Examining Two Green Payment Options To Support Dairy Farm Viability In Northern New England: Anaerobic Digestion And Organic Production

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EXAMINING TWO GREEN PAYMENT OPTIONS TO SUPPORT DAIRY FARM VIABILITY IN NORTHERN NEW ENGLAND: ANAEROBIC DIGESTION AND ORGANIC PRODUCTION

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by

Deborah Krug

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This thesis explores the details and profitability of two distinct operational strategies utilized by dairy operations as alternatives to expanding milk production. It features farms that have either transitioned to organic production or installed a farm-scale anaerobic digester, motivated in part by the opportunity for market specialization or income diversification to increase the viability of their dairy farm businesses.

The first analysis examines the demographics and production characteristics impacting the profitability of organic dairy farmers in Vermont and Maine. This provides policymakers, educators, lenders, and suppliers with a profile of this sector that accounts for 23% of dairy farms in Vermont and 20% of dairy farms in Maine, annually shipping, on average, 787,600 lbs. milk per farm. The study was conducted through a longitudinal survey of 83 organic farmers in Vermont and Maine from 2004 to 2012. A multiple linear regression analysis of the sample demonstrated six significant variables that affect farm profitability measured by return on assets (ROA). Having at least 80% Holstein herd composition, increasing the daily pounds of grain fed to cows during the winter months, a primary farm operator having grown-up on dairy farm, and the use of feed mixing machinery all positively impacted ROA. Farm profitability was negatively affected on farms with a high rate of annual cow morbidity and also tended to decrease over the course of the survey as organic prices leveled. While the model developed here has some explanatory power ($R^2 = 0.387$), variability in farm profitability is affected by complex economic pressures.

The second analysis reports the predicted and actual annual maintenance figures collected from anaerobic digester systems in Vermont. Within Vermont, 16 farms operate methane-generating ADS. All of these farms have received some form of public funds and/or a voluntary consumer premium. The analysis compares costs by creating a ratio of actual maintenance, repair, oil, and labor costs over these same predicted costs. This ratio is used to assess whether the suggested industry operating cost estimator tends to over or under predict annual maintenance costs. The ratio was evaluated with a one-way Student’s $t$-test ($p = 0.046$) finding that maintenance costs tend to be under-predicted compared to the actual costs. One-way ANOVA was used to determine a statistically significant effect of herd size ($F = 6.453$, $p = 0.052$), showing that the maintenance ratio varies significantly between groups. This analysis indicates that predicting annual maintenance, repairs, and labor costs as a function of 3.5% of total kWh production is an acceptable method for digesters on farms with more than 500 cows, but under predicts maintenance costs for smaller farms. For smaller farms, the actual costs were on average 2.5 times higher.
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Chapter 1: Introduction

It is vitally important that dairy farms have models of successful diversification and specialization strategies as a guide to help them survive as family businesses. Dairy farms in the United States face pressure to expand and consolidate in order to remain profitable (Fentress Swanson, 2014). According to Hoard’s Dairyman national industry magazine, since 1992, the number of licensed dairy farms in the United States has declined by 86,165 farms, from 131,509 to 45,344 (2015). This shows a 66% decrease in the number of dairy farms over the past 23 years. This drastic decrease in the number of farm businesses is problematic for the quality of life in rural communities and for maintaining regional dairy infrastructure (Lyson et al., 2008; United States Department of Agriculture, 1998).

Hoard’s Dairyman specifies that for the past six years, the Northeastern United States has retained the most dairy farms among all regions of the country. Pennsylvania has also challenged the national trend by adding 170 dairy farms in 2014. This has kept PA second in terms of the highest number of farms, 7,370 in total. This is promising news, as dairy has historically been the largest agricultural sector in the ‘northern crescent,’ a United States Department of Agriculture farm resource region which includes the Northeast (specifically, New England, New York, Eastern Pennsylvania) and Michigan, Wisconsin and Minnesota. However, aside from Pennsylvania, all other states observed a reduction in dairy farm numbers or maintained a constant number, as seen in Figure 1.1.
Figure 1.1: Reduction in Dairy Farms in Select Northeastern States

Tight and unpredictable profit margins, dwindling dairy supply-chain infrastructure, and increasing development pressures are challenging to the success of dairy businesses. Given these circumstances, many operators look to augment their income through the diversification or specialization of their production methods, due to limited options to increase milk production.

This thesis explores organic production as a method of specialization and biogas production as a method of diversification that may possibly augment farm revenue. In the United States, 247 farm operations use an anaerobic digester system (ADS) to produce useful products from cow manure and added organic materials (Anaerobic Digester Database, 2015). These inputs are converted into biogas, electricity, liquid fertilizer, and a cow bedding product by the ADS.
process which mitigates the methane greenhouse gas emissions. These alternative products serve as a means of diversifying and supplementing the farm income earned from milk sales. As part of a larger plan to reduce greenhouse gas emissions by 2025, the United States Department of Agriculture has the goal of installing 500 new ADS on United States farms in the next 10 years (Bauer, 2015).

For other farm operations, organic milk contracts provide a high and stable milk price in an otherwise volatile dairy market. By specializing in organic production, dairy farms adhere to certain environmental and herd health standards (Coffey & Baier, 2012). There is a growing market in which consumers are willing to pay a premium for the guaranteed standards of this differentiated dairy product (Kolodinsky, 2008).

Organic and biogas production share the commonality that these strategies are both connected to environmental objectives, as is illustrated in Figure 1.2.

Figure 1.2: Agri-Environmental Objectives of Organic and Biogas Production
Whether a farm operator chooses to change production practices to meet organic standards or to install ADS to generate renewable energy and mitigate greenhouse gas emissions, in either case, it is the agri-environmental attributes of these practices that are supplying the extra revenue to the farmer. Thus, these two business strategies allow farmers to receive ‘green’ payments for providing electricity or milk which consumers consider to be ‘green’ products.

The purpose of this thesis is to present original research about these two dairy business strategies. The first article presents a profile of the organic dairy sector in Vermont and Maine, and analyzes significant factors affecting profitability on organic dairy farms in these two states using a linear regression model. The second article compares the predicted versus actual operating costs of Vermont’s farm ADS using a Student’s t-test and an analysis of variance.

The specific questions addressed in this research are:

1. Are these two business strategies with their supporting public policies appropriate for the dairy farms of our region?
2. What is the profile of the organic dairy industry in Vermont and Maine?
3. What are the key factors of profitability on organic dairy farms in Vermont and Maine?
4. How accurate are industry predictions regarding the maintenance costs of anaerobic digester technology, and how do these maintenance costs impact the viability of this technology as a business strategy for Vermont-scale dairies?
1.1.1. Definition of Terms

To provide a point of reference to the reader, the following section details several relevant term definitions that are used throughout this document.

Farm: The USDA Economic Research Service (Bowers and Cook, 1997) defines a farm to be “any place from which $1,000 or more of agricultural products were produced and sold (or normally would have been produced and sold) during the census year.”

USDA farm resource region: The United States Department of Agriculture has defined resource regions that are homogeneous with respect to natural resources and farm production within the United States (Figure 1.3). The Northern Crescent has historically specialized in dairy production, and dairy remains the most important agricultural commodity of the Northern Crescent. The average herd size in these states is less than 200 cows. Farmers in the Northern Crescent use similar dairy housing, raise similar crops, and pasture their herds for the same amount of time throughout the year. The overall climate is comparable. This shared profile contrasts sharply with conditions in the emergent Western dairy states of Idaho, California, New Mexico, and Texas, which tend to have much larger herd sizes (averaging in the thousands). Dairies in these states tend to keep animals on dry-lots and often use more purchased forage and concentrates in feed
components compared to dairies in the Northern Crescent (Bob Parsons, Personal Communication, March 2015).

**Figure 1.3: Map of USDA Farm Resource Regions**

Organic Dairy Production: Organic dairy production must adhere to government standards. The definition of organic dairy refers to these government standards dictating certain farm production practices, and not a milk product with a profoundly different taste. Although conventional milk and organic milk products are not easily distinguished by physical attributes, some customers are willing to pay a premium price for this certifiable guarantee of the organic process.

Anaerobic Digester System (ADS): Anaerobic digestion refers to a biological process that produces a gas from organic wastes known as ‘biogas.’ This output gas is principally composed of methane (CH₄) and carbon dioxide (CO₂).
ADS is a technology by which this renewable fuel is collected from organic wastes.

Agri-environmental services: This term encompasses farm practice or attribute that contributes positively to the overall impact of agricultural practices on the environment. These can include the provision of clean air and water, wildlife habitat, flood-control, nutrient-cycling, and greenhouse gas mitigation. These attributes and services can be difficult to quantify. Rather than assess the agri-environmental services of organic or biogas production, the term is simply used to connect the two business strategies explored by the thesis. The agri-environmental services in both instances are what provide supplemental income to the farmer.

1.1.2. Expected Research Impacts

The original research presented in these articles contributes to the field by informing policy-makers, rural communities, and industry professionals about applied economic challenges and opportunities in local renewable biogas production, organic residuals management, and organic production methods on dairy farms in Vermont and Maine. Since the profile of the dairy industry in these states closely matches that of other traditional dairy states, this information contributes to the overall stream of literature assessing trends in Northern United States agricultural economics.

This thesis is a union of two articles written about topics examining the economic viability of Northern Crescent dairy farms. The first article uses survey data to study values, management practices, demographics and financials for
organic farmers and farm families in Vermont and Maine. The second article analyzes the operating costs and considerations of Vermont’s farm-scale anaerobic digesters, for the purposes of examining the operating costs affecting the economic viability of digester technology on dairy farms. The final chapter presents the overall conclusions drawn from these two studies.
Chapter 2: Literature Review

Dairy has had a prominent role in shaping the history, culture, and economy of Vermont for well over a century, and constitutes an important and changing industry in the state. According to an economic analysis by Jones (2014), the impacts of dairy on the overall Vermont economy include about 2% of overall economic activity, 3% of Vermont salaries and wages, and 12% of the state’s tangible product output. The retail sales of Vermont dairy products were worth more than $1.3 billion (Jones, 2014). Regarding labor contributions, between 6,000 and 7,000 Vermonters are employed in dairy production. Vermont farmland devoted to dairy represents more than 15% of all Vermont land and more than 80% of all Vermont farmland. Dairy also generates over $68 million per year in state and local tax revenue. In addition to these benefits, Vermont residents regard dairy farms as important for their sense of place and state pride (Council on the Future of Vermont, 2009; Smith et al., 2008).

Studies of the dairy industry in traditional dairy states (in the Northeast, Eastern Corn Belt, and Upper Midwest) show that the majority of farms are smaller dairies with fewer than 200 total cows. In Vermont, 82% of dairy farms have fewer than 200 cows, 15.1% have 200-699 cows, and 2.8% have more than 700 cows (Figure 2.1).
While some of Vermont’s dairy farms are increasing their herd sizes, increasing size or production is costly and unfeasible for many of Vermont’s dairies (Jones, 2014; Lyson et al., 2008). Vermont’s share of national milk production has continued to fall in the past two decades from 1.56% in 1994 to 1.43% in 2006, however, the state’s production has not significantly changed (MacDonald et al., 2007; USDA Census of Agriculture, 2012).

Dairy accounts for 70% of agricultural sales in Vermont (Jones, 2014). The dairy industry is important to Vermont, although the number of farms in Vermont has been in steady decline for many decades. Thus, the details of specialization and diversification as viable business strategies for dairy warrant study. Several organic dairy farms in Maine have been included in this study to contribute to the understanding of dairy farms within the Northern Crescent region more broadly.

The U.S. dairy industry has changed considerably in composition since the early twentieth century. Dairy farms have tended toward an increase in the
number of cows per operation while the number of individual operations has
decreased. Between 1950 and 1990 dairy farmers adopted a wide array of new
technologies, which increased total milk production by 25% while decreasing the
overall number of dairy cows by half (Blayney, 2002). Beyond the overall
consolidating trend, there is notable regional differentiation in the scale of dairy
operations and the areas of the U.S. that have become the top producers. To this
day, California continues to produce the most milk. Idaho entered the top ten
producers in the 1980s and by 2009 had become the 4th highest milk producing
state (Industry Statistics: Milk Production by State, 2014). For New Mexico (now
8th in the country), the average herd size was 1,267 cows. For California the
average herd size was 824 cows, more than nine times the average herd size in
Wisconsin (Gould, 2010). The US dairy industry has had significant structural
changes in the location, scale, and number of participants at all levels of
production. Nationally, the overall number of farms in every region is decreasing
(Figure 2.2).
The location of dairy production in the United States has shifted significantly to nontraditional production areas in the American West. Farms in the West tend to be much larger farming operations with lower production costs, but unfortunately are in areas that are prone to droughts. The drought in California is disrupting the dairy feed supply-chain (Merlo, 2014). Of the top 15 milk producing states, five of these states are in the American West, and six are in the Northern Crescent. The dairy industry has expanded in Western states like Idaho, Texas, and New Mexico, often on farms with herd sizes of more than 2,000 cows. Concurrently, historically producing states (including Vermont and Maine) are producing less fluid milk as a proportion of U.S. production, and production is increasingly originating from larger operations (Fentress Swanson, 2014; Gould, 2010).
Strategies for Different Scales of Dairy Production

The transition to organic production commands a more stable and often higher milk price compared with conventional dairy production. Anaerobic digester systems (ADS) can provide a secondary stream of steady revenue from the digestion and processing of cow manure into electricity from methane gas and bedding from digested solids, which can supplant other bedding materials utilized in herd housing. These two options represent what are presently two mutually-exclusive business strategies for augmenting dairy revenue streams in northern climates. Organic farms and smaller conventional dairy farms do not currently utilize ADS because they are unable to easily collect enough manure from their cows, as organic cows must spend at least 120 days per year at pasture in order for the milk to meet organic standards. Even for organic or conventional operations with a confined area, farmers are only able to collect manure when cows are not at pasture. Therefore organic operations could only expect to collect less than half of all manure from overall far fewer cows (Di Camillo, 2011). Farmers operating ADS keep their herds in confined free-stall dairy housing, which allows collection of all manure.

Agriculturalists and economists have researched and written extensively about appropriate and optimal scale in agricultural operations and technology (Born & Purcell, 2006; Lyson et al., 2001). A research initiative called “Agriculture of the Middle” has documented a divergence in agricultural scale. Farms have bifurcated into two groups; small-scale farms selling to direct
markets, or large farms selling to large, diversified food and fiber distribution firms (Lyson, et al., 2008). The majority of farms, however, have a scale somewhere in the middle that are too large to sell to direct markets (or too big to be in close proximity to the direct markets) but too small to directly market, without a distributor or a milk cooperative, to multi-national companies like Dean Foods (the leading U.S. producer of milk and dairy products). This is the case of dairy farms in the Northern Crescent with fewer than 2,000 cows, but without access to direct markets, often operating as a cooperative member. Hence, various dairy farms of the Northern Crescent have utilized alternate business strategies including organic or biogas production.

**Specialization or Diversification**

Commodity milk prices are unstable (Figure 2.3), whereas the costs of operating the farm tend to increase. Facing unpredictable income and rising costs of production, farmers in the Northern Crescent dairy states feel pressured to grow, or change their business model. Although the majority of an average dairy farm’s cash flow continues to come from commodity milk, farmers frequently act as rural entrepreneurs, developing new products such as artisanal cheeses, and exploring new markets such as agro-tourism (Knickel et al., 2009).
Vermont farms have grown and changed. In an effort to maintain cash flow and profitability, nearly all Vermont dairy farms increased their herd sizes over the years. Alternatively, approximately 200 Vermont dairy farmers have sought to stabilize their milk income by transitioning to higher valued organic production. As of this writing, 16 Vermont dairy farms diversified their farm income by installing an ADS. To survive and still be a family dairy operation, these farmers have adopted business strategies that augment their income either through niche specialization or income diversification. Organic dairying is a familiar example of market specialization (Guptill, 2009). In organic dairy production, the farmer relies on the same core farm activity of producing milk, but using a differentiated process which allows the farmer to obtain a price premium for the milk.
Anaerobic digester systems (ADS) provide income distinct from the core activity of producing milk. These systems utilize farm inputs (manure) to produce both market outputs (electricity, renewable energy credits, renewable natural gas, and compost) and agricultural outputs (animal bedding and crop fertilizer). The literature outlines two broad terms to define activities that fall outside of standard core farm activities: ‘diversification’ and ‘pluractivity.’ The latter term refers to farm families engaging in off-farm business activities, whereas diversification is a farm-related activity beyond the primary pursuit (Evans & Ilbery, 1993; Vik & McElwee, 2011). There are no formal limits to what kind of diversification a farmer can undertake, with or without forming a new business entity. Farm income diversification as a strategy for greater economic viability includes transforming or expanding farm activities by varied uses of on-farm resources (Fuller, 1990). According to the Council on the Future of Vermont, (2009) report by the non-profit Rural Vermont, “…the majority of Vermont farms are diversified in one way or another, incorporating maple sugar operations, beef cows, vegetables, poultry or sheep, logging, and other activities to provide supplemental farm incomes.”

This thesis addresses these diversification and specialization strategies and their impacts on Northeastern dairy farmers.
Chapter 3: Vermont & Maine Organic Dairy Industry Profile & Profitability

Abstract

This study examines the demographics and production characteristics impacting the profitability of organic dairy farmers and farm businesses in Vermont and Maine. To date there are very limited studies that provide this information, therefore this gap in the literature leaves policymakers, educators, lenders, and suppliers without a profile of this sector that accounts for 23% of dairy farms in Vermont and 20% of dairy farms in Maine, annually shipping 787,600 lbs. milk per farm, on average. The study was conducted through a longitudinal survey of 83 organic farmers in Vermont and Maine from 2004 to 2012. The survey tool included 63 detailed questions about individual and family characteristics, production practices, attitudes, concerns, and future intentions. Financial data were also collected for each farm. A multiple linear regression analysis of the sample demonstrated six significant variables that affect farm profitability measured by return on assets (ROA). Having at least 80% Holstein herd composition, increasing the daily pounds of winter grain fed to cows, farms in which a primary farm operator had grown-up on dairy farm, and on farms in which the operator uses feed mixing machinery positively impacted ROA. Farm profitability was negatively affected on farms with a high rate of annual cow morbidity per herd size and also tended to decrease over the course of the survey. While the model developed here has some explanatory power ($R^2 = 0.387$), variability in farm profitability is affected by complex economic pressures beyond the scope of this research.

Introduction

“I transitioned to organic dairy in 2003 because I wanted to keep the farm sustainable for the next generation.” -Vermont Organic Dairy Farmer.

The New England States of Vermont and Maine have the highest percentage of organic dairy farms in the United States (Kersbergen, 2008). According to the Northeast Organic Farming Associations of Vermont and Maine, as of 2015 Vermont has 186 organic farms, and Maine has 55 organic farms (Maddie Monty, Dr. Gary Anderson, personal communication, March 2015). In what started as a grassroots movement in the 1960s, conventional dairy farmers and homesteaders in different regions of the United States pioneered modern
organic standards of production, although the markets did not recognize this differentiated process as value innovation until several decades later. Organic production became more popular after the introduction of the commercially produced rBST, in 1994, due to widespread consumer concern (Saucier & Parsons, 2014).

Few studies have quantitatively profiled the modern state of the organic dairy industry. This has hindered informed public policy decisions, private financing, and educators from providing the support needed by this growing sector. Organic dairy grew while the overall number of dairy was otherwise contracting. The number of dairy farms in the United States decreased from 131,510 in 1992 to 45,344 as of the beginning of 2015. During this time, dairy farms in Vermont decreased from 2,283 to 865, and dairy farms in Maine decreased from 670 to 280 dairy farms (Hoard’s Dairyman, 2015).

This article first presents a profile of Vermont and Maine organic dairy farmers from the past decade. The following section then compares the characteristics and performance of the Vermont organic dairy sector with the overall Vermont dairy industry, without any of the Maine cases. The final section quantifies the impacts of farmer experience and management practices on profitability through a multivariate regression.

**Literature Review**

This literature review focuses on the body of work related to the scale, economic viability, and the characteristics of farm managers and production
methods, situating the article within the stream of scholarship analyzing modern agricultural economics.

3.1.1. Organic Dairy in Vermont and Maine

Organic dairy production is differentiated from conventional dairy production by national standards. The USDA’s National Organic Program (NOP) defines organic dairy within the context of organic agriculture; organic livestock must be managed without antibiotics or added hormones, allowed year-round access to the outdoors, raised on certified organic land meeting all organic crop production standards, and fed 100% certified organic feed (National Organic Program, 2013). Although no literature has reported the optimal scale for organic dairy production, Vermont and Maine organic dairy farms tend to milk fewer than 100 total animals.

The USDA Organic Standards dictate that organic dairy cows must have minimum pasture time of 120 days (or longer, depending on local climate and growing season), and must consume 30% of their feed dry matter via pasture forage during this season. Lactating dairy cows will consume up to 60 lbs. in dry matter intake daily (Parsons et al., 2004).

Other germane dynamics include the prohibition of the use of antimicrobial drugs for organic dairy cows (Blayney, 2002). The standard stipulates that all appropriate medications and antimicrobial treatments must be applied to restore an animal to health if organic methods do not work. When methods acceptable to organic production standards fail, then this animal loses
organic certification. The primary reason for which antibiotics are used in dairy operations is for treating mastitis, a bacterial infection of the udder and a major cause of economic loss in the dairy industry (Sato et al., 2005; McConnel et al., 2008). Many organic dairy farms were originally conventional dairy farms that transitioned to organic production due to higher and more stable milk prices. The conversion to organic production can be relatively easy for dairies with cows that already consume pasture-based diets. Farmers choose the organic production business strategy often as an alternative to expansion to remain competitive in the conventional milk market. Expansion was often not possible for these farms due to the existence of geographic barriers that constrained farm size, an inability to obtain the financing necessary to expand, or a lack of desire to operate a larger dairy if confinement systems were incompatible with their expertise or ethical values (Saucier and Parsons, 2014).

### 3.1.2. Economic Viability of Organic Specialization

For organic milk producers, organic milk contracts provide a stable cash flow in an otherwise volatile dairy market. Through the organic dairy niche, many small dairy farms operate during a time when the dairy industry is consolidating and many small and moderately sized dairy herds are going out of business (Sato et al., 2005). Therefore, organic dairy production has become a form of economic specialization through which small producers maintain profitability without feeling pressured to grow. This mode of operation presents a contrast to the original grassroots movement of conventional dairy farmers and homesteaders in
1960-1980 establishing organic methods often at a market loss (Saucier & Parsons, 2014). As the number of organic dairy farms in the state has increased, this thesis presents an analysis of the modern economic viability of the organic operation.

O’Hara and Parsons (2013) used an input-output analysis to show that organic dairies had a greater economic impact than conventional dairies of comparable size. Ahlman et al. (2011) states that on average organic dairy cows have a longer productive lifetime compared to cows at conventional operations. No other studies to date have presented an in-depth quantitative analysis of important production factors of organic profitability in northern climates.

With regards to the consumer demand for organic dairy, the number of consumers who are willing to pay more for the perceived benefits of organic food has increased (Kolodinsky, 2008). Consumer and producer interest in quality food production, animal welfare, and environmental sustainability has increased in recent years. This holds true for the dairy industry across both organic and conventional dairy production systems (Lotter, 2003). In part due to this consumer demand, between 2000 and 2005, the number of certified organic milk cows on U.S. farms increased by an annual average of 25%, from 38,000 to more than 86,000 (McBride & Greene, 2009). Farmers hedge against price uncertainty and fluctuation with a contract to receive the same base price every month. The organic market allows farmers to get contracts for stable milk prices which are on average higher than conventional milk prices, as seen in Figure 3.1.
Figure 3.1: Average Organic vs. Conventional Milk Price in $ per Cwt., 2004-2012

The higher and more stable price of organic milk contributes to overall higher and more stable profits per cow in organic production, as is seen in Figure 3.2.
3.1.3. Characteristics of Organic Dairy Operators & Production Practices

To date, studies profiling farm operators have focused on farmer networks or individual farm profiles. According to Kroma (2006), the adoption of organic farming depends on these social groupings such as farmer networks where participants share practical knowledge and innovations from accumulated experience and insight. Multiple previous studies have analyzed dairy production systems, including the use of management-intensive grazing and farm financial viability relative to other dairy production systems, but few have focused specifically on organic dairy production, (Wisten et al., 2010). Management practices nonetheless vary substantially between otherwise similar operations. Thus, this article examines what practices are in use, how these practices compare with those used in conventional dairy, and how these practices contribute to
organic profitability. The industry profile presented here enables all readers to see aggregated experience and management practices from the past decade of organic dairy in Vermont and Maine.

3.1.4. Organic Dairy Farms compared with the Overall Dairy Sector

To provide some context for how the organic dairy industry compares with the modern non-organic sector, this section visually compares descriptive statistics from the overall dairy industry in Vermont with the organic dairy farms profiled above. A survey (the most recent) for each Vermont organic dairy farm is compared with a previous 2002 mail survey of the overall dairy sector in Vermont, including both organic and conventional operations. For the 2002 survey, a total of 872 surveys were returned from 1460 dairy farms for a return rate of 60.1%. For tables with more than 3 categories per variable, the table includes a column labeled ‘Difference’. This shows the outcome of subtracting the overall dairy statistic from the organic dairy statistic; this is intended to show the range and amount of dissimilarity from organic dairy to the overall industry. The 17 farms reporting from Maine were removed for this comparison.

Organic dairies tend to have fewer cows than non-organic operations. From Table 3.1, the average organic dairy had 59.5 cows, whereas overall 2002 dairy farms had on average 115.5 cows. For this comparison, it is important to consider the median, a measure more resistant to outliers and appropriate for non-normally distributed data: 2.7% of the overall dairy industry in Vermont has 500+ cows, but the industry median is only 70 cows.
Table 3.1: Herd Size Comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>29 and less</td>
<td>7.6%</td>
<td>6.5%</td>
<td>1.1%</td>
</tr>
<tr>
<td>30-49</td>
<td>33.3%</td>
<td>19.6%</td>
<td>13.7%</td>
</tr>
<tr>
<td>50-99</td>
<td>54.5%</td>
<td>40.8%</td>
<td>13.7%</td>
</tr>
<tr>
<td>100-149</td>
<td>1.5%</td>
<td>13.4%</td>
<td>-11.9%</td>
</tr>
<tr>
<td>150-199</td>
<td>1.5%</td>
<td>6.8%</td>
<td>-5.3%</td>
</tr>
<tr>
<td>200-499</td>
<td>1.5%</td>
<td>10.2%</td>
<td>-8.7%</td>
</tr>
<tr>
<td>500+</td>
<td>0%</td>
<td>2.7%</td>
<td>-2.7%</td>
</tr>
<tr>
<td>Mean</td>
<td>59.5</td>
<td>115.5</td>
<td>-48.9</td>
</tr>
<tr>
<td>Median</td>
<td>53.3</td>
<td>70.0</td>
<td>-16.7</td>
</tr>
</tbody>
</table>

As discussed above, organic dairies in Vermont have fewer cows and produce less milk per cow than non-organic dairies. The difference is pronounced in Table 3.2, with overall Vermont herds averaging more than 19,000 lbs. milk per cow vs. 13,000 lbs. milk per organic cow. A clear cross trend shows that organic cows produce less milk per year compared with the overall Vermont dairy industry.

Table 3.2: Comparison of Amount of Milk Produced per Cow

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9999 and less</td>
<td>21.2%</td>
<td>5.4%</td>
<td>15.8%</td>
</tr>
<tr>
<td>10,000-11,999</td>
<td>16.7%</td>
<td>6.5%</td>
<td>10.2%</td>
</tr>
<tr>
<td>12,000-13,999</td>
<td>25.8%</td>
<td>9.4%</td>
<td>16.4%</td>
</tr>
<tr>
<td>14,000-15,999</td>
<td>21.3%</td>
<td>17.4%</td>
<td>3.9%</td>
</tr>
<tr>
<td>16,000-17,999</td>
<td>12.1%</td>
<td>12.9%</td>
<td>-0.8%</td>
</tr>
<tr>
<td>18,000-19,999</td>
<td>3.0%</td>
<td>17.0%</td>
<td>-14.0%</td>
</tr>
<tr>
<td>20,000-26,000+</td>
<td>0%</td>
<td>31.4%</td>
<td>-31.4%</td>
</tr>
<tr>
<td>Average</td>
<td>12,756</td>
<td>19,041</td>
<td>-6285</td>
</tr>
<tr>
<td>Median</td>
<td>12,760</td>
<td>17,460</td>
<td>-4700</td>
</tr>
</tbody>
</table>
Table 3.3 details a comparison of the most frequently used technologies in use on organic farms measured against the overall dairy industry. The use of Bovine Somatotropin (rBST) is not permitted in organic production, but is also only used by 11.1% of the overall Vermont dairy sector as of 2002. The use of milking parlors is highly correlated with herd size, as these additional structures are a substantial cost only afforded by larger herds. Smaller farms tend to use a barn pipeline connected to the stanchion stalls of the herd housing. Similarly, feed mixing machinery is utilized by 18.5% of organic dairy farmers, a rate much lower than the overall dairy sector.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Use DHIA</td>
<td>44.6%</td>
<td>46.5%</td>
<td>-1.9%</td>
</tr>
<tr>
<td>Use feed mixing machinery</td>
<td>18.5%</td>
<td>47.8%</td>
<td>-29.3%</td>
</tr>
<tr>
<td>Use of rBST</td>
<td>0%</td>
<td>11.1%</td>
<td>-11.1%</td>
</tr>
<tr>
<td>Use pail units</td>
<td>7.3%</td>
<td>7.6%</td>
<td>-0.3%</td>
</tr>
<tr>
<td>Barn pipeline</td>
<td>78.8%</td>
<td>53.2%</td>
<td>25.6%</td>
</tr>
<tr>
<td>Herringbone/polygon milking parlor</td>
<td>12.1%</td>
<td>23.4%</td>
<td>-11.3%</td>
</tr>
<tr>
<td>Parallel milking parlor</td>
<td>1.5%</td>
<td>10.6%</td>
<td>-9.1%</td>
</tr>
<tr>
<td>Flat parlor</td>
<td>1.5%</td>
<td>3.9%</td>
<td>-2.4%</td>
</tr>
</tbody>
</table>

Note. *Dairy Herd Improvement Association records system.

Grazing is a primary source of forage for all organic operations but less than half (46.6%) of the overall dairy sector. Organic farmers also tend to move the cows to fresh pasture more frequently compared with those in the overall dairy industry using grazing, with 48% of organic farmers reporting that the cows move to new pasture every 12 hours or fewer. While most organic dairy herds
attempt to maximize grazing nutrients due to the higher cost of purchased grain, there is a distinct difference with more than 36% of the overall dairy sector practicing longer rotation grazing for lactating cows, which is associated with less intensive management and lower quality forage. Figure 3.3 visually depicts the differences in how often organic dairy cows change pasture compared with the overall dairy industry in Vermont.

Figure 3.3: Frequency of Pasture Change by Production Type Comparison in Vermont
Tables 3.4 and 3.5 below document differences in labor and outside income sources. Organic dairy operators report that their income comes only from their farms at a level 21.3% higher than the overall dairy industry. Of organic dairy producers, 24.2% earn more than $12,000 annually from off-farm employment. For the overall dairy industry, 37% earn more than $12,000 annually from off-farm employment.

Table 3.4: Comparison of Off-Farm Income

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>More than $12,000</td>
<td>24.2%</td>
<td>36.6%</td>
<td>-12.40%</td>
</tr>
<tr>
<td>Up to $12,000</td>
<td>16.7%</td>
<td>25.6%</td>
<td>-8.90%</td>
</tr>
<tr>
<td>No off farm income</td>
<td>59.1%</td>
<td>37.8%</td>
<td>21.30%</td>
</tr>
</tbody>
</table>

The overall dairy sector reports an approximate 50% split between farms that have non-family employees vs. farms with only family members employed, whereas 74.2% of the organic sector reports employing non-family labor for any number of hours during the year, as seen in Table 3.5. The ownership structure of the organic dairy sector closely matches that of the overall dairy sector, although organic farms have fewer partnerships (4.8% compared with 19.0% overall) and more sole proprietorships (85.5% versus 71.5%). The smaller farm structure of the organic farms cannot easily support two families or additional partners, which can be limiting to farm succession or transition.
From this visual comparison between descriptive statistics from existing literature and the survey data presented below, we demonstrate that Vermont organic dairy production differs substantially from the overall dairy industry in labor, technology, management practices, herd size, and milk production.

3.1.5. Apertures in the Literature: Organic Dairy

There have been studies that have examined various individual practices or demographic characteristics of organic farmers, however, many of these focus on a single study, or do not distinguish organic dairy farmers from organic agriculture in general (Soder et al., 2012). Therefore, this thesis provides this information through a study on demographic factors and production characteristics of the organic dairy industry.

**Methods**

Quantitative research is considered to be an analytic approach useful to the in-depth understanding of variables capable of numeric representation (Norušis, 2010). This article uses quantitative research methods to present a profile of a population of organic dairy farmers, and to analyze the variables with the highest impact on farm profitability. A survey tool utilized sought to collect...
consistent reliable numerical data from farmers about themselves, their families, and their operations.

3.1.6. Data Collection and Survey Tool

Organic farm characteristics are profiled by an eight-year longitudinal study of organic farmers producing commodity organic milk. No producers of cheese, ice cream, or yogurt were included. This study was conducted in Vermont and Maine as part of an economic analysis from 2004-2012. The survey tool (Appendix A) includes 63 detailed questions on demographics, production practices, attitudes, concerns, and future intentions. This survey was then linked with financial data collected during annual interviews with each farm. Parsons et al., (2004) and Meyer et al., (2011) have both utilized similar in-depth survey methodology to compare a wide sample of different farm management practices.

Vermont farmers volunteering to participate in the study were visited by a research team consisting of faculty from University of Vermont (UVM) and a dairy technical specialist from Northeast Organic Farming Association of Vermont (NOFA-VT). Maine farmers were visited by a team from University of Maine Cooperative Extension. Maine farmers did not participate in the study after 2006. Over the course of the study, some farms have dropped out of the study and others have joined in later years. Some have dropped out for a year or two and then rejoined the study. These circumstances are to be expected because farm conditions and time availability differ for farmers from year to year. All farmers received a payment for participating in the study.
The teams arranged with the farmers to find a convenient time to visit. In Vermont, the UVM Extension faculty visited the farm, and worked with the farmer to obtain financial data to complete a balance sheet, cash flow, and accrual adjusted income statement. This process involved gleaning data from the farmer’s record book, income tax form, lender documents, and production records. The economic analysis has been repeated for tax years 2004 to 2013.

All surveys were analyzed with SPSS statistical software for the social sciences (*IBM SPSS Statistics for Windows*, 2013) to examine the individual frequencies, correlations, and statistical association among factors.

The researchers obtained a systematic sample by asking all organic dairy farmers in the states of Vermont and Maine to share their financial data and complete a survey for $150 compensation. Those that participated were all farmers that accepted the offer, which introduces a sampling response bias. The farmers who did not respond at any point represent the primary source of uncertainty about whether the sample represents the population of Vermont and Maine organic dairy farmers.

3.1.7. Organization of Data

Although the surveys were collected from 2004 through 2012, this analysis utilized the most recent data available from each farm; therefore each farm represented one case in the study. After 2007, surveys were only collected for new farms in the study. This organization resulted in a sample size of 83 individual farms. Farms provided data for up to four principal operators. The
farmers themselves designated who would be termed a ‘Principal Operator.’ Thus, a spouse or child who works off the farm and works limited hours on the farm could still be a principal operator. Data at the level of principal operators is used for descriptive statistics; however, the unit of analysis for statistical tests is the whole farm.

Since this is a sample of farmers drawn independently from one known population, we can best retain degrees of freedom for statistical inference by using tests that make inferences about one population (Norušis, 2010). Decision rules for model selection were based on prior research, economic theory, and expert opinion.

Given the study topic and selection method, there are some limitations in this intensive study: farmers in this sample may face complex pressures and incentives different than the general population of organic dairy producers. With the sample from a relatively small overall population of 198 Vermont organic farms and 55 Maine organic dairy farms in 2013, the overall research objective is to develop rich, qualitative and quantitative data in relation to each farm via the profile to observe if patterns emerged across management practices.

3.1.8. Development of Data for Multiple Linear Regression

The analysis of the demographics and production characteristics of Vermont and Maine organic farms summarizes data containing a combination of continuous and categorical variables. Large volumes of such data such as these may be summarized in statistical tables of means, medians, counts, percentages,
or ranges. In order to test the relationship between farm return on assets and farm management practices, demographic variables, and external factors on Vermont and Maine dairy farms, a multiple linear regression model was developed. The farm return on assets (ROA) variable was the dependent variable in the model. ROA is an interval measure of overall profitability that is independent of the farm debt/equity ratio, and was calculated with the following equation:

\[
\left( \frac{\text{net farm earnings} + \text{interest}}{\text{average assets}} \right) \times 100
\]

where the net farm earnings refers to the residual income available after all the factors of production are paid including a charge for unpaid owner labor and management, interest refers to interest payments on debt, and the average of the total assets from the start and end of the year are used to represent the average value of assets available to support production.

Analysis of survey results and financial statements provided a method for testing demographics and management practices have a causal effect on the farm return on assets for all surveyed farms. The decision rule for whether or not to initially consider a variable in the model was if the regression coefficient of a variable was significant at the \( p = 0.05 \) level. For the developed model to be considered appropriate, the residuals were tested using residual plots for an approximately normally distributed and constant variance.
3.1.9. Study Hypothesis

The multiple regression analysis tests the following study hypothesis: The profitability of organic farms is associated with farmer demographics, specific management practices and external economic and environmental factors.

\[ \text{Farm ROA} = f(\text{management practices, farmer demographics, external economic and environmental factors}) \]

**Results and Discussion**

The results presented here indicate that the profile of Vermont and Maine organic dairy farmers can explain some key factors affecting farm profitability.

3.1.10. Organic Dairy Profile

The first results section presents the profile of both Vermont and Maine organic dairy farmers with descriptive statistics on demographics and labor for principal operators and at the farm level (Tables 3.6 and 3.7), management practices and capital (Table 3.8 and Table 3.9), Herd health variables (Table 3.10), milk production measures (Table 3.11) and financial statements of sources of income, prices over the survey period, expenses, and financial returns (Tables 3.12, 3.13, 3.14, 3.15).

The average year of establishment for all farms was in 1965. All farms except for one had been established as conventional dairy farms and made the decision to transition to organic production between 1995 and 2007, as seen in Figure 3.4.
Figure 3.4: Distribution of Farms with Year of Transition to Organic (n=71)

From Table 3.6, of the 83 Vermont and Maine farms, 42.2% listed only one principal operator. Of 133 individuals identified as principal operators on these 83 farms, 63.9% were males. Females were listed as the first principal operator with a male second principal operator for 15.7% of the farms, and 1.2% had a sole female operator listed. From this population of family-operated farms, the farmers in our sample got experience when they were young, as 77.1% farms had one or more principal operator who had grown up on a dairy farm. Of the 133 principal operators represented, 43.4% reported that they had grown up on the same farm that they were currently managing.

For all reported principal operators from multiple generations (n=132), the average age is 49, although the ages range from 20 to 74. The average number of years in formal schooling is 13.5, with 14% having an associate’s degree, and 22.6% having a bachelor’s degree.
Table 3.6: Demographics and Labor of Principal Operators

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percent of Sample</th>
<th>Min-Max</th>
<th>Median</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raised on dairy farm</td>
<td>77.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same Farm from Childhood</td>
<td>43.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year farm established</td>
<td></td>
<td>1772-2006</td>
<td>1975</td>
<td>1965</td>
</tr>
<tr>
<td>Years Tenure (n=132)</td>
<td></td>
<td>2-49</td>
<td>18</td>
<td>19.51</td>
</tr>
<tr>
<td>Age (n=132)</td>
<td></td>
<td>20-74</td>
<td>50</td>
<td>48.78</td>
</tr>
<tr>
<td>Years Formal Education (n=132)</td>
<td></td>
<td>9-19</td>
<td>12.5</td>
<td>13.48</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td>63.9</td>
</tr>
</tbody>
</table>

Note. Vermont and Maine, farms (n=83) provided data from up to four principal operators, (i =133) unless otherwise noted.

Table 3.7 reports demographics and labor variables related to the farm-level unit. The majority of farmers have health insurance (68.7%); 41% are insured through the farm business; 16.9% are insured through an off-farm employer; and 10.8% have other health insurance. No farmer offered health insurance to non-family employees, although by law they are obligated to provide workers’ compensation insurance for all employees.

Of all farms in the sample, 47% had no income earned from an outside employer. Of the 42 farms who reported an off-farm income, the majority stated that (57.1%) income earned from an outside employer was less important than income from the farm, though this extra income does allow more cash flow for farm investments and current expenses. Though it may contribute to farmer welfare, off-farm income is not included in the calculation for farm profitability and there was no significant difference in profitability between farms reporting an off-farm income and those without off-farm income.
Table 3.7: Labor Practices at the Farm level

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percent of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Off-Farm Income</td>
<td>47</td>
</tr>
<tr>
<td>Off-farm income less important than farm</td>
<td>57.1</td>
</tr>
<tr>
<td>income (n=42)</td>
<td></td>
</tr>
<tr>
<td>Has family health insurance</td>
<td>67.5</td>
</tr>
</tbody>
</table>

Note. Vermont and Maine farm level data (n=83).

Table 3.8 reports the descriptive statistics for management variables with interval data. In describing the labor force, the farms could report up to five family employees and up to five hired non-family employees. Family employees worked, on average, 24 hours per week. However, ‘F1’ or the first family member listed (presumably a primary operator) worked a much longer work week, on average, 71.3 hours per week. The average number of labor hours devoted per milking was two hours. Farms had an average of 303 acres of crop, hay and pasture land.

Table 3.8: Labor and Capital Interval Variables

<table>
<thead>
<tr>
<th>Vermont and Maine Organic Dairy Producers (n=83)</th>
<th>Weekly hours worked by F1 (n=83)</th>
<th>Weekly hours worked by family employees F1-F5 (n=129)</th>
<th>Total Labor hours per milking</th>
<th># Milking Stalls in Dairy Barn (n=80)</th>
<th>Acres Crop, Hay &amp; Pasture (owned, rented or leased) (n=80)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min-Max</td>
<td>Median</td>
<td>Min-Max</td>
<td>Median</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>15-105</td>
<td>72</td>
<td>1-8</td>
<td>24</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1-80</td>
<td>24</td>
<td>0-124</td>
<td>52</td>
<td>52.29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>22-1,399</td>
<td>252</td>
<td>303</td>
</tr>
</tbody>
</table>

Table 3.9 reports the descriptive statistics for management variables with categorical data. The CROPP organic marketing cooperative (Cooperative Regions of Organic Producer Pools), owner of the “Organic Valley” label, has the majority of organic farmers from the sample as members (61.4%) compared with the private processor, Horizon (37.3%), owned by Dean Foods. Farmers structure
their business most frequently as a Sole Proprietorship (85.5%), with LLC or Family partnerships accounting for the other business structure types. Of the partnerships and LLCs, all are family owned with LLC or partnership structure formed primarily for family ownership transition purposes.

The majority (84.3%) use artificial insemination (AI); all other management practices measured in the survey were used by 51.8% of the respondents or fewer. Certain capital-intensive technologies such as feed mixing machinery are used by 19.3% of the farms in the sample. The use of feed mixing machinery combines all inputs (forages, grains, protein feeds, minerals, vitamins and feed additives) and allows the feed to be formulated to a specified nutrient concentration and combined into a single feed mix. This method ensures that the cow gets a specific balance of feed components in every bite, whereas otherwise feed components are unevenly dispersed across the space of the feed trough and the time throughout the day. Such technology is not commonly used by smaller scale operations and farms with stanchion/tie stalls where cows receive individualized rations.

The majority (75.6%) of operations use a stanchion/tie stall milking system with a pipeline, and a stanchion/tie/comfort stall for herd housing (70.7%). As with conventional dairy farms, milking parlors with free stalls are most often found on farms with more cows. Management recommendations for grazing urge farmers to move cows to areas of new grass every 12 hours or as often as possible and limit the area to what the cows can graze without being short of feed while
minimizing wastage (Murphy, 1998). This provides the best quality forage to the dairy cows and allows previously grazed areas to rebound for the next grazing period. The majority of organic dairy farmers (25.3%) move cows to new pasture once daily, and 39.8% move the cows to new pasture twice per day.

Table 3.9: Management practices, Technology and Capital

<table>
<thead>
<tr>
<th>Vermont and Maine Organic Dairy Farms, (n=83)</th>
<th>Percent of Sample ‘Yes’</th>
</tr>
</thead>
<tbody>
<tr>
<td>To whom do the farmers sell their milk?</td>
<td></td>
</tr>
<tr>
<td>CROPP/Organic Valley</td>
<td>61.4</td>
</tr>
<tr>
<td>Horizon</td>
<td>37.3</td>
</tr>
<tr>
<td>Hood</td>
<td>1.2</td>
</tr>
<tr>
<td>Business Structure</td>
<td></td>
</tr>
<tr>
<td>Sole Proprietorship</td>
<td>85.5</td>
</tr>
<tr>
<td>LLC</td>
<td>9.6</td>
</tr>
<tr>
<td>Family Partnership</td>
<td>4.8</td>
</tr>
<tr>
<td>Management Measures</td>
<td></td>
</tr>
<tr>
<td>Balance feed rations at least 4x/year</td>
<td>41.0</td>
</tr>
<tr>
<td>Use feed mixing machinery (n=82)</td>
<td>19.3</td>
</tr>
<tr>
<td>Use seasonal milking program (2-3 months when all cows are dry)</td>
<td>17.5</td>
</tr>
<tr>
<td>Use Dairy Herd Improvement Association Service (DHIA)</td>
<td>42.7</td>
</tr>
<tr>
<td>Use herd management software</td>
<td>24.1</td>
</tr>
<tr>
<td>Use a computer for farm records</td>
<td>48.2</td>
</tr>
<tr>
<td>Use Artificial Insemination (AI) breeding</td>
<td>84.3</td>
</tr>
<tr>
<td>Majority Milking System, (n=82): Stanchion/Tie with pipeline</td>
<td>75.6</td>
</tr>
<tr>
<td>Majority Housing System, (n=82): Stanchion/Tie/Comfort Stall</td>
<td>70.7</td>
</tr>
<tr>
<td>Grazing Practices</td>
<td></td>
</tr>
<tr>
<td>Cows move to new pasture once daily</td>
<td>25.3</td>
</tr>
<tr>
<td>Cows moved to new pasture twice per day</td>
<td>39.8</td>
</tr>
</tbody>
</table>
Table 3.10 reports responses to various herd health questions. Organic dairy producers report that they purchase their medicines and treatments from a variety of locations. The two most popular retailers are route truck salesmen (36.7%) or a farm store (25.3%). Farmers averaged 6.6 scheduled vet visits and 3.7 emergency vet visits per year. One aspect that is not measured is the change in vet visits. Nearly all farmers stated that vet visits decreased dramatically after transitioning to organic.

Table 3.10: Herd Health Management

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percent of Sample</th>
<th>Min - Max</th>
<th>Median</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase location for most medicines/treatments</td>
<td>Route Truck</td>
<td>36.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Farm Store</td>
<td>25.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vet Office</td>
<td>13.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mail Order Catalogue</td>
<td>11.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Internet</td>
<td>5.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other/Combination</td>
<td>7.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td># Scheduled Vet Visits (n=74)</td>
<td></td>
<td>0-26</td>
<td>4</td>
<td>6.59</td>
</tr>
<tr>
<td># Emergency Vet Visits (n=72)</td>
<td></td>
<td>0-20</td>
<td>2</td>
<td>3.72</td>
</tr>
</tbody>
</table>

Note. Vermont and Maine Organic Dairy Producers (n=83).
Table 3.11 shows the milk production on organic dairy farms in Vermont and Maine. The average herd size is 59 milking cows, though the sample minimum was 19.5 cows and the maximum was 210. The average annual milk shipment in hundredweights was 7,876 cwt. (1 cwt. equals 100 lbs. in the United States). On average, farmers marketed 13,051 lbs. of milk per cow per year. These totals do not include milk withheld for mastitis or fed to calves.

Table 3.11: Herd Size and Annual Milk Shipment

<table>
<thead>
<tr>
<th>Milk Production Measures</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herd Size</td>
<td>59.0</td>
<td>51.5</td>
<td>19.5</td>
<td>210</td>
</tr>
<tr>
<td>Annual milk shipment per farm (lbs.)</td>
<td>787,600</td>
<td>670,700</td>
<td>197,000</td>
<td>2,756,200</td>
</tr>
<tr>
<td>Milk marketed (lbs. milk/cow/year)</td>
<td>13,051</td>
<td>13,077</td>
<td>6,115</td>
<td>21,171</td>
</tr>
</tbody>
</table>
Table 3.12 details sources of farm revenue on a per farm basis. The most important income source is from the sale of milk (88.7% of total revenue). Sale of dairy cows, cull cows, and veal calves account for 4.66%, the second highest source of income. All other sources of income each contribute less than 4%. The third highest source of income is from participation in government program payments, primarily the Milk Income Loss Contract (MILC), and NRCS conservation programs through the U. S. Department of Agriculture (USDA).

Table 3.12: Farm Income

<table>
<thead>
<tr>
<th>Revenue</th>
<th>Mean</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>225,963</td>
<td>193,934</td>
</tr>
<tr>
<td>MILC and other government payments</td>
<td>8,797</td>
<td>2,998</td>
</tr>
<tr>
<td>Dairy cattle</td>
<td>6,597</td>
<td>0</td>
</tr>
<tr>
<td>Cull cows &amp; Veal</td>
<td>5,274</td>
<td>3,910</td>
</tr>
<tr>
<td>Other(^a)</td>
<td>5,244</td>
<td>2,990</td>
</tr>
<tr>
<td>Coop Patronage Dividend</td>
<td>1,624</td>
<td>623</td>
</tr>
<tr>
<td>Crop Sales</td>
<td>1,445</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Cash Income</strong></td>
<td><strong>254,750</strong></td>
<td><strong>210,096</strong></td>
</tr>
<tr>
<td>Accrued livestock herd income</td>
<td>8,220</td>
<td>3,400</td>
</tr>
<tr>
<td>Accounts receivable</td>
<td>1,325</td>
<td>700</td>
</tr>
<tr>
<td>Hay inventory</td>
<td>1,921</td>
<td>200</td>
</tr>
<tr>
<td>Grain inventory</td>
<td>108</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Accrued Revenue</strong></td>
<td><strong>10,025</strong></td>
<td><strong>4,714</strong></td>
</tr>
<tr>
<td><strong>Net Farm Revenue</strong></td>
<td><strong>34,200</strong></td>
<td><strong>31,597</strong></td>
</tr>
</tbody>
</table>

\(^a\) Custom Work, Timber, Maple Syrup, and miscellaneous income

As mentioned in the above literature review, organic milk prices over the survey period were more stable than conventional commodity milk prices, and on average higher per cwt. by $10.60, shown in Table 3.13. When asked about the most important reason for their adoption of organic milk production, 25.3% of
farmers cited higher milk prices, 22.9% cited stable milk prices, and 4.8% cited both as the most important reason for their conversion to organic dairy.

Table 3.13: Milk Prices 2004-2012

<table>
<thead>
<tr>
<th>Year of Survey</th>
<th>% of surveys in sample</th>
<th>Organic milk price</th>
<th>Conventional milk price</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>2.4</td>
<td>$22.83</td>
<td>$15.40</td>
<td>$7.43</td>
</tr>
<tr>
<td>2005</td>
<td>19.3</td>
<td>$24.73</td>
<td>$16.90</td>
<td>$6.07</td>
</tr>
<tr>
<td>2006</td>
<td>14.5</td>
<td>$28.71</td>
<td>$16.00</td>
<td>$8.73</td>
</tr>
<tr>
<td>2007</td>
<td>34.9</td>
<td>$29.35</td>
<td>$13.70</td>
<td>$15.01</td>
</tr>
<tr>
<td>2008</td>
<td>13.3</td>
<td>$30.90</td>
<td>$20.60</td>
<td>$8.75</td>
</tr>
<tr>
<td>2009</td>
<td>3.6</td>
<td>$30.19</td>
<td>$19.50</td>
<td>$11.40</td>
</tr>
<tr>
<td>2010</td>
<td>3.6</td>
<td>$30.27</td>
<td>$13.80</td>
<td>$16.39</td>
</tr>
<tr>
<td>2011</td>
<td>0</td>
<td>$30.63</td>
<td>$17.70</td>
<td>$12.57</td>
</tr>
<tr>
<td>2012</td>
<td>8.4</td>
<td>$33.39</td>
<td>$21.60</td>
<td>$9.03</td>
</tr>
<tr>
<td>Total/Average</td>
<td>100.0</td>
<td>$29.02</td>
<td>$17.71</td>
<td>$10.60</td>
</tr>
</tbody>
</table>

Table 3.14 specifies mean and median cash expenses in descending order. We also present these farm averages divided by the average herd size (59 cows) and the average annual milk shipment in hundredweights (cwt). The greatest expenses are purchased feed (on average $1,171.75 per cow per year). Purchased feed is a challenge for organic dairy farms because feed must be certified as organic, meaning it is grown on certified organic cropland. Organic feed has also experienced demand from the growth of organic beef, pork, and chicken (Bob Parsons, Personal Communication, May 2015). Organic feed is 2-3 times the price of conventional dairy feed. The second highest area of expense is repairs and supplies, followed by labor and interest.
<table>
<thead>
<tr>
<th>Operating Costs and Expenses</th>
<th>Mean</th>
<th>Median</th>
<th>Mean Cost Per cow, (by ave. Herd size 59 cows)</th>
<th>Mean cost per cwt. (7,876)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased feed</td>
<td>69,133</td>
<td>57,704</td>
<td>1,172</td>
<td>8.78</td>
</tr>
<tr>
<td>Hired labor</td>
<td>22,580</td>
<td>12,316</td>
<td>383</td>
<td>2.87</td>
</tr>
<tr>
<td>Repairs</td>
<td>14,864</td>
<td>11,619</td>
<td>252</td>
<td>1.89</td>
</tr>
<tr>
<td>Supplies</td>
<td>12,808</td>
<td>10,026</td>
<td>217</td>
<td>1.63</td>
</tr>
<tr>
<td>Interest</td>
<td>10,204</td>
<td>7,775</td>
<td>173</td>
<td>1.30</td>
</tr>
<tr>
<td>Fuel and oil</td>
<td>7,953</td>
<td>6,762</td>
<td>135</td>
<td>1.01</td>
</tr>
<tr>
<td>Utilities</td>
<td>7,911</td>
<td>7,512</td>
<td>134</td>
<td>1.00</td>
</tr>
<tr>
<td>Custom hire</td>
<td>7,289</td>
<td>3,902</td>
<td>124</td>
<td>0.93</td>
</tr>
<tr>
<td>Insurance</td>
<td>4,968</td>
<td>3,964</td>
<td>84</td>
<td>0.63</td>
</tr>
<tr>
<td>Bedding</td>
<td>4,776</td>
<td>3,475</td>
<td>81</td>
<td>0.61</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3,872</td>
<td>2,543</td>
<td>66</td>
<td>0.49</td>
</tr>
<tr>
<td>Rent</td>
<td>3,525</td>
<td>900</td>
<td>60</td>
<td>0.45</td>
</tr>
<tr>
<td>Taxes</td>
<td>3,228</td>
<td>3,051</td>
<td>55</td>
<td>0.41</td>
</tr>
<tr>
<td>Marketing</td>
<td>3,167</td>
<td>2,734</td>
<td>54</td>
<td>0.40</td>
</tr>
<tr>
<td>Breeding</td>
<td>2,623</td>
<td>2,323</td>
<td>44</td>
<td>0.33</td>
</tr>
<tr>
<td>Veterinary</td>
<td>2,520</td>
<td>2,000</td>
<td>43</td>
<td>0.32</td>
</tr>
<tr>
<td>Auto</td>
<td>2,244</td>
<td>1,324</td>
<td>35</td>
<td>0.29</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>1,304</td>
<td>0</td>
<td>22</td>
<td>0.17</td>
</tr>
<tr>
<td>Seeds</td>
<td>1,040</td>
<td>0</td>
<td>18</td>
<td>0.13</td>
</tr>
<tr>
<td>DHIA records</td>
<td>943</td>
<td>943</td>
<td>16</td>
<td>0.12</td>
</tr>
<tr>
<td>Medicinal suppl.</td>
<td>597</td>
<td>0</td>
<td>10</td>
<td>0.08</td>
</tr>
<tr>
<td>Total Cash Expense</td>
<td>187,403</td>
<td>155,822</td>
<td>2,901</td>
<td>0.36</td>
</tr>
<tr>
<td>Depreciation</td>
<td>28,176</td>
<td>24,600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accounts payable</td>
<td>3,118</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-paid accounts</td>
<td>420</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplies adjusted</td>
<td>-21</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Credit adjusted</td>
<td>-404</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Accrued Expenses</td>
<td>32,693</td>
<td>25,356</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Expenses (Cash + Accrued)</td>
<td>219,096</td>
<td>182,497</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The financial overview in Table 3.15 shows the average farm return on assets is 2.00%, indicating that organic farms are on average profitable throughout the survey period. The average net farm revenue was $34,200 per year, farm earnings, after charging for unpaid family labor and management was $10,585.

Table 3.15: Financial Overview

<table>
<thead>
<tr>
<th>Vermont and Maine Organic Dairy Producers (n=83)</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Farm Revenue</td>
<td>34,200</td>
<td>31,597</td>
<td>-95,174</td>
<td>186,728</td>
</tr>
<tr>
<td>Net Accrual Farm Earnings</td>
<td>10,585</td>
<td>9,808</td>
<td>-130,174</td>
<td>151,728</td>
</tr>
<tr>
<td>Return on Assets</td>
<td>2.00%</td>
<td>2.05%</td>
<td>-29.74%</td>
<td>22.03%</td>
</tr>
</tbody>
</table>

3.1.11. Multiple Linear Regression: Impacts on Organic Farm Profitability

The multiple linear regression analysis was used to identify independent variables to explain variation in farm ROA. Any financial variables that comprise the calculation for ROA were not included in the model, as these measures are part of the definition of the dependent variable. Using economic theory and prior research, the list of variables with likely impact was further narrowed. Residual plots of all variables included in the model did not reveal any obvious deviations from homoscedasticity or normality. The linearity, multicollinearity, heteroscedasticity, and normal distribution conditions of the independent variables were also considered. When fitting models, it is possible to increase the explanatory power by adding additional variables, but doing so may result in over-fitting; when a statistical model describes random error or noise instead of the underlying relationship. The adjusted $R^2$ introduces a penalty term for the number of parameters in the model, and is therefore also reported. We tested the
model including each parameter against a limited model without each parameter to determine whether the model had more explanatory power with or without each effect. The model coefficients are shown below in Table 3.16.

Table 3.16: Multiple Linear Regression Analysis

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Std. Error</th>
<th>T</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-3.299</td>
<td>2.610</td>
<td>-1.264</td>
<td>0.210</td>
</tr>
<tr>
<td>Herd &gt; 80% Holstein (binary)</td>
<td>4.278</td>
<td>1.281</td>
<td>3.340</td>
<td>0.001</td>
</tr>
<tr>
<td>Daily lbs. winter grain fed to cows</td>
<td>0.399</td>
<td>.147</td>
<td>2.705</td>
<td>0.008</td>
</tr>
<tr>
<td>Either PO grew-up on dairy farm (binary)</td>
<td>3.405</td>
<td>1.405</td>
<td>2.424</td>
<td>0.018</td>
</tr>
<tr>
<td>Baseline year, 2004=1</td>
<td>-0.718</td>
<td>.311</td>
<td>-2.306</td>
<td>0.024</td>
</tr>
<tr>
<td>Rate of Cow death as percent of overall herd</td>
<td>-0.325</td>
<td>.145</td>
<td>-2.237</td>
<td>0.028</td>
</tr>
<tr>
<td>Use feed mixing machinery (binary)</td>
<td>3.131</td>
<td>1.525</td>
<td>2.052</td>
<td>0.044</td>
</tr>
</tbody>
</table>

Note. PO = Principal operator  
\( R^2 = 0.387; \) adjusted \( R^2 = 0.337; \) SE = 5.275

Breusch–Pagan test for heteroscedasticity: F = 0.859, p = 0.529

Six distinct variables had statistically significant explanatory power in the model. All variables in our final model are significant at the p = 0.05 level.

This study fails to reject the null hypothesis: the profitability of organic farms is associated with farmer demographics, specific management practices and external economic and environmental factors such as weather and land availability.

Two management practices emerged that related to providing dairy cows with a nutritious but cost-effective diet. In question 15B of the survey, all farmers indicated whether or not they used feed mixing machinery as a ‘yes or no’
categorical variable. The use of feed mixing machinery predicts a positive effect on farm ROA of 3.13 percentage points. Investing in this machinery is expensive, so farms with more cows tend to be more likely to utilize it. In addition, it is more likely to be employed on farms without stanchions. The use of feed mixing machinery shows significant positive correlation with herd size ($p = 0.01$). The other feed related management practice was the amount of winter grain fed to cows daily. Winter grain and summer grain, also called concentrates, and refers to the grain that is fed to the cows. Organic dairy farmers integrate purchased grain and quality pasture forage for the diet of their herds. Only 2.4% of farmers surveyed from Vermont raise any grain corn or soybeans on their own cropland. In question 39B of the survey, all farmers indicated the number of lbs. of grain that they fed to each cow daily during the winter months. For each pound of winter grain fed to cows up to 25 lbs., ROA is predicted to increase by 0.40%. This is logical because grain is a high energy feed concentrate for cows that increases their milk production. Organic grain is 2-3 times more costly than conventional grain feed components, so this estimated coefficient is important as it indicates that the benefits of this expensive feed outweigh the costs on higher profit farms.

Dairy farmers utilize certain breeds to achieve higher butterfat content in the milk, higher milk production, or for other breed attributes. Holstein cows tend to produce the highest quantity of milk, and for the organic farmers in our
sample, this herd composition was the most significant factor of profitability. Farms with at least 80% Holstein cows had a predicted ROA increase of 4.28%.

Age, education, location and tenure proved to be less likely to be an affect farm profitability compared with whether either principal operator had spent their childhood on a dairy farm. Having a principal operator that had grown up on a dairy farm had a predicted effect ROA increase of 3.41 percentage points.

Two variables significantly negatively affected ROA. As the years progressed from 2004 through 2012, farm profitability tended to decrease by 0.72% per year. The price of milk edged upwards from 2004 until 2006, and then leveled off until 2011. Meanwhile, feed prices increased dramatically in 2007, and other production costs increased incrementally each year as well. Therefore, even with low inflation, when milk prices leveled off, profit margins tightened each year (Bob Parsons, May 2015, personal communication).

The negative factor within farmer control is the rate of cow death experienced compared with overall herd size. For each increase in the percent of cows that died each year (this variable was normalized by herd size), the farm ROA decreased by 0.33%. This concept refers to both deaths and rendering, in which the farmer involuntarily removes cow from the herd resulting in no income. The voluntary culling of low producing cows is a necessary practice for each farmer that does not want to increase their herd size, as every milking cow gives birth every year, and all female calves are potential replacements. Without culling some older cows and some replacements, a farmer’s milking herd will gradually
increase. However, when a cow is non-ambulatory and must be euthanized, the farmer cannot sell the meat from this animal.

The model has relatively low explanatory power ($R^2 = 0.387$). There is variation in profitability unaccounted for by the variables measured by the survey. Farmers are price-takers, and although the price of organic milk is more stable and higher than conventional commodity milk, based on the average ROA of 2%, organic farming also has narrow profit margins. The U.S. Department of Agriculture compares cost of production data from Indiana, Minnesota, New York, Ohio, Pennsylvania, Vermont, and Wisconsin organic dairies from the 2010 Agricultural Resource Management Survey of dairy operations. The average 2010 value of production less operating costs was $9.18 per cwt sold, with the Vermont average lower at $8.30 per cwt sold (United States Department of Agriculture, 2015). Figure 3.5 compares the average ROA for organic dairies and similarly sized conventional dairies (with under 99 cows) for each year during the survey period.
Figure 3.5: Return on Assets for Organic & Small Conventional Dairies (2004-2012)

The overall average of all cases for each year shows the ROA is 1.80% for organic and 0.86% for conventional fewer than 99 cows. However, conventional was more profitable in five of the nine years. The overall analysis does not show exceptional profitability for organic dairy farms, but that Organic is overall more profitable than conventional farms of the same size.

Conclusions

This study sought to present a current profile of Vermont and Maine organic dairy farmers and the important factors of profitability on organic dairy operations from eight years of longitudinal survey and financial data from Vermont and Maine organic dairy farmers. This approach somewhat reduces the
speculation for producers and highlights the important demographic and management practices that influence the total ROA within this region.

Organic farmers are split between those who list multiple principal operators (57.8%) and those who list only one. There was only one farm which had a female listed as the sole proprietor. The majority of farms (77.1%) had a principal operator who had grown up on a dairy farm. The average herd size in the sample was 59 cows. The average lbs. of milk marketed per cow per year was 13,051 lbs.

The average age for all principal operators is 48.78. The sample included multiple generations of farmers in some cases, as the ages range from 20 to 74. The average number of years in formal schooling is 13.48, and the median number of years of schooling is 12.5. The average length of tenure as a farm operator was 19.51 years.

Farm profitability is overall a complex issue with a great deal of variation across farms. Additional studies need to be done to generalize these findings to a broader population. The five major conclusions from the empirical results are presented here.

First, organic farms still face incentives or the necessity to increase the number of cows in production, and to increase milk production per cow, and to vertically integrate more of their supply chain of feed and capital, just as they did before the transition to organic production. The farms that increase in size are
able to afford the technologies that appear to have the greatest returns on investment.

Second, farms that have herds primarily comprised of Holstein cows are the most profitable in the sample. Organic dairy farmers often utilize other breeds of cow to increase the protein and butterfat content in their milk, or for the perceived grazing benefits of certain breeds. This indicates that the profits from higher quantity of commodity milk produced outweigh the butterfat and protein quality bonuses.

Third, the majority (70%) of organic dairy farms have a positive ROA. This means that the farms in the sample were able to have fewer than 200 head and maintain profitability with meticulous farm management. Even as farms face pressure to expand, the majority of farms are profitable at their current scale, yet there is a challenge for the economic sustainability of the remaining 30%. Organic dairy farming is not a certain path to profitability.

Fourth, the profitability of organic farms is explained much more strongly by the farm-family childhood of a principal operator than by the level of education that operators attained, or the number of years’ tenure that they achieved as farm manager. From this, we can conclude that family farms and succession planning are important for the continued success of the region’s organic dairy sector. For additional detail for the effects of education on profitability when compared with a farm-family childhood, higher education did not significantly affect farm ROA. For farmers that grew up on a farm and
attended any post-secondary education (n=24), the average ROA was 2.9%. For farmers that grew up on a dairy but did not attend any post-secondary education (n=37), the average ROA was 3.6%. For farmers who did not grow up on a farm but did attend higher education (n=14), the average ROA was -3.9%. For the farmers in this sample, on average, post-secondary education had no significant effect on return on assets. This statement is based on the average result, and naturally this does not hold true for all individual farms.

Fifth and to conclude, farm management and farmer demographics are not the only factor of profitability. Farmers face significant exogenous factors beyond their control every year with weather, milk and feed prices, and herd health (Figure 3.5). This research revealed that nearly 0.62 of ROA variation unexplained by variables tested in this research.

Figure 3.6: Conceptual Model of Conclusion

The average ROA of farms in the sample decreased throughout the course of the survey period as prices leveled off but expenses continued to increase. Organic production has helped many of Vermont and Maine’s small
farmers stay in business, but rising feed prices could easily begin to outweigh the higher milk prices and leave these farmers back where they started; managing an unprofitable business. This report attempts to shed light on the profile of organic dairy farmers in Vermont and Maine, and factors affecting dairy profitability. Based on these findings, organic dairy can offer a profitable business model for small farmers. However, conclusions derived from the analysis were based on surveys and financial data from 2004 through 2012. Additional research is needed to account for adjustments in relative milk prices, consumer demand for organic products, markets for conventional and organic feed inputs, progress in farm succession planning, novel organic pasture regulations, and continuing technological improvements in dairy farming.
Chapter 4: Anaerobic Digester Maintenance Costs on Vermont Dairy Farms

Abstract
Farm anaerobic digester systems (ADS) are one means of producing renewable electricity, managing food waste, and a business strategy for diversifying farm income. The objective of this study was to investigate the predicted and actual annual maintenance figures collected from ADS in Vermont. The key operating costs are detailed, in addition to sources of cost variation. The analysis compares costs by creating a ratio of actual maintenance, repair, oil, and labor costs over these same predicted costs. This ratio is used to assess whether the suggested industry operating cost estimator tends to over or under predict annual maintenance costs. The ratio was evaluated with a one-way Student’s t-test (p = 0.046) finding that maintenance costs tend to be under-predicted compared to the actual costs. One-way ANOVA was used to determine a statistically significant effect of herd size (F = 6.453, p = 0.052), showing that the maintenance ratio varies significantly between two size groups of farms, those with more than 500 cows or those with fewer than 500 cows. This analysis indicates that predicting annual maintenance, repairs, and labor costs as a function of 3.5% of total kWh production is accurate for digesters on farms with more than 500 cows, but under predicts maintenance costs for smaller farms. For smaller farms, the mean ratio was 2.55, meaning that actual costs were on average 2.5 times higher than predicted.

Introduction
Anaerobic digester technology is a means of collecting methane from decomposing organic materials for use as energy. This technology is a long-standing means of producing renewable energy (Meynell, 1978), but can also play a role in the diversion of organic materials from landfills and in the business viability of dairy farms. As of June 2015, the New England State of Vermont has 16 farm-based digesters, one community-based digester built and operated by Vermont Technical College, and one digester at a brewery. Between 75 and 2,100 cows provide the input manure for each farm based digester, and the
technology has electric generation capacity ranging from 20-450kW. Vermont uses ADS technology as a means of supporting farmers and generating renewable energy. Farmers are paid for the energy via the Cow Power™ program and Vermont Sustainably Priced Energy Enterprise Development (SPEED) Program through long-term contracts with fixed standard offer rates. The potential for the existing digesters to process organic waste diverted from landfills is still largely undetermined (Scruton, 2007).

To determine the expected maintenance and repair costs, this article first qualitatively assesses sources of revenue and costs for digester system. The next section uses an ANOVA test to analyze the variance of maintenance costs of digester systems that have operated consistently for at least two years, followed by a student’s t-test to compare these means to an industry expected cost. For farmers to undertake the business risk of installing an ADS there is a need to assess the cost of operations and maintenance for these systems. Additionally, the ADS in Vermont have all been built using some level of public grant funding, and so it is also in the public interest to understand the lifecycle costs of these systems.

4.1.1. Motivation for Investigating Operational Costs

Dairy farmers face fluctuating milk and input prices. Increasing economic viability for dairy farmers often means increasing the size of their herd to produce more milk, and managing the herd for more milk per cow. Stabilizing income has become a major concern of dairy farmers. Therefore some farmers
look to the conversion of animal waste into electricity and a bedding product by ADS as a means of diversifying and supplementing their income earned from milk sales. The electricity produced using ADS can be connected to the grid, for which farmers may use net-metering to receive the market price for electricity, or sign a contract that will lock them into a per kWh price over a specified time period (Lazarus & Rudstrom, 2007). This can provide consistent supplemental income or cover other farm electricity costs due to the constant flow of manure on a farm operation, and relatively stable electricity prices (Giesy et al., 2009).

With multiple vendors and data from existing digesters, there exist reliable cost estimates and cash flow considerations, as well as suitable estimates for expected revenues (Wang et al., 2011). As for the questions of how long a system and the equipment will operate, and how much annual maintenance will cost, these remain an undefined puzzle worthy of investigation. None of ADS have been in place for the entire potential lifecycle of the structure, although they are assumed to last approximately 20 years. One large challenge is with operating smaller scale digesters; two farmers with smaller digesters (less than 200 kW installed capacity) indicated that it had been difficult for them to find industry estimates for digester maintenance and repairs costs.

“One of the interesting things is that before we built this thing, I was never able to get ahold of a Profit and Overhead report for an operating Digester. We were given numbers for all maintenance costs under $10,000 per year for digesters that are considerably larger than ours. As you can see, certainly the costs are running more than $20,000 to $30,000 per year.” – Vermont Digester Administrator
The industry vendors and engineering firms therefore have not consistently been able to provide the necessary predicted costs for the farmers to inform this business decision, largely due to the lack of available information. There is a question of practicality for small scale farmers considering installing an ADS and no data collected to inform the decision.

“The only thing that I asked for when I signed, I wanted to know what it costs to run this for those first 5 years, so that I could make a decision at the end… [The vendor] did not seem to really want to share those numbers with me, and that was when they were thought that they had a working system. And now, I’m sure that they would be embarrassed to share the figures, because it has cost them a lot more than it should have.” –Vermont small scale digester operator

This conundrum of wanting to provide potential adopters with real lifecycle cost data partly motivates this investigation (Lusk, 1991). The broader context of this research is motivated by a desire to provide the public with an assessment of this technology. The Federal and Vermont state governments, and utilities have provided significant grant funding for the initial construction costs, and set up a program for consumers pay a premium feed-in tariff in part to make the project financially feasible. The farmers need a rate which will provide a return on investment to cover the cost of the system. Maintenance costs and replacement equipment are the biggest unknown sources of variation in cost. Therefore it is in the public good to assess the maintenance costs incurred to fairly set the rate for this feed-in tariff (Anderson et al., 2007).
4.1.2. Sources of Variation in Operating Costs

An ADS is an example of a complex system. An ADS is composed of several parts or modules, of which each part performs a well-defined task. The different parts interact non-linearly, and this non-linear aspect of the interactions makes it very difficult to predict the behavior of the system under different perturbations. For instance, water in the systems is used to reduce CO₂ content, but too much water condensate in the gas supply system causes big problems with blockage and rusting and too little water does not allow manure to flow through the system (Miller, 2003). In this way the system also exhibits collective responses to external perturbations, meaning that perturbations on one part will propagate to the entire system, non-linearly affecting its entire behavior. For example, anaerobic digestion is the combined action of two forms of bacteria commonly referred to as the “acid formers” and “methane fermenters.” A slight change in input feedstock, or external temperatures, can cause an imbalance in bacteria populations and either increased biogas production or a bacteria die-off. Once one includes economic influences in these systems, their operation begins to exhibit emergent behavior. This means that the macroscopic behavior of the system cannot be explained in terms of the behavior of its constituent parts. For instance, a farm in the sample had much lower maintenance costs than expected, in part because of excellent in-house mechanic skills, the seemingly right amount and constituents for feedstock, and remarkably low amount of corrosion from hydrogen sulfide, which is as yet unexplained. This emergent result is the outcome of the non-linear interaction of the system's constituent parts, location,
and operator. Since the operation and related costs of these systems are a complex system, there are potentially a great many sources of variation in cost. This analysis here attempts to account for some of the variation in costs resulting from this complexity.

The following analysis divides operation and maintenance costs into four major categories; 1) administrative costs, 2) farm and outside labor, 3) basic routine maintenance, and 4) major equipment replacement and rebuilding. Administrative costs, the first category, includes expenses such as accounting, phone lines, legal fees, increased taxes, and general liability of equipment/income loss insurance policies. Depending on the ownership structure of the digester and the farm, the digester may owe ‘rent’ for the farm land on which it is situated as another potential legal administrative cost. The second category, farm and outside labor, covers the hourly wages or portion of the salary attributed to working on the digester for either a farm employee or outside consultant. Thirdly, basic routine maintenance refers to expected monthly costs largely associated with the engine, including oil changes, filters and replacement spark plugs. Although each cost category described thus far can cause variation in the annual operating costs of ADS, the fourth category, major equipment replacement and rebuilding, represents the largest source of variation. This category includes the costs of rebuilding or replacing equipment, structures, or elements of the digester pit itself. These costly replacements can occur seemingly relentlessly due to the build-up of hydrogen sulfide, a destructive acid component that condenses out in
the gas lines and corrodes expensive equipment (Miller, 2003). This factor proves to be the most significant source of variation in cost within the complexity of operating costs.

4.1.3. Projected Operating Costs

Vendors have unquestionably attempted to accurately calculate the projected operating costs of ADS. A firm that has built digesters in Vermont disclosed their method for estimating these annual operating costs for this research. This method was shared with the understanding that this estimation is unlikely to be absolutely accurate for every system, as ADS are as yet uniquely designed and scaled for each site, climate, and feedstock where they ultimately are built (Chapman et al., 1990). The firm accounted for all equipment and components, which have a specified metric for the maintenance that is needed after a certain number or hours (similar to the metric for a standard automobile oil change: every 3,000-5,000 miles, or at least two times per year). After accounting for the individual maintenance costs of each piece of equipment, along with the necessary labor, the firm normalized this cost for various scales of ADS by estimating these average costs as 3.5% of the total kilowatt hours (kWh) produced.

This estimate was confirmed by an independent energy consultant. Since several ADS have now been operating consistently for at least one year, it is pertinent to collect actual maintenance costs for these systems and test them against this predicted cost estimate.
Several of Vermont’s smaller dairies have had custom digesters installed, and these farmers have experienced a variety of failures and challenges with the systems (Gould 2013). Two of the smaller-scale ADS in the analysis have not operated consistently or at their expected capacity for at least one year. Therefore the actual maintenance costs for these particular maintenance systems are thus far unknown and cannot be included in the analysis. Small scale ADS are similar in expense to construct compared with larger systems, but the reduced amount of manure naturally produces less energy. Therefore the cost per kilowatt hour produced is already higher for smaller ADS.

4.1.4. Research Question

Have Vermont’s digester operators confirmed or failed to confirm a vendor calculated expectation of maintenance costs for the anaerobic digester systems in the state (Figure 4.1)?

![Conceptual Model of Research Question](image)

*Predicted Annual Maintenance Costs = Total kWh produced * 3.5% \( \frac{\$}{kWh} \)
4.1.5. Structure of Anaerobic Digesters in Northern Climates

In Vermont, there have been efforts to construct and maintain ADS on farms ranging in size from 75 cows to 2,000 cows that provide the input manure for these systems. Multiple studies on ADS over the past several decades have explored the subject of appropriate scaling of the technology (Sims & Richards, 1990; Downing et al., 2005; Klavon et al., 2013; Namuli et al., 2013; Singbo & Larue, 2014). Within the U.S. dairy industry, 31 percent of dairy production occurs in facilities where animals do not graze, an arrangement known as “confined animal feeding operations” (CAFOs) through the use of free-stall dairy housing with a center drive-through feed alley. Operations utilizing a free-stall tend to have more than 250 cows, and in some cases up to tens of thousands of cows (O’Hara & Parsons, 2013). According to Di Camillo (2011), in the United States CAFOs are the principal agricultural beneficiaries of digester technology.

Likewise, Klavon et al. (2013) posit that in the United States, only large dairies (those with more than 500 cows) can economically utilize ADS. Moss et al., (2014), Thompson et al., (2013), and Welsh et al., (2010) make the case that ADS can be considered scale neutral, as is seen by successful digester application in both very small farms around the world and large-scale agricultural enterprises in the USA (Moss et al., 2014). Therefore, although the capabilities of AD technology are arguably scale-neutral, the application of that technology is dependent on the community cultural context (Gould, 2013). The idea that ADS
can only be beneficial for larger farms in the United States is an economic and social construction upheld by its conflation with industrialized agriculture (Thompson et al., 2013). Experience in Vermont appears to agree. Existing ADS around the globe range in size from household level to municipality level. A look at the international use of ADS reveals that millions are used at household scale (Chen et al., 2012). Smaller digesters (utilizing food residuals or manure) supply cooking and heating fuel to households. Such ADS do not require infrastructure for generating electricity, as technology for collecting and burning methane gas costs a great deal less than connecting to the power grid (Hilkiyah Igoni et al., 2008). Thus any digester units that require burning of methane gas specifically to generate electricity require a large capital investment in interconnection costs and engine costs. Current research is underway through the Vermont Agency of Agriculture, Food, and Markets to investigate the costs of refining the biogas output of ADS to be injected into the natural gas pipeline in Vermont’s Northeast Kingdom as renewable natural gas (RNG). One farmer in the sample has been investigating the scrubbing technology necessary to clean biogas to RNG standards, and reports this refinement technology, costs approximately $200,000 for the equipment.

On the other end of the scale of size and expense, municipal digesters, or any systems dealing with household sewage, are much more expensive. This expense is due to the fact that they must adequately process pharmaceuticals and
human waste to meet health and safety standards (David Dunn, personal communication, February 2014).

When public dollars are used to fund ADS that fail to operate correctly, this represents a market failure. Without clear knowledge of the long term maintenance costs, digester operators find themselves in tight financial situations. More research is needed to assist the decision-making of farmers in such circumstances. To make biogas feasible in the marketplace, policy-makers must offer the right balance of incentives and regulations. Renewable energy producers, including digester operators, need to be producing clean energy at competitive prices while earning a return on investment. These sentiments are voiced within the public and private sectors; Andrée-Lise Méthot, keynote speaker at the first Vermont-Quebec Forum Bio-Energy Challenge, warns that natural gas and shale gas are still supplied at market rates lower than that of digester biogas. Mr. Philippe Thellen, Ministère des Finances et de l’Économie of Quebec, advises that small businesses need financial incentives and regulatory certainties to ensure a return on their investments.

4.1.6. Lifecycle Costs of Anaerobic Digester Systems

The total costs of ADS vary significantly by region and technology. The ranges of absolute costs for different types of biomass power technologies were published by the International Renewable Energy Agency IRENA (Taylor, 2012) from 130 member countries. For ADS, investment costs in U. S. dollars range from $2,574 to $6,104 per Kilowatt of power. The levelized cost of electricity
refers to an economic assessment of the cost of an energy-generating system, including all the costs over its lifetime. This includes the initial investment, operations and maintenance, cost of fuel, and cost of capital. The range of the levelized costs of electricity for ADS is between 0.06 and 0.15 USD/kWh. Unlike other renewable energy technologies like wind, solar, or hydropower, the operations and maintenance costs for biomass are a significant percentage of the levelized cost of electricity (LCOE). Further research is needed to see how the 16 digester systems operating in the state of Vermont compare with this aggregated data, especially the smaller farms which represent an outlier in U.S. Digester scale. Of 195 operational U. S. farm-scale digesters with manure input from cows or heifers, the median herd size providing manure to the system is 1,500 animals, and the average herd size is 4,233 animals (Anaerobic Digester Database, 2015).

A first consideration when deciding whether to adopt AD technology is choosing appropriate and cost-effective digestion systems, given limited funding and alternative renewable technologies. Farm ADS in Vermont have cost between $500,000 and $3 million to construct and connect to the power grid, indicating expensive entry into the market. Every part of the ADS has high costs, from construction and utilization to operation. Costs are incurred during the digestion process and while methane is burned to create the electricity. Finally, farmers must maintain these ADS. Maintenance costs, which deal primarily with corrosion of the engine used to generate the power, can be prohibitively expensive; for example, one Vermont digester administrator reported regularly
replacing parts and machinery ranging from $2,000 to $10,000 every three months since installation.

The process of using methane to produce electricity or biofuels has the potential to support Vermont’s dairy sector and renewable energy future, but the projected operating and repairs costs must be better projected to entice additional entrants.

**Methods and Data Collection:**

Between June 2012 and April 2015, researchers from the University of Vermont Department of Community Development and Applied Economics and University of Vermont Extension have maintained semi-annual communication with Vermont dairy farmers operating digesters. Interviews were conducted by telephone or in-person. Farmers were asked the costs of construction materials, labor, design, and the income potential including the offset of bedding costs, electricity production sold to the grid, and any other benefits and operating costs directly related to the operation of the digester. Grant amounts were collected, in addition to loans and financing costs. Farmers were also asked about the considerations that went into the decision to build the digester, in addition to if and how the process would have been approached differently after having been through the construction and permitting processes. Interviews lasted between one and three hours, and follow up phone calls and visits were made as necessary. Using the primary data collected from representative farms, this study patterns the annual maintenance and operating costs of Vermont digesters.
System outputs and expenses are private information, and the farmers have not recorded these data in a standardized manner. Indeed, according to energy consultant Mike Raker (personal communication, 2015), it has been difficult for farmers and researchers to separate out the portion of loans, labor, and maintenance costs attributed exclusively to the digester, unless the digester is specifically operated as a separate business with separate financial records. Farm business accounting is often based on the month-to-month cash flow rather than on specific cost categories and allocations. Therefore gathering data is difficult and imprecise at times. The researchers were fortunate enough to have outstanding relationships with eight of the farms with long running and consistent AD systems, who were willing to share their digester data. Numbers were also verified with industry biogas output calculators.

In the fall of 2014, a stakeholder group undertook a planning process to calculate the feed-in tariff that should be available to farmers who operate a farm methane project, and provided the calculations, along with an explanation, to the Vermont Public Service Board to consider when reviewing feed-in tariffs and consumer rates. The stakeholder group consisted of staff from the Vermont Agency of Agriculture, the Public Service Department, the University of Vermont, and an independent digester consultant. The three-step planning process engaged stakeholders and policy-makers in the agricultural and renewable energy fields from development to installation (Figure 4.2).
Until consistent data could be gathered from additional small scale digesters, the maintenance figures from some smaller and some larger operating digesters was used, for a sample size of seven (n=7).

4.1.7. Statistical Tests

The cliché “more is better” unquestionably applies to statistical inference. According to the law of large numbers, a larger sample size implies that confidence intervals are narrower and that more reliable conclusions can be reached. Small sample sizes can increase vulnerability to assumption violations in the analysis of variance test. A study by de Winter (2013) suggests that applying the t-test on small samples is feasible (i.e., n ≤5), and indeed William Sealy Gosset developed the t-test for small sample sizes. Accordingly, this methodology includes a comprehensive literature review, critical thinking, and an investigation of the existing evidence in the field. Any extraordinary claim made here would require more extraordinary evidence; therefore this field continues to have opportunities for further research.
The one-sample t-test is a method to test the null hypothesis that a sample comes from a population with a particular mean. It is used when the mean and standard deviation of the total population are unknown and must be estimated from a sample. This analysis tests the null hypothesis that the sample of the actual versus predicted maintenance costs ratio: \[
\frac{\text{actual maintenance costs}}{\text{predicted maintenance costs}}
\] comes from a population where the actual maintenance costs closely match the predicted maintenance costs, a mean ratio of ~1. The alternative hypothesis is that the mean of the actual maintenance costs is higher than the mean of the predicted maintenance costs.

An analysis of variance (ANOVA) is a statistical technique that is used to test hypotheses about two or more population means. The F-ratio output of an ANOVA test is a ratio of two estimates of population variance: the mean squares of the ‘between-groups’ variance and the ‘within-groups’ variance (Norušis, 2010). In this analysis, the mean ratio of actual and predicted maintenance costs is compared between two groups; digesters operating on farms with a herd size of more than 500 cows, and digesters operating on farms with a herd size of fewer than 500 cows. The variables in the analysis are summarized in Table 4.1.

Table 4.1: Summary of Variables in the Analysis

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Calculation of Dependent Variable</th>
<th>Independent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of Actual</td>
<td>Maintenance Ratio</td>
<td>Herd Size &gt;500 or</td>
</tr>
<tr>
<td>Maintenance over Predicted</td>
<td>$\frac{\text{actual costs}}{\text{predicted costs}}$</td>
<td>≤500 cows</td>
</tr>
</tbody>
</table>
**Results and Discussion**

This research builds on the Wang et al. (2011) study using data collected on maintenance and operating costs for Vermont’s small digester operations. The goal was to contribute to the body of research investigating the economic viability of operating ADS technology in a northern climate within different contexts of scale, feedstock inputs, and funding. Table 4.2 provides a summary of the size, capacity, and length of overall operating time for eight of the ADS in Vermont, although it should be noted that only seven of these cases had enough data to be used in the analysis.

Table 4.2: Characteristics of Sample ADS in Vermont

<table>
<thead>
<tr>
<th>Farm</th>
<th>Cows¹</th>
<th>Installed capacity² (kW)</th>
<th>Operational period³ (months)</th>
<th>Months non-operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1,650</td>
<td>450</td>
<td>96</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1,000</td>
<td>300</td>
<td>54</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1,250</td>
<td>450</td>
<td>52</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>1,600</td>
<td>450</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>500</td>
<td>155</td>
<td>45</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>375</td>
<td>150</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>200</td>
<td>65</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>H</td>
<td>100</td>
<td>20</td>
<td>21</td>
<td>12</td>
</tr>
</tbody>
</table>

Note. ¹ Number of cows providing manure to the ADS
² This can be different from the operational capacity as some ADS installed more capacity than the herd size due to grant eligibility or anticipated growth in herd size.
³ Number of months that the digester has been operational, as of March 2015.

4.1.8. Sources of Revenue

To contextualize the operating costs, it is important to understand the financial complement; the sources of revenue. Table 4.3 details the energy revenues for five of the ADS in the sample, normalized based on the kW capacity and the number of cows providing manure. The table divides the sources of revenue into two groups. The farms earn revenue from energy sales, which
includes subcategories of electricity sales and renewable energy credit sales. Another source of revenue is in fact an avoided cost, the total value of any additional benefits, which is described below. With regards to electricity production, the engine typically runs continually with 95% uptime, with stoppages every three weeks for an oil change, and in cases of any system failure. In each case the digester itself uses approximately 20% of the energy produced to run, known as the “parasitic load.”

Table 4.3: Summary of Revenue Sources for a Sample of Vermont’s Digesters

<table>
<thead>
<tr>
<th>Case</th>
<th>Annual Production (kWh)</th>
<th>Total Energy Sales*</th>
<th>Value of Additional Benefits</th>
<th>Revenue per Cow</th>
<th>Revenue per kW installed capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1,800,000</td>
<td>$312,204</td>
<td>$136,000</td>
<td>$358.62</td>
<td>$836.79</td>
</tr>
<tr>
<td>C</td>
<td>1,649,86</td>
<td>$339,749</td>
<td>$102,000</td>
<td>$441.75</td>
<td>$1,472.50</td>
</tr>
<tr>
<td>D</td>
<td>2,558,729</td>
<td>$534,445</td>
<td>$4,500</td>
<td>$336.84</td>
<td>$1,197.66</td>
</tr>
<tr>
<td>E</td>
<td>747,000</td>
<td>$110,739</td>
<td>$20,600</td>
<td>$200.45</td>
<td>$646.62</td>
</tr>
<tr>
<td>H</td>
<td>44,920</td>
<td>$4,660</td>
<td>$8,060</td>
<td>$169.60</td>
<td>$635.99</td>
</tr>
</tbody>
</table>

Note. n= 5, *total Energy sales including Renewable Energy Credit Sales

Variation largely based on the value of additional benefits, where the farmers themselves assess the values of these benefits.

For renewable energy generation to be economically viable, these technologies need to be producing clean energy at competitive prices. In 2009, the Vermont legislature passed a law to pay above-market prices for renewable energy, referred to as the Standard Offer Program (SOP) through Vermont SPEED (Vermont’s Sustainably Priced Energy Development). The SPEED Program was enacted by the Vermont Legislature in June 2005 in 30 V.S.A. § 8005 and § 8001. This included an exemption that allowed farmers to retain ownership of the environmental attributes created by digester projects, so that the
farmers could participate in both the SOP and Cow Power program through Green Mountain Power.

Farmers also receive other revenues, benefits or offsets from digester systems, as detailed in Table 4.3 The digested solids can be used as bedding for the cows, or sold to other farms or compost-users. The bedding sales to the farm represent the average avoided cost of purchasing sawdust or some other outside bedding source. The bedding sales to others is cash receipts of sales to others. Of note, digester operators must pay sales tax on this transaction if they bag and sell it directly to an end consumer. Waste heat from the engine can be used to heat agricultural buildings, offsetting the heating bill. Other benefits can be indirectly attributed to increased herd health and increased milk quality. By utilizing the solids as bedding a farm might be able to provide more bedding, and change the bedding more frequently. This can lead to increased cow comfort and herd health, resulting in a reduction in health issues and an increase in quality bonuses from milk sales. One farmer attributed increased milk quality (lower somatic cell count) to the higher quality and quantity of bedding provided by the ADS. If the ADS was constructed using a Yankee Farm Credit loan (YFC is a cooperative), the operator receives some of this money back in the form of a patronage refund counted here as other income instead of initial project investment. These ancillary benefits are can tip the balance of profitability for farm operators.
4.1.9. Consideration of Equipment Replacement

The financial model developed by the digester working group accounted for equipment replacement by assuming a seven-year life and straight line depreciation schedule for all equipment, including pumps, the solids separator, and the engine, often referred to as the ‘Genset.’ However, there is a lot of guesswork in when engines will need to be rebuilt or replaced, dependent on the sulfur content of the manure. Farm ‘A’, which has been operating for eight years, has purchased a new engine at year six for $497,000. This farmer is also saving to rebuild the original engine at a cost of $60,000 for use as a back-up. The old engine ran for 51,000 hours, and although the manufacturer suggests an overhaul at 45,000 hours, the farmer reported wanting to wait for a new gas delivery fueling system to be developed before making any changes. Operators in Vermont report that although the equipment is depreciated on a seven year schedule, the life of their engines has in some cases been closer to 4-5 years before the operator must spend $30,000-$60,000 to rebuild it. An engine rebuild is still considerably cheaper than the full replacement, which is likely still necessary after seven years.

4.1.10. On-Going Operational Costs and Replacements

A key issue for farmers is whether the projected maintenance costs will be overly prohibitive. Hydrogen sulfide is present in the manure in relative low quantity, in the 1000 to 20,000 ppm range. Acid and overall high moisture content in the methane create corrosion in the engine and in the equipment in the facility. Even at very low concentration hydrogen sulfide creates corrosion on building components. According to one digester operator,
“We have a tremendously expensive piece of equipment failing all the time. It's an extremely messy and caustic operation. If we have a chiller go down, it costs $15,000 dollars; we'll have to replace the spark arrester, that will be $6,000-7,000; The pipes that lead to it will go out, the radiator will go out, and we'll lose… 20-30 gallons of coolant. It's an extremely expensive thing to keep running.” -VT small-scale Digester Operator

The long term environmental implications for the surrounding area are minimal, since the hydrogen sulfide precipitates out of the exhaust quickly. Vermont’s Renewable Development Fund has announced their focus on finding cost-effective solutions to the problem of hydrogen sulfide for the size or scale of Vermont’s dairy farms, working with digester vendors as well as the engine generator suppliers to seek a variety of solutions that are out there and are relatively low cost, and test them for their efficiency. Some solutions are very simple iron-based chemical additives. These additives are environmentally benign, but are expensive. Natural gas producers have refineries to remove contaminants. Such refinery technology would makes economic sense for large dairy farms, but are not cost effective for smaller-scale farms.

As seen in Table 4.4., Operators report paying several thousand dollars per year in maintenance and repairs, including farm labor. In any given year, the digester might need sieve screens or flame erectors (both $8,500 replacements). One farm needed a $16,000 repair to the after-cooler, which cools the gas after it comes out of the digester so that it does not go into the engine hot. This is part of the machinery in place to stop engine corrosion; the methane must be cooled to get the moisture out of it. The useful life is less than two years on some parts.
Table 4.4: Annual Digester Maintenance Costs

<table>
<thead>
<tr>
<th>Farm</th>
<th>Maint. &amp; repairs</th>
<th>Labor</th>
<th>Oil &amp; fuel</th>
<th>Interest payment</th>
<th>Insurance</th>
<th>Other expenses</th>
<th>Total annual expenses</th>
<th>Total column 1,2,3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14,903</td>
<td>30,680</td>
<td>11,677</td>
<td>71,500</td>
<td>10,000</td>
<td>8,080</td>
<td>146,840</td>
<td>57,260</td>
</tr>
<tr>
<td>B</td>
<td>25,279</td>
<td>15,000</td>
<td>5,648</td>
<td>14,278</td>
<td>4,910</td>
<td>950</td>
<td>66,065</td>
<td>45,927</td>
</tr>
<tr>
<td>C</td>
<td>96,750</td>
<td>13,780</td>
<td>15,500</td>
<td>35,130</td>
<td>6,750</td>
<td>1,943</td>
<td>140,573</td>
<td>126,030</td>
</tr>
<tr>
<td>D</td>
<td>86,531</td>
<td>9,400</td>
<td>14,930</td>
<td>32,201</td>
<td>1,282</td>
<td>7,847</td>
<td>141,420</td>
<td>110,861</td>
</tr>
<tr>
<td>E</td>
<td>10,155</td>
<td>11,000</td>
<td>24,000</td>
<td>15,399</td>
<td>2,375</td>
<td>9,898</td>
<td>72,827</td>
<td>45,155</td>
</tr>
<tr>
<td>F</td>
<td>14,000</td>
<td>7,333</td>
<td>10,000</td>
<td>6,400</td>
<td>-</td>
<td>9,216</td>
<td>46,949</td>
<td>31,333</td>
</tr>
<tr>
<td>H</td>
<td>399</td>
<td>4,380</td>
<td>1,042</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5,821</td>
<td>5,821</td>
</tr>
</tbody>
</table>

The industry estimate does include basic annual maintenance, repairs, replacements, and labor costs. However, the estimate does not include annual costs such as insurance, taxes and fees, administrative costs, or interest payments. Table 4.5 details the predicted and actual maintenance costs for the seven farms with clear annual maintenance figures, along with the maintenance ratio and difference between predicted and actual.

Table 4.5: Maintenance Figures for the Farms in the Study

<table>
<thead>
<tr>
<th>Case</th>
<th>Predicted Maintenance Costs</th>
<th>Qualified Maintenance Costs*</th>
<th>Maintenance Ratio</th>
<th>Difference Predicted-Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$63,000</td>
<td>$57,260</td>
<td>0.91</td>
<td>$5,740</td>
</tr>
<tr>
<td>B</td>
<td>$57,745</td>
<td>$45,927</td>
<td>0.80</td>
<td>$11,818</td>
</tr>
<tr>
<td>C</td>
<td>$75,091</td>
<td>$126,030</td>
<td>1.68</td>
<td>($50,939)</td>
</tr>
<tr>
<td>D</td>
<td>$89,556</td>
<td>$110,861</td>
<td>1.23</td>
<td>($21,305)</td>
</tr>
<tr>
<td>E</td>
<td>$26,145</td>
<td>$45,155</td>
<td>1.72</td>
<td>($19,010)</td>
</tr>
<tr>
<td>F</td>
<td>$14,109</td>
<td>$31,333</td>
<td>2.22</td>
<td>($17,224)</td>
</tr>
<tr>
<td>H</td>
<td>$1,572</td>
<td>$5,821</td>
<td>3.70</td>
<td>($4,249)</td>
</tr>
</tbody>
</table>

Note. *Column 8 from Table 4.4 above.
4.1.11. Statistical Tests

As previously discussed, predicting the maintenance costs of ADS is a complex process. Are proportionally higher maintenance costs the curse of the small digester operators, or are all digester operators facing operating costs higher than they anticipated, regardless of size? The distribution of the ratio of maintenance variable is normally distributed (p > 0.10, Kolmogorov-Smirnov test) with a mean of 1.753 and a standard deviation of 0.99. The null hypothesis is therefore, “the ratio of actual vs. predicted annual operating costs is equal to 1.”

The first alternative hypothesis is that “the ratio of actual vs. predicted annual operating costs is not equal to 1,” which is tested with a two-tailed t-test. As the cross-tabulated data (Table 4.6) suggests that the actual costs are greater than what is predicted for several of the farms, the analysis also included a one-tailed t-test to gain statistical power.

Table 4.6: Cross tabulation of Maintenance Ratio by Two Size Groups

<table>
<thead>
<tr>
<th>Maintenance Ratio</th>
<th>≤ 500</th>
<th>&gt; 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.91</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0.80</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1.68</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1.23</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1.72</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2.22</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3.70</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

This preliminary analysis indicates that predicting annual maintenance, repairs, and labor costs as a function of 3.5% of total kWh production is accurate
for digesters on farms with more than 500 cows as these ratios were generally
closer to 1, a perfect ratio. However, this method under predicts maintenance
costs for smaller farms. For smaller farms, the mean ratio was 2.55, meaning that
actual costs were on average 2.5 times as much as would be predicted with a
standard deviation of 1.03. This distribution of data is described with the second
alternative hypothesis “the ratio of actual vs. predicted annual operating costs is
greater than 1.” These hypotheses are restated in equation form below.

\[
H_0 = \frac{\text{actual costs}}{\text{predicted costs}} = \text{Maintenance Ratio} = 1
\]

\[
two - tailed \ test: H_{A1} = \text{Maintenance Ratio} \neq 1
\]

\[
one - tailed \ test: H_{A2} = \text{Maintenance Ratio} > 1
\]

Table 4.7 provides the summary of the above discussed t-test. For the
two-tailed test, the mean of the ratio of maintenance costs is not significantly
different from 1. However, the one-tailed test is a way of “focusing on one
direction;” a test of whether or not the maintenance costs tend to be under-
predicted is significant at \( p = 0.046 \). The analysis provides a 95% confidence
interval of the difference between means.

The interpretation that can be drawn from the confidence interval is that
to be 90% sure against a type I error (the incorrect rejection of a true null
hypothesis or a "false positive"), the confidence bounds includes the test statistic
of 1. The true mean ratio could be between 1.84 and 3.68.

Table 4.7: T-test Analysis of Null Hypothesis: Maintenance Ratio = 1

One-Sample Test, n=7
1.12. Working Group

On April 2, 2015, the public service board accepted the digester working group’s recommendation to establish two standard-offer prices for farm methane projects, to be differentiated by the installed capacity of the digester (Vermont Public Service Board, 2015). The threshold installed capacity is 150 kW; farms that install ADS of less than 150 kW will be offered a higher standard-offer rate of $0.199 per kWh, compared with an avoided cost of $0.145 per kWh for farm

<table>
<thead>
<tr>
<th>Test Value = 1</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance Ratio</td>
<td>2.005</td>
<td>6</td>
<td>Sig. (2-tailed)(^a) &amp; (1-tailed)(^b)</td>
</tr>
<tr>
<td>(t)</td>
<td>Df</td>
<td>(</td>
<td>t</td>
</tr>
<tr>
<td>a) (p &gt;</td>
<td>t</td>
<td>)</td>
<td></td>
</tr>
</tbody>
</table>

Note. * denotes significant p-value at (p = 0.10) level.

The analysis of variance (summarized in Table 4.8) compared the maintenance ratios within and between herd size groups of > 500 cows vs. ≤ 500 cows. While the ratio within larger and smaller herd size does not vary significantly within either group, the maintenance ratio varies significantly between groups, (F = 6.453, p = 0.052).

Table 4.8: Summary of ANOVA test

<table>
<thead>
<tr>
<th>ANOVA Ratio Maintenance, n=7</th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Herd Size Groups</td>
<td>3.337</td>
<td>1</td>
<td>3.337</td>
<td>6.453</td>
<td>0.052</td>
</tr>
<tr>
<td>Within Herd Size Groups</td>
<td>2.585</td>
<td>5</td>
<td>0.517</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5.922</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
methane projects with a nameplate capacity greater than 150 kW. The board states explicitly that while prices are based on efficiently sized and located projects to ensure that the incentives do not outweigh the risks, and that higher prices for smaller projects requires consumers to pay more without acquiring more watts of renewable energy, they deemed that a higher price for smaller farms was appropriate. The concept of avoided cost is based on the marginal cost for a public utility to produce one more unit of power. Because qualifying facilities such as farm scale ADS reduce the utility's need to produce this additional power themselves from a nonrenewable source, the price that utilities pay for ADS power has been set to the avoided, or marginal, cost. Since many of the farms that could possibly host a larger 300-kW project are already participating in the standard offer program, the establishment of a second price for smaller farms will allow a larger portion of Vermont dairy farms to participate.

**Conclusions**

Maintenance costs are a significant factor in the profitability of all ADS in Vermont. They eat away at profit margins, and at a larger percent of the profit margins of smaller-size digester systems (~50%) compared with larger systems (~20%). A key contributor to high maintenance costs and high variability is the presence of hydrogen sulfide gas, which is corrosive to metal components of the system.
Many of Vermont’s farmers are willing to innovate, but as responsible business owners need economic assurance to do so. As stated by one farmer in the sample, “I want to be at the forefront of the followers.”

The state of Vermont is willing to provide additional economic certainty for farmers considering a small-scale farm methane project, by setting a higher price for projects with an installed capacity of 150 kW or less. The 150 kW engine has been successfully implemented on dairy farms with 500 cows providing input, so this new offer will benefit Vermont’s smaller farms with fewer than 500 cows.

The analysis concludes that this higher rate is necessary for these small scale farm methane projects to be viable, as their maintenance costs are empirically more than 3.5% of the total kWh produced. This study found that for farms with fewer than 500 cows, operating costs were better estimated at 12% of the total kW produced.

With a higher feed-in tariff for small farm-scale digesters and a clearer prediction of annual maintenance costs, the state of Vermont will likely continue to see these projects benefitting small-scale farmers. Further research is needed as to the potential for biogas refinement to renewable natural gas, which will remove the initial costs of grid interconnection, but add additional costs for advanced scrubbing technology. Another expected change is increased biogas output from additional organic residuals from Vermont’s institutions. These organic residuals must be diverted from landfills by VT Act 148, and as ADS
operators and composters start to process more off farm inputs, a market will form for these materials formerly treated as waste.
Chapter 5: Overall Conclusions and Recommendations

This chapter presents a summary of the thesis, highlights the major conclusions drawn from the empirical results of each component article, and closes with a discussion about the limitations of this research and recommendations for future research.

Summary of the Thesis

Dairy farms are an important part of community social and economic capital in historically milk-producing areas of the United States, including Vermont and Maine. The intellectual and conceptual framework of Agriculture of the Middle presents a pathway for understanding the needs of farms “in the middle”: those with a structure too large for a great deal of direct marketing but too small and unable or unwilling to expand to benefit from the efficiencies of scale. The framework assumes that these dairy farms are very important for Vermont’s rural communities, and that action should be taken to support their economic viability. These farms face economic pressures to remain nationally competitive with the large dairy operations emerging in the Western states, and are turning to farm diversification to do so. Of all of the ways that farms find to diversify their revenues, this thesis has focused on the profitability of two distinct economic strategies utilized by all scales of Vermont farms, from 19 cows to 1,700 cows. The farms in this study have either transitioned to organic production or installed a farm-scale ADS, motivated to increase the viability of their dairy farm businesses with income diversification from farm activities.
The first article uses survey data to identify management practices, demographics and financial information for 183 Vermont and Maine organic farmers to determine factors of profitability. The second article analyzes the operating costs and benefit considerations of a sample of Vermont’s farm-scale ADS, for the purposes of contributing to the informed decision-making ability of farmers, ADS engineers and equipment vendors, and policy-makers. The researchers involved in this thesis informed a state conversation to set a higher standard-offer price for small scale farm digester operators.

**Major Conclusions**

This section addresses the major conclusions from the empirical results presented in the two component articles.

1. Are these two revenue diversification strategies and supporting public policies appropriate for the dairy farms of our region?

   Both organic production and ADS have been successful means of maintaining current farm structure and staying profitable for the majority of the farms that have implemented them. Of the organic farmers in our sample, 75.9% reported that they were satisfied or very satisfied with their decision to transition to organic. Several gave testimony that organic production had allowed them to maintain a small herd with limited land, and to keep the farm sustainable for the next generation.

   For the digester operators, 83% indicated that they were satisfied or very satisfied with their decision to install ADS. The farmers indicated that they had
chosen ADS to be more vertically integrated in providing their own farm
electricity, heating, and cow bedding, which allowed them to be more financially
independent.

Both ADS and organic production provide farmers with a stable form of
cash flow, to augment or replace the unstable conventional milk prices.

2. What is the profile of the organic dairy industry in Vermont and Maine?

Organic dairy farmers have had a lifetime of dairy farming, as 77.1% had
one or more principal operator who had grown up on a dairy farm. Of the 42
farms who reported an off-farm income, the majority (57.1%) stated that this
income earned from an outside employer was less important than income from the
farm. There was no significant difference in profitability for farms reporting an
off-farm income.

The majority (68.7%) of the sample has health insurance; 41% are
insured through the farm business, 16.9% are insured through an off-farm
employer, and 10.8% have other health insurance. No farmer offered health
insurance to non-family employees.

The average farm was established in 1965, and the average principal
operator had 19.51 years’ tenure. For all reported principal operators (n=132), the
average age is 48.78 (the ages range from 20 through 74). The average number of
years in formal schooling is 13.48, with 14% having an associate’s degree, and
22.6% having a bachelor degree.
The primary operators work long hours, on average 71.3 hours per week. The average number of labor hours devoted per milking was two hours. Although these are family-operated farms, farmers structure their business most frequently as a Sole Proprietorship (85.5%), with LLC or family partnerships accounting for the other business structure types.

The majority (84.3%) use artificial insemination (AI); all other management practices measured in the survey were used by 51.8% of the respondents or fewer. Technologies such as feed mixing machinery are not commonly used by smaller scale operations and farms with stanchion/tie stalls where cows receive individualized rations. The majority (75.6%) of operations use a stanchion/tie milking system with a pipeline, and a stanchion/tie/comfort stall for a herd housing (70.7%). As with conventional dairy farms, milking parlors are most often found on farms with more cows. The majority of organic dairy farmers (61.5%) move cows to new pasture daily, and 39.8% move the cows to new pasture twice per day.

The most important income source is from the sale of milk (88.7% of total revenue). The greatest expenses are purchased feed (on average $1,171.75 per cow per year). The average farm return on assets is 2.39%, indicating that organic farms are, on average, profitable throughout the survey period.

3. What are the key factors of profitability on organic dairy farms in Vermont and Maine?
The majority (70%) of organic dairy farms have a positive return on assets. This means that the farms in the sample were able to have fewer than 200 head and maintain profitability with meticulous farm management. Even as farms face pressure to expand, the majority are profitable at their current scale.

Though organic farmers have transitioned to a production system for which it is possible to be small and profitable, these farmers still face incentives to increase the number of cows in production, to increase milk production per cow, and to vertically integrate more of their supply chain of feed and capital to maintain profitability. In this way, organic farmers face similar pressures as before the transition to organic production. The farms that increase in size are able to afford the technologies that appear to have the greatest returns on investment, such as total feed mixing machinery.

The farms that have herds primarily comprised of Holstein cows are the most profitable in the sample. Organic dairy farmers often utilize other breeds of cow to increase the butterfat and protein content in their milk. This indicates that the profits from higher quantity of commodity milk produced outweigh the butterfat and protein quality bonuses.

The profitability of organic farms is explained much more strongly by the farm-family childhood of a principal operator than by the level of education that operators attained, or the number of years’ tenure that they achieved as farm manager. From this, the researchers conclude that family farms and succession
planning are important for the continued success of the region’s organic dairy sector.

Farm management decisions and farmer demographics are not the only factor of profitability. Farmers face significant exogenous factors beyond their control every year with weather, milk and feed prices, and herd health. The average ROA of farms in the sample decreased throughout the course of the survey period, indicating that organic marketing may not continue to be a clear path to profitability for small dairy farms. Organic production has helped many of Vermont and Maine’s small farmers stay in business, but rising feed prices could easily begin to outweigh the higher milk prices and leave these farmers back where they started; managing an unprofitable business.

4. How accurate are industry predictions regarding the maintenance costs of anaerobic digester technology, and how do these maintenance costs impact the technology as a viable business strategy for Vermont-scale dairies?

The annual operating costs of labor, repairs, and replacements can be predicted for ADS operating on farms with more than 500 cows providing the input manure. The evidence from this analysis shows that farmers on larger operations can use the 3.5% of kWh electricity produced to reasonably predict the approximate annual maintenance costs of an ADS. However, for ADS operating on farms with fewer than 500 cows providing the input manure, this method of estimating annual maintenance costs will likely under-predict the true annual costs. To support small-scale farm digester operators, the evidence provided by
this on-going research helped shape recommendations to the Vermont Public Service Board to establish two standard-offer prices for farm methane projects differentiated by projects with a nameplate capacity greater than 150 kW and projects with a nameplate capacity less than or equal to 150 kW. Further research is needed to continue monitoring the annual maintenance and repairs for all sizes of ADS.

Limitations and Recommendations for Future Research

Similar to many other studies of social science and economics, there are limitations of this research. This section presents major limitations, explanations, and recommendations for future research.

First, both articles present information from a sample drawn from a known small population of either Vermont or Maine organic dairy farmers (approximately 260 farmers), or Vermont farm-scale digester operators (16 farmers). To tolerate a margin of error of 5% or a confidence level of 95% in these circumstances, the analysis should have information from more than a third of the population (Norušis, 2010). However, given the limited research on both topics to date, these studies provide valuable information for researchers, farmers, policy-makers, and other interested parties. While the research team had a great relationship with the farmers, more surveys and interviews might have been attained with shorter targeted survey and interview tools. Future researchers may decide to truncate these investigative tools to focus on one particular attribute of organic farming or ADS. It should be noted, however, that by limiting a survey or
interview tool, the researcher risks missing important information because a question was never asked, leading to model under-specification.

This research has shown that many profitable organic farmers learned relevant skills and lifestyle from a childhood spent on a dairy farm. This finding presents many new questions about how to best support first generation dairy farmers and ensure that multi-generational farms have viable business succession plans in place. For the organic farmers that are not profitable, to what degree would procedures and improvements that reduce herd death improve their profitability picture? Alternatively, does the problem have more to do with lack of access to land or an unbalanced debt to asset ratio?

The farm-scale digester analysis has shown that repairing and maintaining the engine to generate electricity is a considerable cost for any scale of digester. This outcome introduces questions about whether digester operators could reduce maintenance costs by scrubbing the methane for impurities for use as renewable natural gas to power farm machinery or milk hauling trucks.

Aside from organic or biogas production, what are the factors of profitability for other business strategies available to support small and mid-size dairies, and how many dairies are currently utilizing these strategies? For example, what influences the profitability of robotic milking machines or on-farm production of artisanal cheese? The investigation of these questions will continue to advance successful diversification and specialization strategies for dairy businesses.
Comprehensive Bibliography


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# APPENDIX A: Organic Dairy Survey Instrument

**SURVEY of VERMONT ORGANIC DAIRY FARM OPERATORS 2011 TAX YEAR**

## PART 1: OPERATOR/OWNER PROFILE

(If nothing has changed check here and we will update from last year’s answers  

<table>
<thead>
<tr>
<th></th>
<th>Person 1</th>
<th>Person 2</th>
<th>Person 3</th>
<th>Person 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Did you grow up on a farm (Yes or No)?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. If yes to Q1, is this the same farm you are currently operating Yes or No)?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. If yes to Q2, what <strong>year</strong> did your family establish this farm?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. How many <strong>years</strong> have you been a primary operator/manager on this farm?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Did you farm anywhere else before operating this farm (Yes or No)?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. What is your current age?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. What is your sex?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. For how many <strong>years</strong> did you attend formal school? (<strong>Indicate number of years.</strong>) (FOR EXAMPLE: 11= junior year in high school; 12= High school diploma; 14= Associate degree; 16= Bachelor’s degree; 18= Master’s degree)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## PART 2: FARM DESCRIPTION

9. Please indicate the legal business structure of your operation. *(Check one box.)*
   - a. Sole Proprietorship
   - b. LLC, S-Corporation or C-Corporation, Limited Partnership
   - c. Non-family partnership
   - d. Family partnership

9A. If the operation is a family partnership, how many families share the income from this farm? *(Indicate number of families)*
   ____________ Families

10. From January 1, 2011 to December 31, 2011, how many pounds of milk did you ship from this farm? *(Indicate total amount of milk shipped for 2011)*
    ____________ lbs.

11. Who do you sell your milk to? *(Indicate name of organization, firm or company.)*

________________________
12. What was your base milk price in Jan 2011?
   $_____/cwt.

13. Did your contract (base) price or MAP change during 2011?
   No
   Yes

   13A. If yes, what month(s) did the price change and with is the new contract price?
   __________________________________________________________

14. What year did you begin your transition to organic?
   ________

15. Do you currently use any of the following milking practices, management techniques or production technologies on your dairy farm? (Check one box per question.)

   YES       NO
   ☐ ☐ a. Balance feed rations at least 4 times per year?
   ☐ ☐ b. Use total mix ration (TMR) machinery?
   ☐ ☐ c. Use a seasonal milking program (2-3 months when all cows are dry)?
   ☐ ☐ d. Use DHIA
   ☐ ☐ e. Use a PC computer based herd management software
   ☐ ☐ f. Use a PC computer for farm records
   ☐ ☐ g. Use AI Breeding
   ☐ ☐ h. Use a Quarter milker

16. Which system best describes your milking system? (Check one box.)

   ☐ a. Stanchion or tie stall barn with dumping transfer station
   ☐ b. Stanchion or tie stall barn with pipeline transfer
   ☐ c. Herringbone parlor
   ☐ d. Side-open stalls (tandem or diagonal) parlor
   ☐ e. Rotary parlor
   ☐ f. Parallel parlor
   ☐ g. Flat parlor
   ☐ h. Other (describe)____________________________

17. How many milking stalls are in your dairy barn? (Indicate maximum capacity.)
   ________Stalls
18. Which system best describes how you house your milking cows dairy herd? (Check one box.)

- [ ] a. Loose housing
- [ ] b. Stanchion, tie or comfort stall
- [ ] c. Cold covered free stall
- [ ] d. Warm enclosed free stall
- [ ] e. Other (describe)______________________

19. How many people typically help with milking your herd at one time, and how many hours does it take to milk your herd? (Indicate number of people and hours per milking)

______ Milkers and Helpers

______ Hours per milking

______ = Total Labor hours per Milking

Check: Multiply the number of people milking by the hours. Does this represent the TOTAL amount of labor per milking?

20. Please check yes or no whether your farm buildings include the following.  (If nothing has changed check here and we will update from last year’s answers)

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>
|     |    | a. Dairy barn
|     |    | b. Separate milking parlor
|     |    | c. Separate hospital barn
|     |    | d. Separate maternity barn.
|     |    | e. Separate heifer barn
|     |    | f. Hutches or super-hutches
|     |    | g. Equipment shed/barn
|     |    | h. Machine/repair shop
|     |    | i. Tower silos
|     |    | j. Bunker silos/trenches
|     |    | k. Housing for hired help

21. Please check yes or no whether your farm equipment includes the following. Check “yes” if the equipment works and is used on a regular basis for your farm. (If nothing has changed check here and we will update from last year’s answers)

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>
|     |    | a. Generator
|     |    | b. Tillage equipment
|     |    | c. Seeder (drill or no-till)
|     |    | d. Lime or applicator for organic fertilizer/
|     |    | e. Combine
|     |    | f. Forage harvester
|     |    | g. Mower/conditioner
|     |    | h. Baler
|     |    | i. Manure spreader

100
PART 3: LIVESTOCK HOLDINGS AND HUSBANDRY

22. Where did you purchase most of your medicines/treatments for your dairy herd?
   (Check the box of the source used most frequently.)
   a. Route truck
   b. Mail order through catalog
   c. Mail order through internet
   d. Feed or Farm store
   e. Veterinarian
   f. Other (describe)_____________________

23. Approximately how many veterinary visits were made to your farm in 2011?
   ______ a. Regularly scheduled visits
   ______ b. Emergency visits

24. On average, how many weeks do you feed calves milk before weaning? ____ weeks

25. Approximately how much milk do you feed your calves PER DAY before weaning?
   _____ (lbs. or gallons)

26. What percentage of your dairy herd (cows, heifers, calves and bulls) are of the following breeds? (Indicate percentage from 0 to 100%)

   % of Herd
   ______% Holstein
   ______% Jersey
   ______% Guernsey
   ______% Brown Swiss
   ______% Ayrshire
   ______% Milking Shorthorn
   ______% Other, including cross-breeds (please indicate breed)
   ______________________breed
   ______________________breed

27. When was the last time you added outside animals to your herd?
   a. Less than 1 year
   b. Less than 5 years
   c. Less than 10 years
   d. More than 10 years

28. Please indicate the reason and the number of milking cows that you culled or sold in 2011:

   Number of cows
   ___ Died or rendered
   ___ Sold to other organic dairy producer/intermediary
   ___ Sold to conventional dairy producer/intermediary
   ___ Poor adaption to organic milk production
   ___ Low milk production
___ Mastitis
___ Breeding problems
___ Other reason (please list)
___ __________________
___ __________________

29. Please rank in order of importance which cow traits are the most important for your
farm (what traits are producers looking for when selecting animals for their herd)

___ Milk production
___ Milk component test values (protein, butterfat, other solids)
___ Ease of handling
___ Ability to produce under grazing management
___ Resistance to mastitis
___ Resistance to illnesses other than mastitis
___ Feet and Legs
___ Other (please specify)

30. If you pre- or post-dip your cows what do you dip them with:

Pre-dip        Post-dip
☐             ☐     Iodine
☐             ☐     Chlorhexidine
☐             ☐     Other

31. What type of towel do you use for wiping cows at milking?
☐ Paper
☐ Individual cloth
☐ Wipeouts
☐ common rag or sponge
☐ none

32. Roughly what percentage of the forage component of your feeding ration (hay,
haylage, silage, greenchop) fed to your dairy herd in 2011 was purchased? (Please
provide your best estimate.)

_______%

33. How often did you move your milking herd to fresh pastures during the grazing
months? (Check one box that best describes your practices.)
☐ a. twice per day
☐ b. every day
☐ c. every 2-3 days
☐ d. every 4-6 days
☐ e. about once per week
☐ f. longer than one week between fresh pastures

34. Approximately what percentage of your milking cows’ forage (on a dry matter basis)
comes from grazing during periods of adequate pasture?

_______%

35. How do you characterize your pasture(s)?
☐ Native seeded
☑ Reseeded in the past five years with __________
☑ Some pastures native, some pastures reseeded in the past five years
      If reseeded, when did you last reseed? (Indicate year) ____________

36. In the past 5 years have you sown any warm season grasses?
☑ No
☑ Yes

37. Did you lime any of your pastures in 2011?
☑ No
☑ Yes

37A. If yes, approximately how many tons per acre? ____ tons/acre over how many acres ____?

38. Do you mechanically apply manure or other approved soil amendments to your pastures in 2011?
☑ No
☑ Yes

38A. If yes, approximately how much was applied: _______ Tons/acre of manure
      _______ Other (list name and amount)

39. Approximately on average how much grain do you feed to your milking dairy cows during the summer and winter? *(Please provide your best estimate.)*
   Summer ______ lbs. of grain per cow per day
   Winter ______ lbs. of grain per cow per day

PART 4: EMPLOYMENT AND LABOR USE
40. How important to your family is income earned from off-farm sources? (Check one box.)
   ☑ a. More important than farm income (greater than 50% of total income)
   ☑ b. As important as farm income (about 50% of total income)
   ☑ c. Less important than farm income (between 1 to 50% of total income)
   ☑ d. No off-farm income

41. Do you participate in the Federal crop insurance programs, including CAT, APH, GRP, AGR, GRIP, CRC, IP or RA? *(Check one)*
   ☑ Yes
   ☑ No

42. Do you have health insurance?
   ☑ No
   ☑ Yes

42A. If “YES” to question 42, who provides your health insurance? *(Check one box.)*
   ☑ a. Farm business
43. Do you provide health insurance for your non-family employees?
   □ Yes
   □ No

44. Please indicate which family members, including the owners, contribute labor to your dairy farm operation, the approximate number of hours that they work per week and the form of direct compensation (wage, salary, income share, in-kind) if any. (List the number of hours worked per week per individual, number of weeks worked and whether they were paid using the index 0 to 4 provided in the final column head.)

**FAMILY MEMBERS ONLY**

<table>
<thead>
<tr>
<th>Who? (Use initials for your benefit.)</th>
<th>Estimated average hours of farmwork per week</th>
<th>Number of weeks that the person worked on the dairy farm</th>
<th>How were they paid?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 = not paid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 = hourly wages</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 = salary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 = draw/income share</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 = in kind</td>
</tr>
</tbody>
</table>

1.

2.

3.

4.

5.

45. Please indicate the number of hours, the number of weeks, and payment for hired non-family labor used on this dairy farm operation. (List the number of hours worked per week per individual, number of weeks worked and whether they were paid using the index 0 to 4 provided in the final column head.)

**HIRED WORKERS ONLY**

<table>
<thead>
<tr>
<th>Who? (Use initials for your benefit.)</th>
<th>Estimated average hours of farmwork per week</th>
<th>Number of weeks that the person worked on the dairy farm</th>
<th>How were they paid?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 = not paid</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>1 = hourly wages</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2 = salary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 = share of income</td>
</tr>
</tbody>
</table>
CROP PRODUCTION AND FEEDING PRACTICES

46. How many acres did your farm business own or operate as part of the farm operation in 2011? (Please divide between owned and rented/leased. In column A, indicate the total owned acreage for each category. If you rented or leased land to another farmer, please indicate the number of acres in column B. These acres should already be counted in column A. If you rented/leased land from another farmer indicate the acreage in column C. Include even those that you did not have to pay rent in column C. If you bought or sold land in 2011, please give the average for the year.)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Acres OWNED by the farm (include those that you lease/rent out to others)</td>
<td>Owned acres but leased/rented to another farmer</td>
<td>Owned by someone else but LEASED, RENTED, or used at NO COST by your farm</td>
</tr>
<tr>
<td>Tillable crop land (included land that was grazed with crops in place)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permanent Hay Field</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All other (buildings, barnyard, wasteland etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please total your column to check your answer.
47. If you grew crops in 2011, how many acres of the following crops did you grow, what was the average yield (at storage moisture level), and what percent of the production was consumed on the farm or stored for feeding in 2011? *(Indicate the number of acres, the average yield per acre, and the unit used to measure the yield, for example tons, bushels, cwt, large round bales, square bales etc. Also, how much of this production was used on farm for your herd? Please indicate other crops in the last 3 rows of the table.)*

<table>
<thead>
<tr>
<th>CROP</th>
<th>Acres</th>
<th>Average Yield/acre</th>
<th>Unit</th>
<th>% Used on Farm for Herd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn for grain or high moisture corn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn for silage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley for grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oats for grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; cutting hay or haylage (clover, alfalfa, Timothy, other legumes, small grains, trefoil, triticale, grass include new seedings)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; cutting hay or haylage (clover, alfalfa, Timothy, other legumes, small grains, trefoil, triticale, grass include new seedings)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; cutting hay or haylage (clover, alfalfa, Timothy, other legumes, small grains, trefoil, triticale, grass include new seedings)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th cutting hay or haylage (clover, alfalfa, Timothy, other legumes, small grains, trefoil, triticale, grass include new seedings)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please describe)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please describe)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please describe)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

48. If you are growing grains, are you considering expansion of that enterprise?
   - [ ] Yes
   - [ ] No

49. If you are not growing grains, are you considering growing grain in the future?
   - [ ] Yes
50. What are your top 2 issues with organic purchased concentrates, beyond the expense?

1) ______________________________________________________________

2) ______________________________________________________________

PART 5. FUTURE OUTLOOK

51. What are your future plans for your dairy farm (Check one box.)?
   □ a. I expect to stop milking in 2011.
   □ b. I expect to stop milking in the next 5 years.
   □ c. I expect to stop milking in the next 5-10 years.
   □ d. I expect to keep milking cows for more than 10 years.

52. As you look ahead to the next 5 years, how likely is it that you will see any of the following changes on your dairy farm? (Check circle the answer that best describes your opinion of each statement.)

<table>
<thead>
<tr>
<th>Change</th>
<th>Very Likely</th>
<th>Likely</th>
<th>Unsure</th>
<th>Unlikely</th>
<th>Very Unlikely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add more cows</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Reduce the number of cows</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Discontinue dairy farming</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Transfer management to another person</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

53. What is the most important reason for your adoption of organic milk production:
   □ Higher profit
   □ Ethical and philosophical
   □ Lifestyle
   □ Environmental
   □ Stable milk prices
   □ Other: ____________

54. How satisfied are you with your decision to switch to organic production:
   □ Very Satisfied
   □ Satisfied
   □ Neutral or unsure
   □ Dissatisfied
   □ Very Dissatisfied

55. What are the top three most challenging production or management activities with organic dairy farming that you wished you’d known about before transitioning or starting your organic farm?
56. Please name 2 items that you were concerned about before you began your transition but did not turn out to be major issues:

1. 

2. 

57. During your time of transition to organic, what were your top 3 sources of assistance and resources (please rank the top 3):

   ____ NOFA-VT
   ____ NRCS
   ____ UVM Extension
   ____ Other farmers
   ____ NODPA News
   ____ Organic magazines
   ____ Grazing magazines
   ____ Websites: (Please list) ____________________________
   ____ Other ____________________________

58. During your time of transition, what turned out to be the 3 most costly areas list any estimate you have of the costs and any comments.

   ____ Grain
   ____ Forage
   ____ Livestock Health
   ____ Buildings
   ____ Purchase livestock
   ____ Fencing for grazing
   ____ Water in pastures
59. Please rank the areas that you could use assistance in right now?
___ Grazing management
___ Animal health
___ Energy Efficiency/Alternative Energy
___ Buildings
___ Ration balancing
___ Locating herd replacements
___ Locating feed sources
___ Other

60. Are you considering going back to conventional milk production?
   ____ Yes
   ____ No

61. Check all that apply to your grain feeding strategies as a result of high feed prices.
   ____ a) feeding less of same ingredients
   ____ b) lower protein
   ____ c) different ingredients
   ____ d) feeding more forage
   ____ e) Other: ___________________________________________________________

Allow the producer to discuss any other issues or information that they would like to share.