that a more rigorous study would fill. As such, this study offers a starting place for future research. The evidence collected during this study suggests that further examination using an innovation lens would be beneficial for those interested in helping Vermont to achieve greater degrees of energy independence, greenhouse gas reductions, and renewable energy generation. All of the farm energy sub-sectors covered in this briefing would benefit from further examination.

Most farmers have limited time, energy, resources and capacity to assume the burden for learning the many complicated aspects of farm energy. If Vermont is to see substantial increases in farm energy production to meet anticipated levels projected by Vermont 25 by ’25, farmers and farm energy innovation networks will need considerable assistance. The desire to move in this direction clearly exists. By building effective learning systems that enable farmers to access the knowledge they require from trusted sources, it is possible to accelerate the development of each farm energy sub-sector.

Dedicated innovation networks can support farmers’ investigations of energy options including the financial, legal, regulatory, technological and administrative burdens of each, along with potential economic, environmental and agricultural paybacks. With the winds of change constantly reshaping the field, a focus on building innovation capacity will help position the state to not only provide examples from which others can learn but also respond to broader changes affecting the economy.
Table 1: Components of Innovation

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Table 1. This table includes estimates based on preliminary data. Each farm energy sub-sector contains several innovation components. Due to the limited sample pool for this report, examples may exist that are currently left blank.
End Notes

3 Vermont Milk Commission Investigates Retail Milk Prices, Bruce Edwards, Rutland Herald. November 2, 2008
7 State Awards Over $2.5 Million for Clean Energy Projects, Media Release, Vermont Department of Public Service, October 31, 2008.
9 Current list of Vermont REAP grant recipients as of November 1, 2008, Vermont Agency of Agriculture.
11 Personal communication with Rick Marsh, Vermont Maple Sugar Makers Association, September 23, 2008
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16 Personal communication with Marie Audet, Blue Spruce Farm, September 23, 2008
17 Anaerobic Digesters Continue Growth in U.S. Livestock Market, US Environmental Protection Agency AgStar Program, November 2007
18 These five stages correspond to the five stages of the innovation-decision process developed by Everett Rogers. See Diffusion of Innovations, 5th Edition, Everett M. Rogers, (Free Press, New York, NY) 2005.
19 Personal communication with Bill Rowell, Green Mountain Dairy, December 12, 2008
21 Personal communication, Marie Audet, September 23, 2008
23 On-Farm Anaerobic Digestion Education Mission Vermont USA Report, British Columbia Ministry of Agriculture and Lands, October 20-22, 2008
24 Personal communication with David Dunn, CVPS, October 7, 2008
25 What Are the Different Types of Anaerobic Digesters? The Bioplex Project at the University of West Virginia, (http://bioplexproject.wvstateu.edu/typeofdigesters.html)
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27 Personal communication with Guy Roberts, Avatar, September 30, 2008
30 Personal communication with John Williamson, State Line Farm, November 15, 2008
32 Personal communication with Netaka White, Vermont Sustainable Jobs Fund, August 13, 2008
33 See Vermont Sustainable Jobs Fund (www.vsjf.org)
34 Personal communication with Kate Duesterberg, Cedar Circle Farm, September 23, 2008
35 Personal communication with Bill Rowell, Green Mountain Dairy, December 12, 2008
36 Personal communication with Brent and Regina Beidler, November 29, 2008
37 Ibid
38 Personal communication with Gail Bush, Algepower, Inc. October 17 and December 10, 2008
39 Personal communication with Chris Dutton, Vermont Technical College, December 2, 2008
41 Personal communication with John Kidder, Vermont Technical College, December 9, 2008
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43 Vermont Clean Energy Development Fund FY 2009 Program Plan and Budget, Vermont Department of Public Service (http://publicservice.vermont.gov/energy/ee_files/cdf/Annual%20Plan%20FY%202009.pdf)