# AN ASSESSMENT OF INITIAL EXPERIENCES WITH ANAEROBIC DIGESTERS AMONG WASHINGTON STATE DAIRY FARMERS AND DEVELOPERS

by

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# ABSTRACT

An Assessment of Initial Experiences with Anaerobic Digesters among Washington State Dairy Farmers and Developers

Mitchell Redfern

An increasing focus on anthropogenic greenhouse gas emissions (GHG) has prompted countries around the world to look for ways to reduce their carbon emissions. Anaerobic digesters (ADs) have been shown to be a potential option for generating renewable energy and reduce GHG emissions from livestock operations. Worldwide, it is estimated that livestock production accounts for approximately 18% of global GHG emissions—contributing about 50% of total methane emissions. ADs have also been shown to reduce nutrient runoff from agriculture, reduce odor associated with animal farms, and remove harmful pathogens from animal waste. Washington State has 443 commercial dairy farms with over 250,000 mature dairy cows. Despite the many benefits ADs have to offer, only eight ADs have been developed. There are a number of potential reasons for a lack of AD development including the renewable energy policy framework in place, dairy digester economics, and undeveloped environmental offset markets. There are no known studies that attempt to identify the specific motives, concerns, opinions and experiences of dairy famers and developers who have participated in a dairy digester project. Through interviews with dairy farmers and developers active in the dairy digester industry, this study attempted to address what factors are inhibiting the adoption of AD technology by Washington State dairy farmers. The results of this study suggest that, while many potential answers to this question were identified, the most common answer among interviewees was low and volatile electricity rates. Based on these results and the literature reviewed, this study suggests that a fixed-price, cost-based, technology-specific feed-in tariff policy, similar to Vermont's Sustainably Priced Energy Enterprise Development Program (SPEED), be considered by policy makers for potential application in Washington's renewable energy policy framework.

Table of Contents

List of Figures

List of Tables

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# Introduction

## Historical and Current Uses of Anaerobic Digesters

India is credited with building the first anaerobic digester in 1897, generating biogas from human waste for use in lamps. The first ever successful attempt to produce biogas from animal manure was also in India in 1937 by a microbiologist of the Indian Agricultural Research Institute. Even though India led the way with anaerobic digester technology, China currently has the largest biogas program in the world with over 25 million households relying on biogas from either animal manure or household wastewater for their energy needs. Energy is expensive and in short supply in China, India, and other developing countries. These factors have contributed to the development of millions of small- to large-scale anaerobic digesters since the mid-1900s to supplement these countries' energy needs (Abbasi, Tauseef, & Abbasi, 2012).

European and other Western nations however just recently started looking at anaerobic digestion as a means of producing renewable energy as part of their efforts to combat climate change and many other environmental problems associated with waste. Since then, there has been exponential growth in both interest in and use of ADs, most notably in Germany (Abbasi et al., 2012). ADs primarily have been used in European and other Western nations either in wastewater treatment plants, landfills, municipal solid waste facilities, or in livestock production. Up until now the most common use of biogas from anaerobic digestion in these countries has been for electricity production from agricultural operations. Despite the exponential growth of anaerobic digestion worldwide, the United States has been relatively slow to adopt AD technology compared with other agriculturally industrious Western nations (Figure 1).

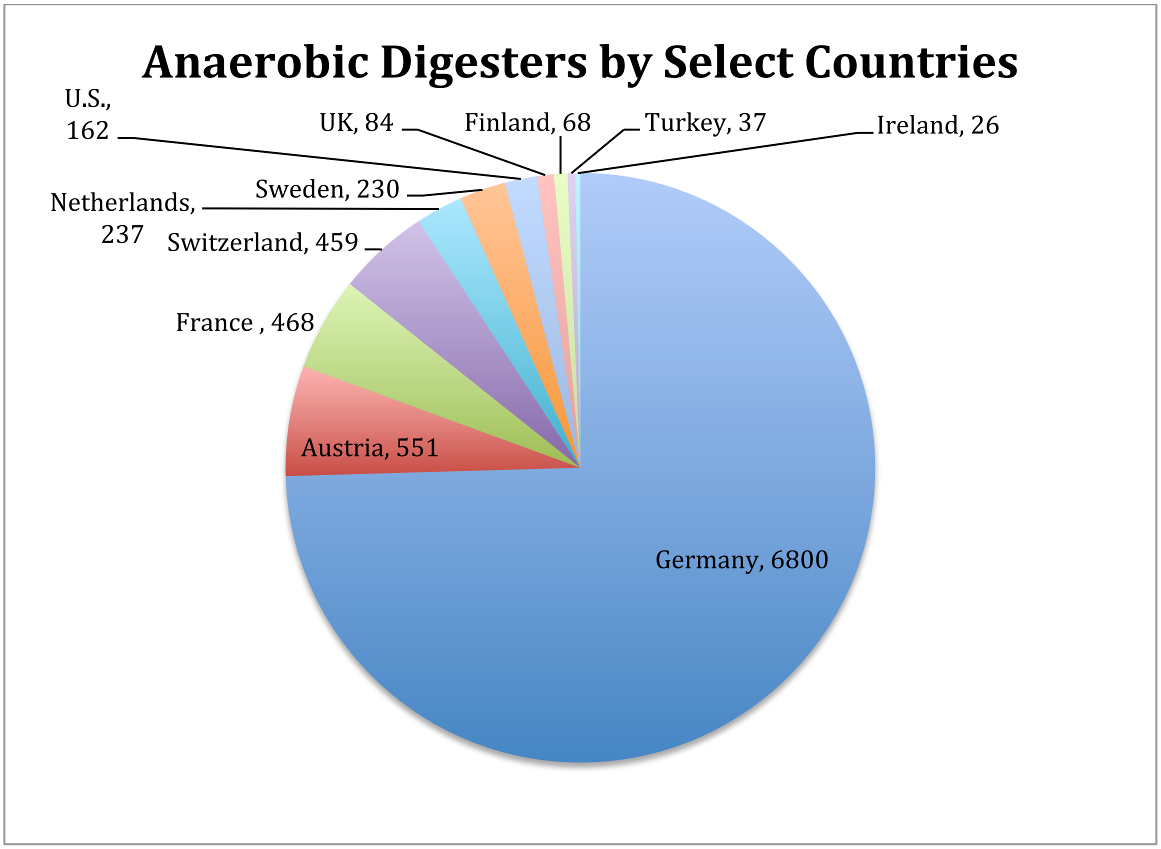


**Figure 1. Total number of operating agricultural anaerobic digesters as of April 2011 (Center for Climate and Energy Solutions, 2011)**

**Anaerobic Digesters as a Potential Solution**

Anaerobic digestion is the process by which microorganisms break down organic material in the absence of oxygen. ADs are units that contain a multitude of different organic materials and essentially trap the gas (biogas) that is released from the digested material which otherwise would have been emitted into the atmosphere. ADs come in a variety of shapes and sizes to accommodate a variety of uses, feedstock, and geographical regions. Digesters are designed for a number of different feedstocks, which will produce a variety of different outputs as shown below in Figure 2. The burning of biogas through a generator to produce renewable electricity is currently the most common use for biogas in the U.S. There are a number of environmental benefits from AD application on dairy farms including reducing GHG emissions, reducing nutrient runoff, and pathogen removal.

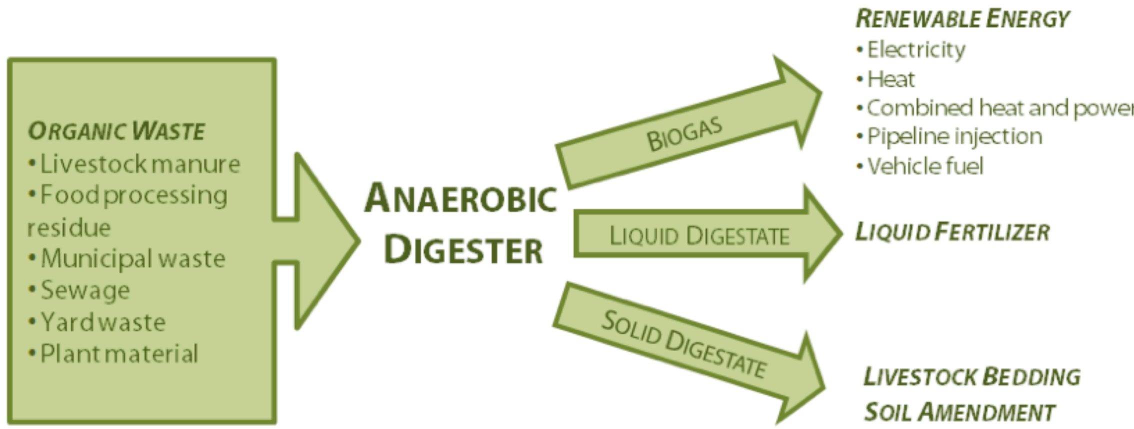


**Figure 2. Some common inputs and outputs of anaerobic digesters (Weisberg & Roth, 2011)**

A recent article published on the credibility of climate change found that 97–98% of climate researchers actively publishing in the field believe climate change is caused by anthropogenic activities (Anderegg, Prall, Harold, & Schneider, 2009). Worldwide it is estimated that livestock production accounts for approximately 18% of global GHG emissions—contributing about 50% of total methane ($CH_4$) emissions (Kebreab, Clark, Wagner-Riddle, & France, 2006). Methane, a GHG with a warming potential 21 times greater than carbon dioxide ($CO_2$) is emitted form traditional open-manure lagoons straight into the atmosphere (Gloy, 2011). The EPA estimates 62% of methane emissions from dairy farms could potentially be eliminated through application of AD systems. Dairy digesters essentially trap the biogas released from cow manure before it is emitted into the atmosphere (Figure 3). There have been eight ADs developed in the last ten years in Washington State which process manure from approximately 14,000 dairy cows. With over 250,000 dairy cows in Washington State, application of ADs on dairy farms show a lot of potential for reducing GHG emissions.

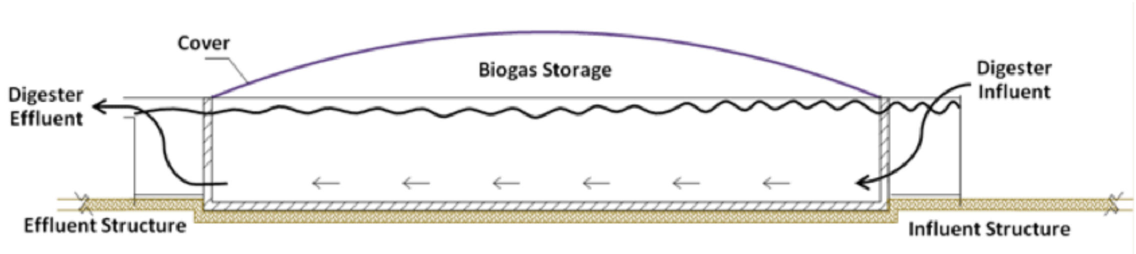


**Figure 3. Typical plug-flow digester (http://www.epa.gov/agstar)**

Commercial dairy farms produce large amounts of waste in a relatively small area. A dairy cow produces between 110 and 120 pounds of nitrogenous manure a day, 300–400 pounds for lactating dairy cows (EPA, 2012b). On commercial dairy farms manure is held in lagoons and then land applied to crops as fertilizer. Animal waste applied to land can contaminate ground and surface water leading to eutrophication and human health problems (EPA, 2012b). Additionally, eutrophication of waterways has been shown to lead to highly undesirable changes in ecosystem function and structure in freshwater, marine, and terrestrial systems (Smith, Tilman, & Nekola, 1999). There have also been several studies conducted on fish kills due to nutrient runoff from dairy farms (Massé, Talbot, & Gilbert, 2011). With a trend toward more animals on fewer farms, it is becoming increasingly more difficult to effectively store and manage manure including finding enough land on which it can be applied without risk of polluting (EPA, 2012b).

The nitrogen content of liquid effluent after anaerobic digestion has been shown to have a faster absorption rate by crops, which not only is preferred by farmers but may reduce the amount of nutrient runoff (Benedict & Redfern, 2013). However, the digestion process alone does not reduce the amount of nutrients in the effluent and, with the addition of off-site nutrients added through "tipping fees," there are often more nutrients present in the digested effluent. Consequently, additional steps are needed for removal of these nutrients from AD operations. Nutrient recovery systems are currently being developed which may serve as a method of separating out the nutrients from the effluent and making them available for transfer to agricultural areas deficient in nutrients (Benedict & Redfern, 2013). A system patented by WSU and installed at the Vander Haak Dairy in Whatcom County, Washington has been shown to recover up to 80% of phosphorus and nitrogen from the digested effluent, which the dairy can then sell off the farm as bio-fertilizers (Benedict & Redfern, 2013).

Untreated manure can contain over 150 pathogens or disease causing microorganisms which has been shown to pose health risks to both humans and animals (Saunders, Harrison, Fortuna, Whitefield, & Bary, 2012). A recent study found a correlation between elevated levels of nitrate concentrations in drinking water above the EPA's maximum contaminant level in areas of high dairy farm concentrations in Washington State (EPA, 2012b). Even though most dairies are required to treat their manure under the Dairy Nutrient Management Act, in order to lower the pathogen concentrations (Liu, Shumway, & Collings, 2003), they still pose a threat as many pathogens, including enterococci, *E. coli,* fecal streptococci, and *Salmonella,* have been shown to exhibit regrowth after being land applied. Treatment of manure through anaerobic digestion has been shown to be an effective method of reducing harmful pathogens from the manure (Saunders et al., 2012).

**Study Design**

The present thesis aims to address the question of what factors are inhibiting the adoption of AD technology by Washington State dairy farmers. There is no known study that addresses this question from the views of the farmers and developers who have either developed their own digester or have participated in a dairy digester project. Therefore, this study sought out 16 individuals active in the dairy digester industry for interviews, of which ten agreed. One of the ten interview recordings was lost due to technical problems, resulting in a total of nine interviews transcribed and analyzed for this study. Of the nine interviewees that participated, three were affiliated with a farmer-owned and operated digester, three were affiliated with a developer-owned and operated digester, and three were affiliated with a non-profit partnership owned and operated digester—representing three participants from each dairy digester model currently operating in Washington State. Data were transcribed using Dragon Dictate 3.0 software. Themes were drawn from the transcribed interviews through a multistage data analysis technique obtained from the article "Techniques to Identify Themes" (Ryan & Bernard, 2003).

For the purpose of this thesis, "developer-owned and operated digester" refers to a private, third-party business that partners with dairy farmer(s) to build and operate a dairy digester. The views of the developers in this study are relevant to the current thesis as they represent one of the three business models in the state, work directly with the dairy farmers, operate the day-to-day maintenance, and handle all the financing costs associated with the digesters.

**Intended Outcomes & Contributions**

It is hoped that the results of the present case study will extend what is known about Washington State dairy digester development and may also be transferable to other contexts within the renewable energy disciplines. Furthermore, other professionals interested in the promotion and facilitation of anaerobic digestion technology may find the results of this study of particular interest to their own agendas. The results of this thesis may also be informational for farmers and/or developers who are considering developing or participating in a dairy digester project. Finally, this information may also be useful for policymakers in identifying policies that result in a positive reaction from all three business models.

Through interviews with dairy farmers and developers active in the dairy digester industry, this study attempted to address what factors are inhibiting the adoption of AD technology by Washington State dairy farmers. The results of this study suggest, that while many potential answers to this question were identified, the most common answer among interviewees was low and volatile electricity rates. Based on these results and literature reviewed, this study suggests that a fixed-price, cost-based, technology specific feed-in tariff policy, similar to Vermont's Sustainably Priced Energy Enterprise Development Program (SPEED) be considered by policy makers for potential application in Washington's renewable energy policy framework.

# Literature Review

## Introduction

Research for this study was conducted on renewable energy policy, dairy digester economics, environmental offset markets, and community digesters. There has been a fair amount of literature published in the last decade on renewable energy policies, most notably for feed-in tariffs (FITs) and renewable portfolio standards (RPS), however hybridization between the two policies just recently started to surface. This literature review will discuss the policies that regard the variations of FITs and RPS policies, whether or not they are effective, and how those variations compare to one another.

Multiple feasibility studies have been conducted on dairy digester economics that tend to be site specific, as discussed below. The academic literature on dairy digester economics also tends to be site specific, typically using a specific farm as a "base-digester," and then applying different economic models that use a host of variables, to suggest possible market scenarios. These models tended to be fairly speculative and there is a general lack of consensus among the authors, most of whom point to the problem of insufficient dairy digester data.

As governments have become more aware of climate change they have sought out ways of identifying and quantifying the sinks and sources of greenhouse gas emissions (GHG), and therefore there has been extensive research conducted by government agencies that are made publically available online pertaining to the agriculture sector and GHG emissions. There is also a fair amount of academic literature on the potential carbon offsets of ADs, however most authors note that it is currently difficult to accurately assess how carbon offset markets would affect the dairy digester industry.

Community digesters are generally used in European countries, though there are community digesters in the U.S. Due to the potential of community digesters for reducing risk and fragmenting investment costs, a discussion of their potential is warranted. The few studies that have been published on the subject typically attempt to assess and/or explain the views of farmers about community digesters.

## Policy Framework

One possible reason that the U.S. has been slow to adopt dairy digesters is the renewable energy policy framework in place. There are many different policies around the world that encourage renewable energy development, however, in the last 10 years the feed-in tariff (FIT) and renewable portfolio standards (RPS) approaches have been the most popular policies. There are a variety of different styles and configurations of these policies and it is not uncommon for a government to have both in effect. Descriptions of each of the policies, as well as potential for hybridization of the two policies, are discussed in this section.

### Feed-in tariffs.

FIT policies have been enacted in 63 jurisdictions around the world and are credited to be the driving force behind the success of the renewable energy markets in Europe (Klein et al., 2010). FITs are energy-supply policies that focus on the growth and development of renewable energy generation. While there are several different varieties of FITs in place around the world, the working definition of a "state-level, feed-in tariff" in the U.S according to the National Association of Regulatory Utility Commissioners (NARUC) and the National Renewable Energy Laboratory (NREL) is

> A publicly available, legal document, promulgated by a state utility regulatory commission or through legislation, which obligates an electric distribution utility to purchase electricity from an eligible renewable energy seller at specified prices (set sufficiently high to attract to the state the types and quantities of renewable energy desired by the state) for a specified duration; and which, conversely, entitles the seller to sell to the utility, at those prices for that duration, without the seller needing to obtain additional regulatory permission. (Patel & Reitenbach, 2010)

Simplified, FITs offer a guarantee of payments to a renewable energy (RE) generator per kWh of electricity produced for a guaranteed period of time, typically 15–20 years (Cory, Couture, & Kreycik, 2009). There are two main methodologies for setting the FIT price paid for RE—to base the price on the cost of RE generation, which is termed “cost-based,” or to base the price on the value of that generation to the utility or society, termed “value-based” (Klein et al., 2010). In the first approach, the price is calculated based on the various costs associated with RE generation, including the cost of the plant, licensing and permitting expenses, operation and maintenance costs, fuel costs, inflation, and appropriate profit margins (Klein et al., 2010). Taking into account the costs along with the expected amount of electricity output and lifetime of the project, a fixed price is then calculated for the duration of the contract (Klein et al., 2010). Cost-based FIT policies are the most popular and successful policy choice for spurring rapid RE growth and development, and are also the most common FIT design used in Europe (Couture & Cory, 2009).

FIT payment structure in the cost-based approach varies in two different ways and is generally dependent on whether the renewable energy price is tied to fluctuations in the electrical market or not. If the price for RE is independent of market fluctuations, it is generally called a "fixed-price policy" (Cory et al., 2009) (Figure 4). Fixed-price FIT policies are used in more than 50 countries around the world including Greece, Germany, France, Switzerland and Canada (Couture, Cory, Kreycik, & Willams, 2010).

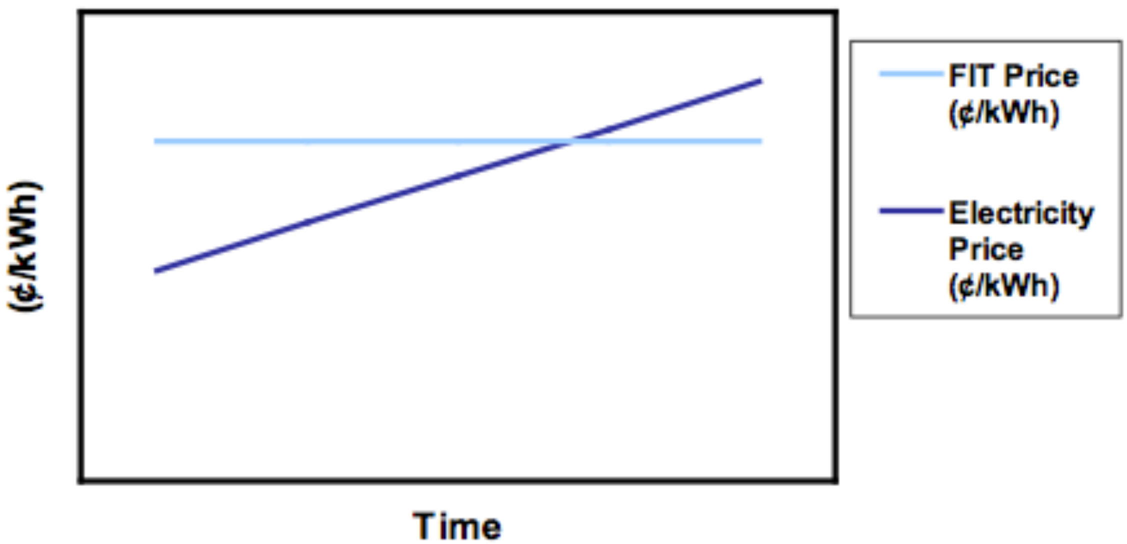


**Figure 4. Fixed-price feed-in tariff policy model over time (Cory et al., 2009)**

As discussed in the literature, potential advantages to this option include easier finance options for RE projects, reduction in contract negotiation costs, creation of more entrepreneur opportunity in the market (Grace, Rickerson, & Corfee, 2008), encouragement for technological innovation, and agreement regarding interconnection costs and access to the grid (Couture et al., 2010). Potential disadvantages of the fixed-price policy option discussed in the literature include upward pressures on electricity prices due to a potential rapid growth of higher cost technologies, discouragement of a competitive atmosphere among developers and engineers (Couture et al., 2010), and potential economic risk transferred from investors to society (Schmalensee, 2011).

The second option in the cost-based scenario is to have a premium price paid for RE and have the price tied to market fluctuations. This policy is often referred to as "premium price" or "above spot-market policies" (Figure 5)(Cory et al., 2009), and the price paid is typically technology-specific (Couture & Cory, 2009). The premium-price FIT policy has been implemented in Spain, the Czech Republic, Estonia, Slovenia, the Netherlands, and Denmark (Couture et al., 2010). One of the main advantages to this policy discussed in the literature is that it provides RE developers with an above market price for a more stable atmosphere for project-financing while still keeping all of the benefits associated with being "market-oriented," like encouraging competition and R&D between producers and developers (Couture et al., 2010). Disadvantages of this type of FIT discussed in the literature include the risk of windfall profits for developers with potential electricity market spikes, and conversely a pressure of project-financing costs in the case of a rapid decline in market prices (Cory et al., 2009).

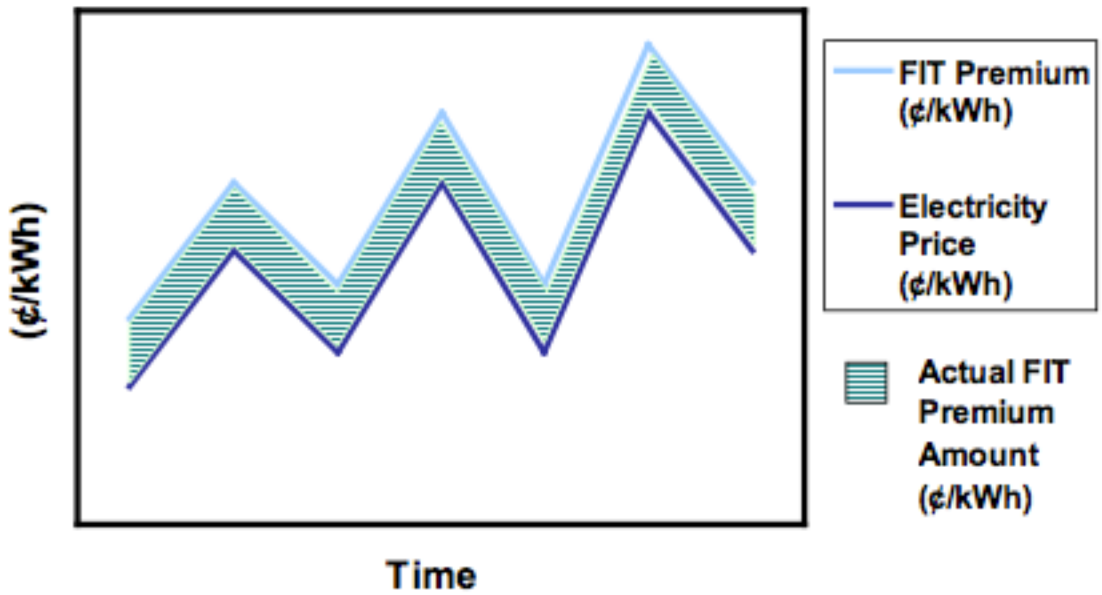


**Figure 5. Premium-price feed-in tariff policy model over time (Cory et al., 2009)**

The second method of calculating the price for RE involves calculating the value of the avoided costs of RE to a society, or the avoided costs to a purchasing utility. There are a number of methods used for calculating these values (Cory et al., 2009). The avoided external costs to a society may include the value of climate change, health damage from air pollutants, agricultural yield loss, and effects on the energy supply security (Klein et al., 2010). There are many environmental and social welfare factors included in this method, and although it has the potential to have positive effects on society and the environment, the tariff itself is currently very difficult to determine and leads to unpredictable prices. Portugal is the only country to fully implement this type of policy (Klein et al., 2010).

Another way of estimating the value of renewable energy is by calculating the utility's avoided costs—the estimated cost of supplying electricity if it were produced by the utility or bought from another electricity generator (Couture & Cory, 2009). The term "avoided costs" refers to the criterion identified under the Public Utilities Regulatory Policies Act of 1978 (PURPA) (Couture & Cory, 2009). PURPA arguably implemented the first FIT policy, as it introduced fixed-prices paid for renewable electricity based on avoided costs (Lipp, 2007); however the act left it up to the individual states to determine what constituted a utility's avoided costs (Rickerson & Grace, 2007). In general, the avoided costs are based on either real-time, or long-term projections of fossil fuel prices (Couture & Cory, 2009). One of the challenges of these value-based policies is that the RE prices based on long-term fossil fuel price projections may not be high enough to make RE projects economically attractive to developers (Cory et al., 2009). Value-based FIT policies are more common in the United States and have so far been unsuccessful in spurring rapid renewable energy growth and development (Cory et al., 2009).

**Renewable portfolio standards.**

The renewable portfolio standard (RPS) is the most common state-level policy in the United States today (Cory et al., 2009). Currently, twenty-nine U.S. states and the District of Columbia have adopted RPS programs in order to promote renewable energy generation, and seven more states have implemented RPS programs with non-binding (i.e., voluntary) goals (Figure 6) (Barbose, 2012).

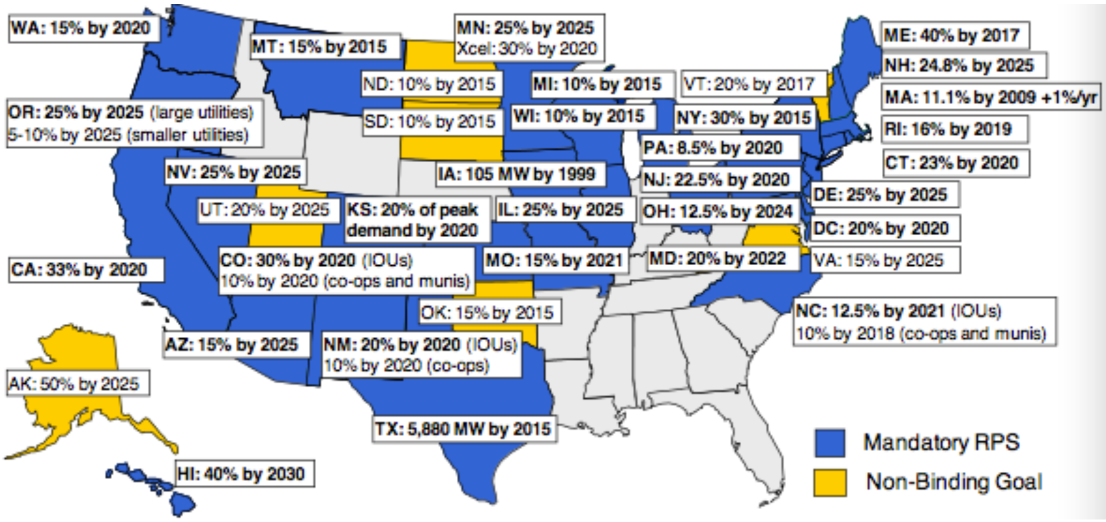


**Figure 6. States with either mandatory or voluntary (non-binding) renewable portfolio policies in place (percent data refers to the quantity of electricity a utility must obtain from renewable energy sources) (Barbose, 2012)**

Even though no two state RPS programs are identical, they generally work by requiring load-serving entities, such as utility companies, to obtain a certain percentage of their electricity from a renewable energy source (Schmalensee, 2011), with most states tracking compliance via renewable energy certificates (RECs), which provide a supplemental revenue stream on top of electricity sales (Wiser & Barbose, 2008). While there are many forms of FIT and RPS policies, the main difference between them is that FIT policies are focused on setting the right price for driving RE development (investor certainty), while RPS policies are focused on the quantity (percentage) that must be met by a utility (state mandated), leaving the price paid for RE up to competitive bidding among RE developers (Cory et al., 2009).

A utility generally complies with filling its RPS mandates by issuing a request for proposal (RFP), a process that creates competitive bidding between renewable energy developers for the contract to supply the requested renewable power. Due to the competitive nature of the bidding process inherent in RPS programs (which some argue is why it is an accepted policy in the U.S. [Laird & Stefes, 2009]), the market decides the source and price of RE (Lipp, 2007). Discussion of this process in the literature suggests that, even though RPS policies in the U.S. have been successful in motivating an estimated 8,900 MW of new non-hydro renewable capacity (Cory et al., 2009), the process largely favors large-scale developers using well established technologies, mainly from wind-farm development (Lipp, 2007)(Figure 7).

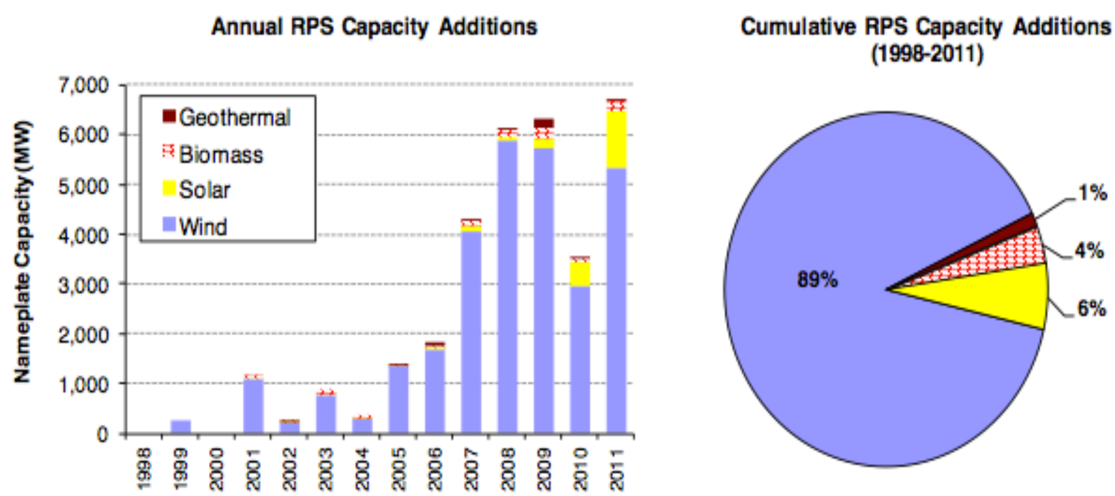


**Figure 7. Non-hydro renewable energy capacity additions by technology type in renewable portfolio standard states (Barbose, 2012)**

One of the main advantages to RPS policies argued in the literature suggests that, due to market competition for RE rates, renewable power is being generated at the lowest possible price, thus employing the least amount of burden on consumers and taxpayers (Lipp, 2007). Disadvantages discussed in the literature are that it inhibits the growth of emerging technologies and does not allow non-traditional developers into the RE market. Also, because of the RFP process, it often excludes small-scale renewable energy developer participation (Lipp, 2007).

### U.S. FIT policies.

States and municipalities have been experimenting with FIT-like policies in the U.S., typically associated with a utility's avoided cost or fixed-price incentives. However, the FIT policies in place in the U.S. differ drastically in scope, size and design from their European counterparts (Couture & Cory, 2009). As of June 2010, three states have enacted policies based on RE project cost; one state based on avoided cost; and representatives in ten states have proposed cost-based FITs (Couture et al., 2010).

### Comparison to European FIT policies.

In 2005, Washington State was one of the first states successful in passing a fixed-price style FIT policy which was targeted for solar PV, solar thermal, wind, and anaerobic digesters (Couture & Cory, 2009). There are three main differences in Washington's FIT policy, as compared to those in Europe. First, Washington utilities are not obligated to participate; second, the policy is financed through a utility tax credit that cannot exceed $100,000 or 0.5% of the utility's taxable power sales; and, third, the incentive is capped at $5,000 per project per year (DSIRE, 2012). There are currently three utility-based FIT policies in place such as the one outlined above and it is argued they fall short of addressing many of the key elements responsible for the success of the European-style FIT policies and therefore have achieved limited success (Couture et al., 2010; Lipp, 2007; Ragwitz et al., 2007).

According to the literature, the two most important reasons why European-style FIT policies work so well for renewable energy growth are that they offer long-term contracts and base the payment levels on the cost of RE generation in ways that are specifically based on technology type, project size, and resource quality (Ragwitz et al., 2007). While some state-FIT policies offer long-term contracts that are technology specific, Maine, Hawaii and Vermont are the only states that have enacted a FIT policy with payments based on the cost of RE generation that takes into account technology type (Couture & Cory, 2009).

Vermont's Sustainably Priced Energy Enterprise Development Program (SPEED) is the most comparable to a European-style FIT policy in the U.S., with prices based on technology, size, and cost of generation plus profit. Profits are set by a reasonable rate of return and project size is limited to 2.2 MW capacity. The SPEED Program also provides long-term contracts, is routinely reviewed, and is funded by ratepayers, not taxpayers as in the Washington system (Gibe, 2009). Additional premiums are paid through a voluntary ratepayer program called Central Vermont Public Service's (CVPS) Cow Power program where customers can choose to pay a premium to support sustainable, renewable, or clean energy. Participants typically pay a $0.04/kWh premium, which transfers directly to the RE producers (Wang, Thompson, Parsons, Rogers, & Dunn, 2011). Many states offer similar green power programs, and consumer support for renewable energy technologies has been established in the literature (Sanders, Roberts, Ernst, & Thraen, 2010). In Washington, Puget Sound Energy's (PSE) Green Power Program asks customers to make a contribution of $4–$12 dollars per month to help PSE purchase power from local renewables. The program currently gets 8% of its power from dairy digesters (Benedict & Redfern, 2013). Vermont has also passed a bill to address the issues pertaining to small-scale renewable participation inherent in the RFP through a new market-based mechanism. The new policy caps RFPs at 5MW capacity each year from 2013-2015, 7.5 MW each year from 2016-2018, and 10 MW each year in 2019 and 2020 (DSIRE, 2012).

**Conclusion**

Well-designed FIT policies that offer fixed-prices calculated to account for the cost of generation—technology specific and coupled with long-term contracts—have been shown to be an effective policy option for spurring small-scale renewable energy projects. The RPS policies used by many U.S. states do not work nearly as effectively for small-scale renewable energy and have many associated complications, including the RFP process of bidding for contracts. Vermont has found a way to incorporate a well-designed FIT policy into its RPS, addressing the issues pertaining to the RFP process.

**Financial Feasibility**

Anaerobic digesters are capital intensive and range in a variety of ways which can make calculating the costs for new digester projects difficult. This in turn makes lenders hesitant, as there are not a lot of dairy digester data available as discussed below. There are a number of different markets and offsets currently available for dairy digester outputs including sales from electricity produced, taking in food-processing waste in the form of tipping fees, and digested fiber offsets. Additionally, there is mention in the literature of non-marketable attributes associated with AD technology, which arguably should be made available for digester owners; they include GHG markets, renewable energy production, and odor control. Dairy digester economics along with potential revenue streams and offsets are discussed below.

**Financing.**

Given the range of herd size, digester models, digester sizes, site location to co-product markets, varying electrical markets and the small number of ADs currently operating in the U.S., there is minimal agreement within the literature as to the appropriate costs associated with AD development and operation (Gloy & Dressler, 2010). For example, previous studies estimated the average capital costs for digesters installed on farms with a given herd size to be $940 per cow for a 1,000 cow-dairy (Enahoro & Gloy 2008); $530 per cow for a 800-cow dairy (Lazerus and Rudstrom 2007 via Gloy, 2011); and $1,608 and $887 per cow for 500-cow and 2,000-cow dairies respectively (Leuer, Hyde, & Richard, 2008).

Similarly, the estimated energy output of dairy digesters ranges from 1,115 kWh per cow per year (Enahoro & Gloy, 2008) to 1,377 kWh per cow per year (Leuer et al., 2008). Gloy & Dressler (2010) point out that there is even less known about the operating costs associated with dairy digesters and how long they are expected to run before costly repairs are needed. Digester projects require a lot of up-front capital investment, usually involving lenders. Uncertainties within the literature and a general lack of data on dairy digester capital costs, energy output, and operational costs may make lenders apprehensive (Gloy & Dressler, 2010). A recent study has attempted to remedy this problem by developing an online workbook that allows a multitude of technical and financial variables to be inputted for assessing the financial feasibility of farm-based anaerobic digesters (Anderson, Hilborn, & Weersink, 2013). The workbook is available at www.bioeconproject.com and the authors note that not only potential investors but also those evaluating renewable energy policy and funding opportunities can use the workbook.

**Power purchase agreements.**

The electricity produced from AD operations is one of its main sources of revenue (Benedict & Redfern, 2013; Binkley, Harsh, Wolf, Safferman, & Kirk, 2013; C. P. Bishop & Shumway, 2009). Generally, in the U.S. there are three revenue options for electricity produced: power purchase agreements (PPAs), net-metering, and renewable energy credits (RECs). A PPA is a contract between the producer and a purchasing utility. The contract is typically for ten to fifteen years with a fixed-price based on the utility's avoided costs. The price paid per kWh in the U.S. is generally region-specific as different regions have different energy resources available. The Pacific Northwest region has particularly low rates for electricity due to relatively inexpensive hydro-electric generation (Bishop & Shumway, 2009). The current retail price for electricity in Washington State is the second lowest in nation at $0.085/kWh (EIA, 2013).

Net metering is another option for small renewables that allows a renewable energy producer to offset electrical consumption and receive credit for electricity generated in excess of what is used on site (Binkley et al., 2013). Because dairy digesters often produce much more electricity than they use on site, they end up either exceeding the net-metering limit on energy production or reducing their engine size to become eligible, resulting in a loss of energy production potential (Binkley et al., 2013). Washington State currently has a 100 kWh system capacity limit—all current operational dairy digesters in the state exceed that limit (DSIRE, 2012a).

Due to the low rates paid for electricity in the Pacific Northwest, complementary revenue streams are needed in order to make ADs economically feasible (Bishop & Shumway, 2009). Figure 9, below, shows the possible digester co-products from dairy digester operations. (Digester co-products that currently have no market or no cost-effective technology are shaded. Waste heat from the generator may have value, depending on proximity to nearby facilities, and is used in various ways around the country but its potential value is site specific [Bishop & Shumway, 2009]).

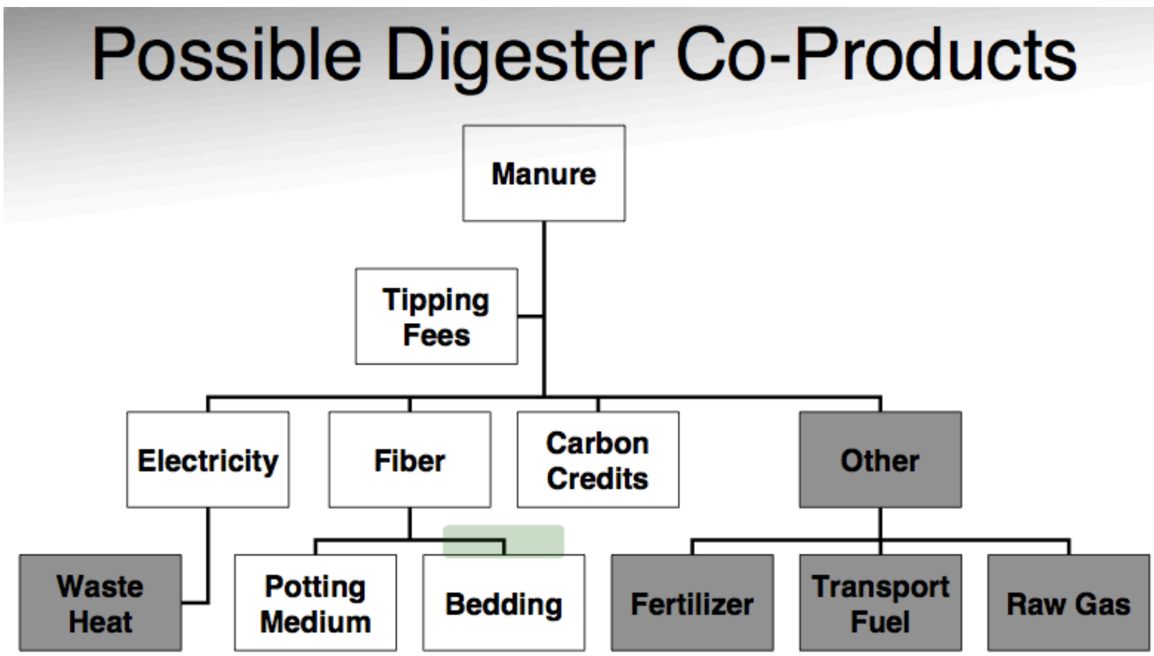


**Figure 8. Possible co-products from dairy digester operations, shaded co-products currently have no market value, except for waste heat on a site-by-site basis (Shumway & Bishop, 2009)**

**Tipping fees.**

Dairy digesters are not limited to just manure; food waste breaks down and releases methane, which can digest alongside the manure inside the digester. Food waste added into digesters is generally post-industrial waste such as trap grease, inedible eggs, cheese whey, and salmon carcasses, and usually has an even higher energy output than manure (Bishop & Shumway, 2009). Instead of the food processors paying waste disposal fees where the waste would end up in a landfill, they pay a digester owner a "tipping fee." Because farmers use the effluent from the digester as fertilizer for their crops, there are concerns about the additional nutrients going into their fields and what that may mean for new rules and regulations pertaining to dairy nutrient management plans (Bishop, Frear, Shumway, & Chen, 2010). There is a suggestion that if new rules and regulations come into effect, unless the farm can effectively utilize or move the additional nutrients off-site, the removal of the accumulated nutrients may be costly (Shumway & Bishop, 2009).

The results of a study conducted on the financial feasibility of an AD under different scenarios of a Washington State dairy farm suggested that establishing a relationship with food processors may be even more important than electrical generation, as the study found the single most important contributor to the digester's net present value to be tipping fees (Bishop & Shumway, 2009). A similar feasibility study in Washington State suggested that digesters located in western Washington are at a significant advantage if they are in close proximity to urban areas abundant with substrates that generate tipping fees (Coppedge et al., 2012a).

**Digested fiber.**

Dairy manure contains fibrous material. Non-AD commercial dairy farm management strategies separate out this raw fibrous material in order to apply the effluent to their feed crops. Separated raw fiber contains a moisture content of 67–75% and has relatively high fecal and pathogen contamination, giving it a fairly low market value.

Fiber separated through an AD can significantly destroy indicator pathogens, remove odor, reduce wastewater contamination, and partially destroy weed seeds. Potential markets for digested fiber that have not fully developed yet include topsoil bedding, nursery greenhouse bulk soil, turf top-dressing, peat replacement, and transportation erosion control. Many industry professionals feel that digested fiber market success is the key to AD adoption on dairy farms (Bishop et al., 2010).

Currently, the most common use for the digested fiber is as bedding for the farm's dairy cows (Shumway & Bishop, 2009). This can be a huge monetary offset, as bedding for a commercial dairy farm can be expensive. Bishop et al. (2009) calculated avoided bedding cost at about $18,000/year for a 500-cow dairy farm. Some of the digested fiber is already being sold to nearby farms as bedding in Washington State (WSDA, 2011)

**Offset Markets & Societal Benefits**

There is mention in the literature that some of the byproducts from digester operations have significant value to society and nearby communities. This literature suggests that, if valued properly, these byproducts could be substantial revenue streams for digesters (Bishop & Shumway, 2009; Gloy, 2011; Gloy & Dressler, 2010). The byproducts discussed in this section are non-marketable or the literature suggests that current U.S. markets significantly undervalue the direct benefits to society. Byproducts discussed in this section include carbon offsets, renewable energy production, and odor control.

**Carbon market.**

A 2009 EPA report found that methane emissions from manure management on dairy farms produced 18.1 million metric tons of carbon dioxide equivalent (Gloy, 2011).

According to Baylis and Paulson (2011), if only the largest 4.5% of the nation's dairy farms (comprising 32% of the nation's dairy herd) applied AD to their farms, about 50% of dairy-associated emissions would be offset. The carbon offsets associated with AD application have the potential for being a major source of revenue for dairy digesters, however the potential for carbon offset revenue relies on there being a functional carbon credit market available.

The U.S. has yet to implement a national cap and trade program and, unlike in countries that ratified the Kyoto Protocol, U.S. states do not have access to world carbon trading markets (Gloy, 2011). The Chicago Climate Exchange, a voluntary carbon market where ADs were eligible for carbon trading, crashed in 2011 due to extremely low carbon pricing. It is suggested that the prices digester owners can receive for their carbon offsets is further reduced by the fees and commissions of large brokerage firms which are usually required for trading (Gloy, 2011). Additionally, the time and efforts required to become certified often outweigh the expected benefits (Gloy & Dressler, 2010). The combination of these factors significantly affects the real value of AD operations on diary farms, and consequently directly affects project financial feasibility.

California is the first and only state to implement a carbon market, and has implemented a carbon cap on GHG emissions (Bosworth, 2013). California's program is second in size only to the European Union's Emissions Trading System of emissions covered (Center for Climate and Energy Solutions, 2012) Whether or not California's program will be successful will have implications for other state and or a national cap and trade programs. At what price would carbon offsets have to be in order to spur AD development and reduce emissions? Gloy (2010) suggests that offset prices of $5.00/ton would result in a 11% methane reduction, $20.00/ton would result in a 60% reduction, and $35/ton would be required to achieve an 80% reduction.

**Renewable energy.**

The renewable electricity an AD produces is easily priced, but the values of offsetting fossil-fuel-based electricity are not. The renewable attributes of renewable electricity are only valuable, in the most practical sense, if willing buyers are found . There are a number of utilities across the U.S. that offer green power programs in which customers can choose to pay a premium for renewable energy, however the customer's willingness to pay is what determines the value of this output (Gloy & Dressler, 2010).

Consumer support for renewable energy has been established in the literature, and there are some recurring results (Sanders et al., 2010). The literature suggests that there are positive correlations between ecological concern, political liberalism, education, income and willingness to pay a premium for renewable energy (Sanders et al., 2010); furthermore, there is a negative correlation between age and willingness to pay (Borches, Duke, & Parsons, 2011; Sanders et al., 2010). Borches et al. (2011) also found that customers prefer solar over wind, and renewable electricity from farm methane was the least preferred. However, Sanders et al. (2010) found that, although most large dairy farms are viewed as fairly negative by their surrounding communities, distinctive groups show strong support for anaerobic digestion, and are willing to pay a premium for the associated benefits.

A study conducted on the Central Vermont Public Service Corporation (CVPS) Cow Power program found that its success was attributed to significant grants from government agencies and other organizations, strong customer support, well managed electricity payments to farms, and cohesive collaboration among involved parties (Wang et al., 2011). The study also suggests that, even though CVPS Cow Power is a successful program, in order to make the ADs financially feasible the program was dependent on the base electricity price, premium rate, government and organizational financial support, and sales from byproducts.

#### Odor control.

Some literature suggests that the odor reduction associated with digester operations should be monetized, however it may prove difficult to value (Gloy & Dressler, 2010). A reduction in odor may change a community's perception of a local dairy, resulting in higher consumer support for green premiums. Widespread education about the societal and community benefits of anaerobic digestion application on dairy farms may help place a value on AD byproducts such as odor control.

### Community Digesters

One potential solution to the high capital costs and risky economics associated with dairy digester development advocated in the literature is community digesters. Community digesters are digesters that receive manure from multiple farms and are often owned by multiple owners, reducing the financial risks and initial costs to individual farmers. The money saved on the investment costs could allow the joint owners the ability to hire a fulltime manager for the digester as well (Gremelspacher, Gillespie, & Welsh, 2010).

There is only one known study that specifically examines the dairy farmer's views on community digesters. Gremelspacher et al., in a preliminary study (2010), interviewed six New York State dairy farmers, of which three expressed opinions on community digesters. The three farmers expressed concern over issues such as a lack of interest from other farmers, being unclear about the transportation and mixing of different manures, and not being sure if they could recoup their investment by getting back their share of manure or income from the electricity sold (Gremelspacher et al., 2010).

In a media article on the issue, suggestions were made by some of the interviewees that the method of transportation to and from the digester from surrounding farms had been an issue for quite some time. It was suggested also that there may be issues regarding the truck noise, potential spills and odors, and that the cost of trucking the manure may not be cost-effective (Linderoth, 2006). A Washington State digester feasibility study found that trucking in manure from a farm one mile away cost more to the digester owner than the value of the additional electricity (Shumway & Bishop, 2009).

Gremelspacher et al., (2010) through mail-out questionnaires to over 400 New York State dairy farmers found that 46.5% of all respondents had heard of community digesters, and 53.5% expressed “some” or “great” interest in them. The study suggested that the income associated with digester operations and odor reductions are more appealing to farmers than the ecological benefits or “public goods” produced by community digester operations. More studies on farmer’s interests on community digesters, as well as studies of the experiences of farmers who have used community digesters are needed in order to accurately assess their potential.

**Current Thesis Objective**

While there has been literature published on the renewable energy policy frameworks, economic feasibility, and environmental benefits pertaining to dairy digesters, there are no known studies that attempt to identify the specific motives, concerns, opinions and experiences of dairy famers and developers who have participated in a dairy digester project. Moreover, because every state has a unique blend of agricultural industry and energy policies, a study conducted within the scope of a given state is warranted in order to fully understand the potentials and limitations of small renewable energy projects. In order to recommend the most effective policy measures needed to spur dairy digester development in Washington State, this study attempts to identify why Washington State dairy farmers have been slow to adopt AD technology from the farmers' and developers' perspective.

Since there are no other studies of this exact nature in publication, methods for this study were replicated from a similar study on New York dairy farmer views on alternative energy production (Gremelspacher et al., 2010). The research was conducted in order to answer questions pertaining to dairy farmers' awareness of AD technology benefits, feelings towards AD, overall farmer interest and the reasons for such interest (Gremelspacher et al., 2010). The study used a multi-methods data collection approach of conducting interviews with farmers who had already adopted the technology. Then, using the foundation of those interviews, draft survey questions were mailed out to the remaining farmers in that county (Gremelspacher et al., 2010). This thesis initially was intended to replicate both methods of data collection, however, due to time constraints, and after careful consideration it was decided that the survey component to the study was beyond the scope and time available for this thesis.

# Methods

## Introduction

This chapter begins with an overview of data collection, interview questions, and study design. Following this are descriptions of the two most common dairy digester designs in Washington State and detailed profiles for each of the digesters, organized by business model. Lastly, methods of data analysis are described.

## Data Collection

As mentioned previously, there are currently eight operational dairy digesters in Washington State. Internet research through media outlets as well as public information from the Washington Department of Agriculture (WSDA), Washington Department of Commerce, and United States Environmental Protection Agency websites were used to identify information about the digester owners, participants and developers associated with them. A request for public disclosure was then submitted to the WSDA Dairy Nutrient Management Plan Program for the contact information for Washington State dairy farms meeting the criterion of having a herd size greater than 200 or more mature cows.

The EPA has determined that, in general, a dairy farm must have a minimum 500-cow herd for AD to be financially viable (EPA, 2012a) however this criterion is for individual farms and does not account for community digester projects where multiple smaller farms are contributing to a central digester. As shown below in Figure 10, Washington State has farms within the 200–499 herd-size range that are contributing to a digester.

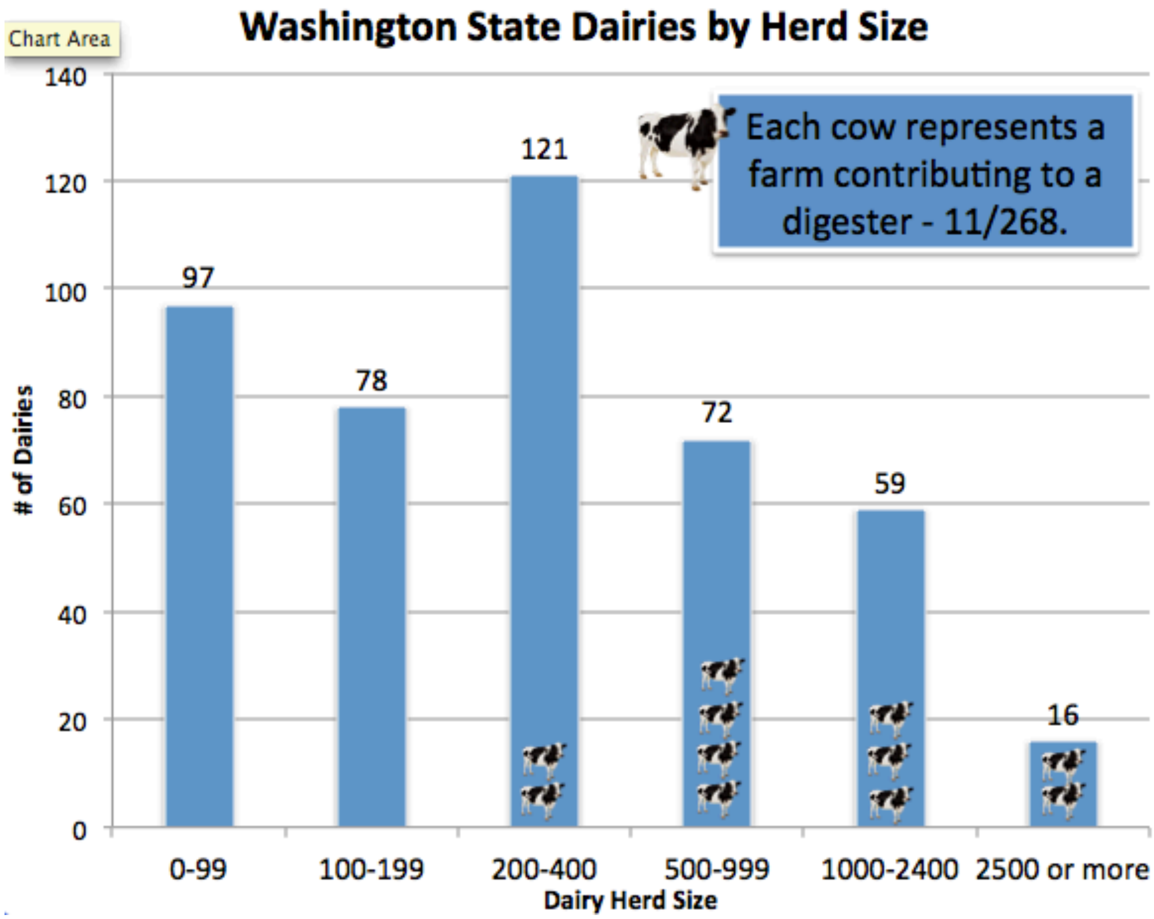


**Figure 9. Washington dairies by size noting dairies contributing to a digester adapted from (WSDA, 2011)**

With the intention of researching farmers' and developers' perspectives about the eight digesters in Washington State, 16 individuals were identified and contacted by phone and/or e-mail because they had either developed their own digester, participated in developing a digester, or were contributing manure to a digester. Ten, out of the 16 individuals contacted, responded. One of the interviews was lost due to technical difficulties and was dismissed, giving the study a total of nine interviewees. Due to the nature of the questions this study is attempting to answer, and because there are relatively few individuals in the targeted population, a qualitative study design was chosen.

Of the nine interviewees that participated in the study, three were affiliated with a farmer-owned and operated digester, three were affiliated with a developer-owned and operated digester, and three were affiliated with a non-profit partnership owned and operated digester, representing three participants from each dairy digester model currently operating in Washington State. A generic set of questions was used, with some questions slightly altered to accommodate different business models and levels of participation as well as different roles within that model[1] (Figure 11).

Questions asked pertained to personal views on motives for becoming active in the industry, financing, environmental offset markets, and the current state and future of the dairy digester industry. Interviews were audio-recorded and were conducted either in person at the digester or over the phone. Interview questions were designed to be open-ended and to cover a wide variety of topics pertaining to experience with dairy digester development, in order to attain a holistic perspective. The dairy digester industry in Washington State contains three distinct and very different business models, and consists of a small community of individuals. Consequently, these individuals could be recognized by the information they shared, so their anonymity was assured throughout the study. Lengths of interviews ranged between 14 and 55 minutes.

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1. Question sets can be found in Appendix A of this document.

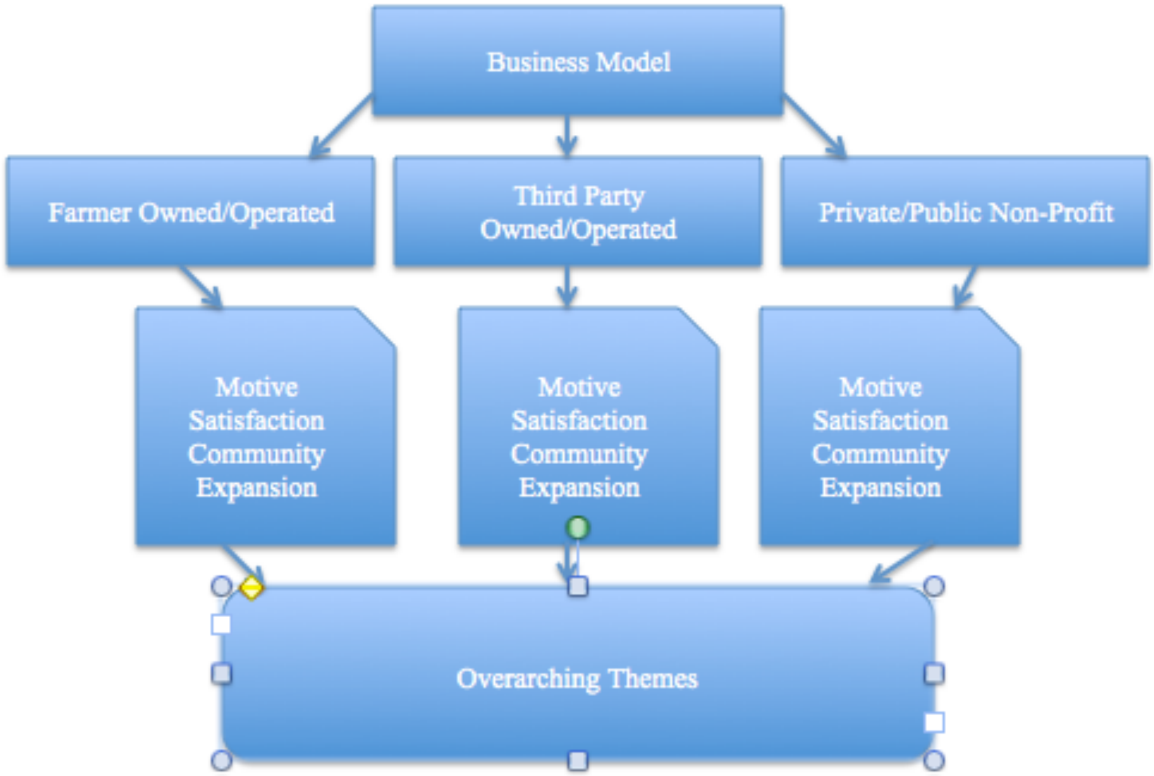


**Figure 10. Study design**

### Dairy Digesters

While there are several different anaerobic digester designs around the world, there are two basic types of ADs used in Washington State to digest manure from dairy farms: the plug-flow digester and the complete-mix digester. A plug-flow digester typically has a long, narrow concrete tank with a flexible cover. This type of design is generally used with dairies that collect manure by "scraping"(EPA, 2012a), however there are exceptions and variations. The tank is built partially or fully below the ground for heat stability, as shown below, in Figure 3. Scraping is typically done with a large chain mechanism that transports manure to the digester.

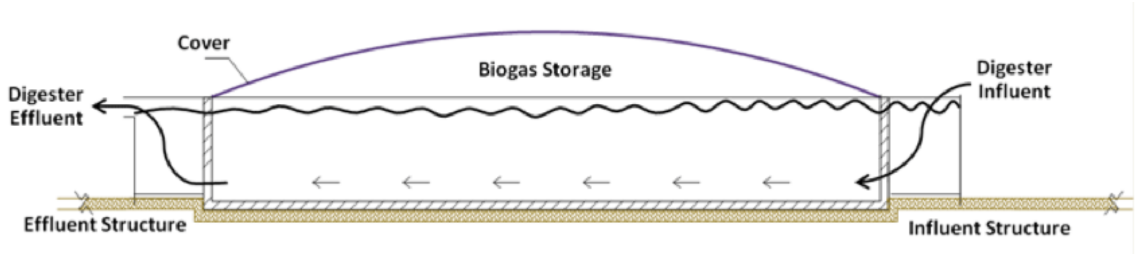


**Figure 11. Typical plug-flow digester (http://www.epa.gov/agstar)**

A complete-mix digester typically is an erected, above ground, heated container with some sort of hydraulic, mechanical, or gas mixing system (Figure 13). Generally, dairies that collect their manure with "flush" systems will use this type of design (EPA, 2012a), however there are variations. Flush systems usually incorporate large amounts of water to convey the manure to the digester. In both types of digesters, the cover is designed to expand as the organic material breaks down and releases biogas, and retention time ranges from 16–22 days.

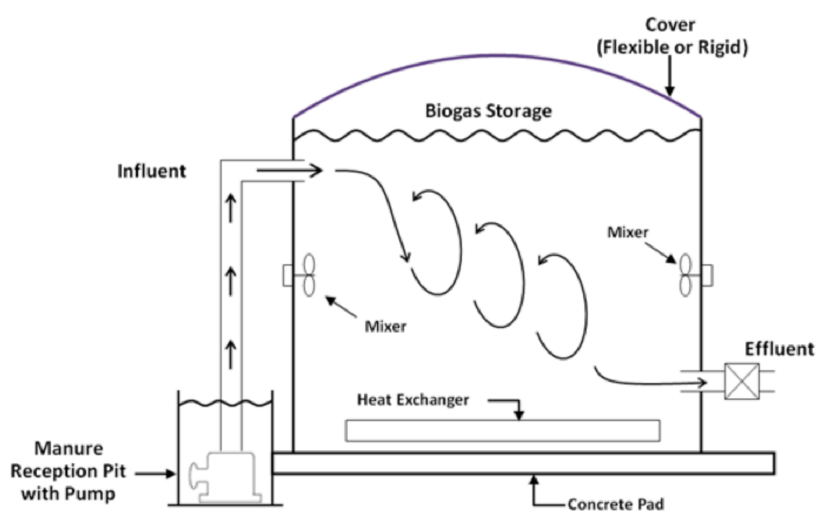


**Figure 12. Typical complete-mix digester (http://www.epa.gov/agstar)**

## Digester Profiles

Below are the key characteristics of the eight operational dairy digesters in Washington State as of January 2013 (Table 1). All of them supplement their manure with 30% additional feedstock, such as food processing waste, and use the biogas for electricity production and heating requirements for the digestion process (Benedict & Redfern, 2013). There are four farmer-owned and operated digesters, three developer-owned and operated digesters, and one public-private partnership owned and operated digester. Interviews were conducted with at least one person from each digester listed below. For the developer-owned and operated model, one-person interviewed had been active in the operations of more than one digester.

**Table 1: Washington State Dairy Digesters (Benedict & Redfern, 2013)**

| | **FPE Renewables** | **DeRuyter & Sons Dairy** | **Qualco Energy** | **Farm Power Rexville** | **Farm Power Lynden** | **Van Dyk-S Holsteins** | **Rainier Biogas** | **Edaleen Cow Power** |
|---|---|---|---|---|---|---|---|---|
| **Business model** | Farm own/ operate | Farm own/ operate | Public/ Private partnership | Developer own/ operate | Developer own/ operate | Farm own/ operate | Developer own/ operate | Farm own/ operate |
| **County** | Whatcom | Yakima | Snohomish | Skagit | Whatcom | Whatcom | King | Whatcom |
| **Year Complete** | 2004 | 2006 | 2008 | 2009 | 2010 | 2011 | 2012 | 2012 |
| **Biogas use** | Electricity /digester heating | Electricity/ digester heating | Electricity /digester heating | Electricity /digester heating | Electricity /digester heating | Electricity /digester heating | Electricity /digester heating | Electricity /digester heating |
| **kW capacity** | 600 | 1,200 | 450 | 750 | 750 | 400 | 1,000 | 750 |
| **Receiving utility** | Puget Sound Energy | Pacifi-Corp (Pacific Power) | PSE through Snohomish PUD | Puget Sound Energy | Puget Sound Energy | Puget Sound Energy | Puget Sound Energy | Puget Sound Energy |
| **Solids use** | Bedding | Sold for processing | Land application | Bedding | Bedding | Bedding | Bedding | Bedding |
| **Liquids use** | Crop production Nutrient recovery | Crop production | Crop production | Crop production | Crop production | Crop production | Crop production Nutrient recovery | Crop production |
| **Products currently sold or used by digester** | Electricity Heat Solids RECs CC | Electricity Heat Solids RECs CC | Electricity Heat RECs | Electricity Heat Solids RECs CC | Electricity Heat Solids RECs CC | Electricity Heat Solids RECs | Electricity Heat Solids RECs CC | Electricity Heat Solids RECs CC |

(RECs – Renewable Energy Credits)(CC – Carbon Credits) (Chart adapted from "WSDA, 2012")

**Farmer-owned and operated.**

There are currently four farmer-owned and operated dairy digesters in Washington. A representative of each one responded to the interview requests and, subsequently, all four were interviewed. However, the interview for DeRuyter and Sons Dairy was lost due to technical difficulties. Due to time constraints and the location of the DeRuyter dairy, a second interview could not be conducted. Profiles of each of the four digesters in this business model are outlined below.

***Vander Haak dairy (FPE Renewables).***

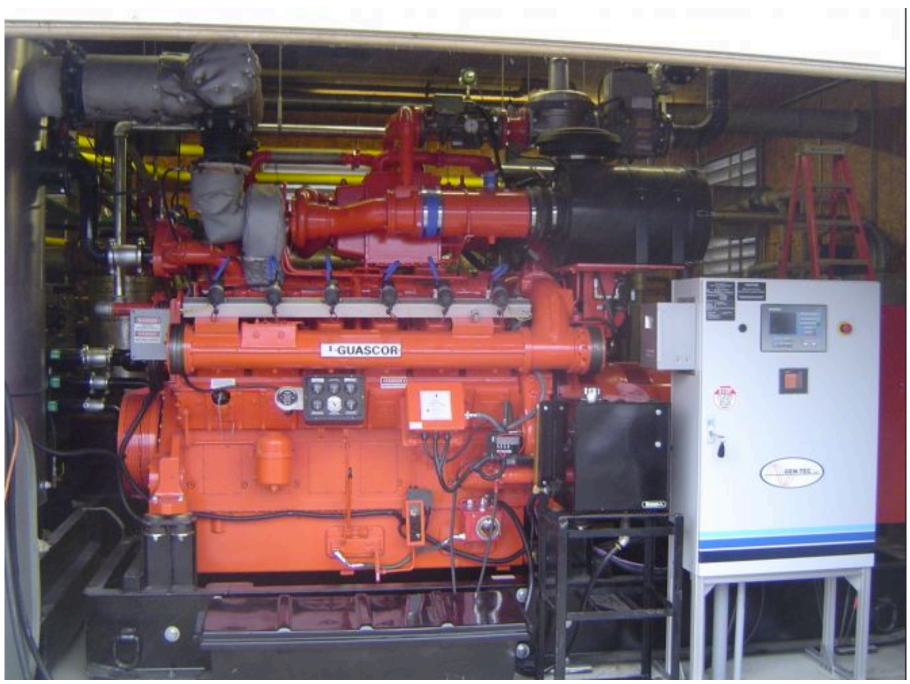


**Figure 13. Vander Haak Dairy's 600 kW digester generator (Andgar, 2012a)**

Vander Haak Dairy's digester came online in November of 2004 and was the first dairy digester in Washington State. Located in Whatcom County, the farm has 800 mature cows contributing waste to the digester. The digester was designed by Andgar Corporation and is a hybrid plug-flow/complete-mix design that can hold up to one million gallons. The original project cost $1.2 million and runs a 600 kW Guascor generator (Figure 14) (WSDA, 2011). The farm accepted additional manure from surrounding farms by truck in the past. Current revenue streams for the digester include electricity, RECs, carbon credits, tipping fees, and solids. The dairy currently has a power purchase agreement to sell its electricity to Puget Sound Energy. Solids are separated and used by the dairy as bedding for the cows. Liquid effluent is stored and applied to cropland. The digester has been involved in a number of research collaborations with both Washington State University (compressed natural gas production) and Western Washington University (nutrient recovery and economic feasibility) (WSDA, 2011).

***Van Dyk-S Holsteins.***

**Figure 14. Van Dyk-S Holsteins Dairy digester facility, with generators in building on left; complete-mix digester with flexible cover for biogas collection on right (Daritech, 2011)**

The Van Dyk-S Holstein digester (Figure 15) came online in June of 2011 and has a Dari Tech, aboveground, complete-mix digester design with flexible cover—the first of its kind in Washington State. The new Dari Tech digester is more affordable to build, has lower operating and maintenance costs, and removes hydrogen sulfide from the biogas. Located in Whatcom County, the farm has around 1,000 mature cows contributing waste to the digester. The project cost $2 million and runs a 400 kW, 2G generator. Current revenue streams for the digester include electricity, RECs, and tipping fees (WSDA, 2011). The dairy currently has a power purchase agreement with Puget Sound Energy. This dairy uses both flushing and scraping methods to collect manure, which is then transported into three lagoons. Solids are separated and used by the dairy as bedding for the cows. Liquid effluent is stored and applied to cropland.

***Edaleen Cow Power LLC.***

**Figure 15. Edaleen Cow Power's plug-flow digester (Andgar, 2012b)**

The Edaleen Cow Power digester came online in August of 2012 and has the below-ground, plug-flow digester design (Figure 16). Located in Whatcom County, this digester is fed from the dairy's 2,450 dairy cows, and the project cost was at least $2.6 million (USDA, 2013). The digester powers a 750 kW generator, which generates electricity that is sold to Puget Sound Energy. Revenue sources for the digester include electricity, RECs, tipping fees, and carbon credits. Solids are separated and used as bedding for the cows. Liquid effluent is stored and applied to crops.

***DeRuyter & Sons Dairy.***

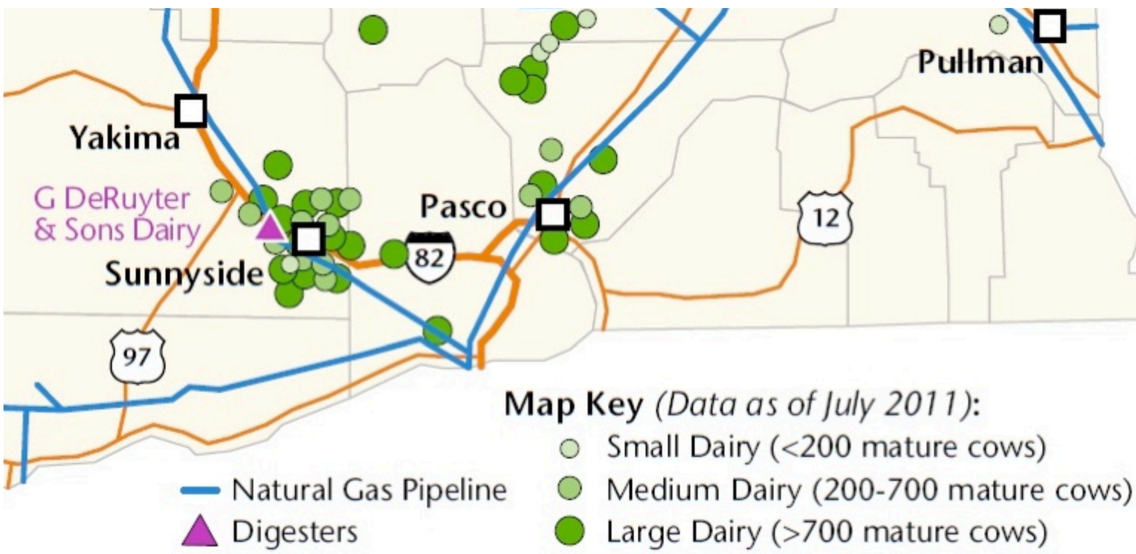


**Figure 16. Southeastern Washington dairy farms by size (WSDA, 2011)(Maas & Maas, 2011)**

Located in Yakima County, the DeRuyter dairy has the only dairy digester in Washington east of the Cascades. Although the DeRuyter interview was lost, it is important to note here that there are key differences in revenue streams for this digester due to its location east of the Cascades. Electricity markets there offer much lower prices, and tipping fees from industrial waste facilities are not nearly as abundant as they are west of the Cascades. As shown above in Figure 17, there are many dairies in eastern Washington that meet the EPA's criteria to support AD development. A discussion of the potential of those farms for renewable energy generation—through various avenues, including community digester options—and more research about the potential inhibitors of AD development in that region are warranted.

**Developer-owned and operated.**

Developer owned and operated digesters represent the second business model currently active in the dairy digester industry in Washington State. Farm Power Northwest is a Washington and Oregon company that is operating at the intersection of sustainable agriculture and renewable energy (Maas & Maas, 2011). Farm Power is an investor-owned company founded by two brothers. Farm Power currently owns and operates all three developer-owned and operated digesters in Washington State.

The company typically handles all the financing, revenue streams, maintenance, and construction of the dairy digester, while dairy farmers offer a lease on their land and their animal waste to be transported into the digester. In return, farmers generally receive some of the benefits dairy digesters produce, such as lower manure management costs, pathogen-free bedding for their cows, reductions in odor, and nutrient-rich effluent. One of the founders of Farm Power Northwest, as well as two of the farmers that contribute animal waste to their digesters, were interviewed for this study. Below are profiles of each of the three digesters that are owned and operated by Farm Power.

***Farm Power Rexville.***

Located in Skagit County on the property of Beaver Marsh Farms, Rexville was Farm Power's first digester in Washington State. The digester became operational in

August of 2009 and cost $3.5 million. This digester is fed from 1,200 mature cows from two nearby dairies—Harmony Dairy, and Beaver Marsh Dairy (Figure 18). The digester is a hybrid plug-flow/complete-mix design and powers a 750 kW generator. Revenue sources for the digester include electricity, RECs, carbon credits, and tipping fees; electricity is currently sold to Puget Sound Energy. Separated solids are used as bedding for cows from both dairies, and liquid effluent is stored and land applied to crops (WSDA, 2011).

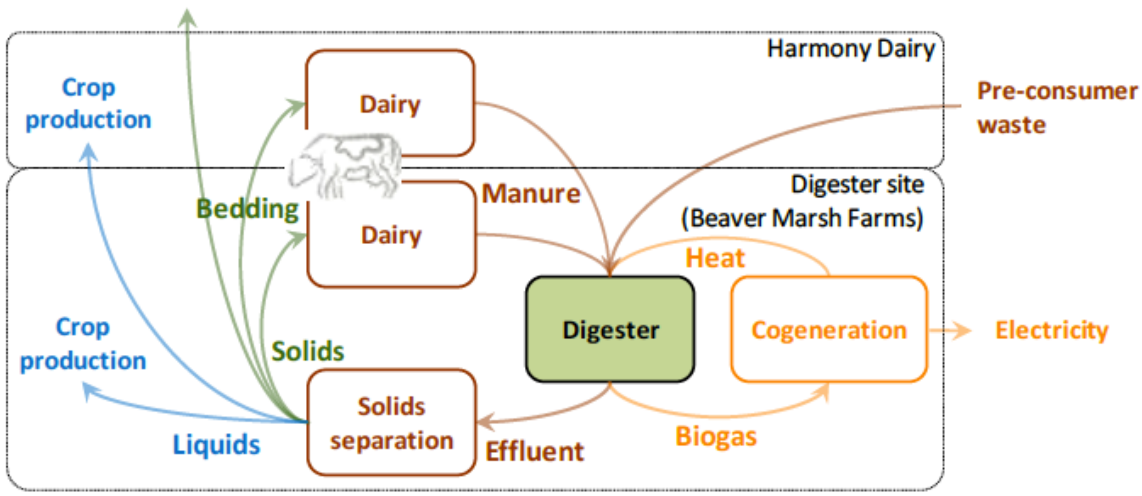


**Figure 17. Digester inputs and outputs at Farm Power Rexville (WSDA, 2011)**

***Farm Power Lynden.***

Located in Whatcom County on Van Windergen Greenhouses' property, Farm Power Lynden is Farm Power's second digester to become operational in Washington State. The digester came online in November of 2010 and is unique because of the collaboration with a greenhouse, which purchases excess heat from the digester, using it for radiant floor heating (Figure 19). The digester is a hybrid plug-flow/complete-mix design and powers a 750 kW generator.

Approximately 2,000 mature cows on a nearby farm feed the digester and the project cost $4.5 million. Revenue sources for the digester include electricity, RECs, carbon credits, and tipping fees; electricity is currently sold to Puget Sound Energy. Solids are separated and used by the contributing dairy as bedding. Liquid effluent is stored and applied to crops (WSDA, 2011).

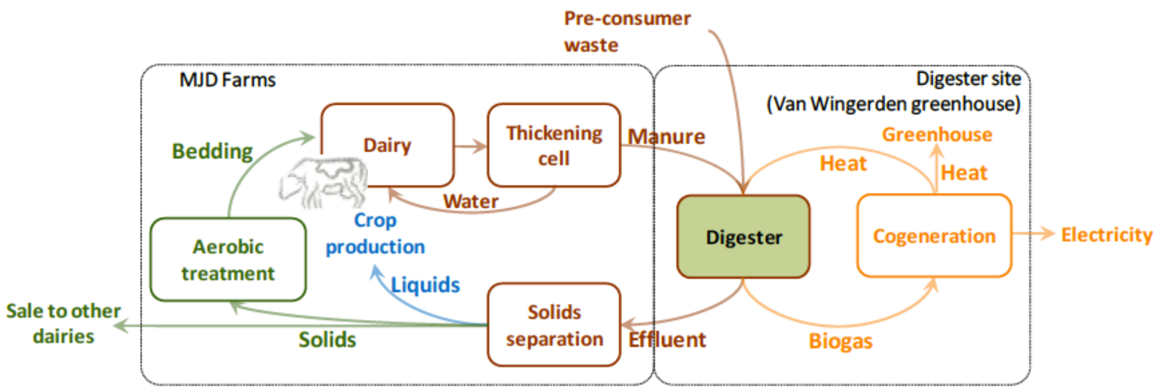


**Figure 18. Digester inputs and outputs at Farm Power Lynden including greenhouse utilizing excess generator heat (WSDA, 2011)**

***Rainier Biogas.***

Located in Enumclaw, Washington (King County), Rainier Biogas is a partnership between Ritter Dairy and Farm Power Northwest, and is Farm Power's third digester to become operational in Washington State (Figure 20). Coming online in November 2012 this digester is the most recent digester built in the state. As with Farm Power Rexville, this digester has manure coming in from multiple farms—four including the Ritter Dairy—for a total of 1500 cows. The digester will also demonstrate a unique first of a kind nutrient management system designed by Washington State University (Climate Solutions, 2012).

The digester is a hybrid plug-flow/complete-mix design and powers a 1,000 kW generator. Revenue sources for the digester include electricity sales, tipping fees, carbon credits, and RECs; electricity is currently sold to Puget Sound Energy. Separated solids will be used as bedding for the contributing dairies and liquid effluent will be stored and applied to crops. The total project cost is $4 million (Climate Solutions, 2012).

**Figure 19. Construction of Rainier Biogas, Farm Power's third digester and the most recent digester built in Washington State (Andgar, 2012c)**

**Public/Private Partnership.**

Public/private partnership digesters represent the third business model in in the dairy digester industry in Washington State. Currently, there is only one digester within this business model—the Qualco digester. According to its website, the Qualco digester is owned and operated by Qualco Energy—a nonprofit partnership made up of Northwest Chinook Recovery, a nonprofit working to restore and improve salmon habitat; the 3,500 member Native American Tulalip Tribes; and the Sno/Sky Agricultural Alliance, which is directed by five local dairymen and one cattle farmer (Figure 21). Qualco aims to generate revenue from the digester to invest in new, renewable energy and recycling projects, fish and wildlife habitat restoration, and state of the art farming practices (Qualco Energy, 2011). Three individuals representative of the Qualco digester were interviewed for this study.

**Figure 20. Qualco logo, representing partnership of Northwest Chinook Recovery, Tulalip Tribes, and Sno/Sky Agricultural Alliance (Qualco Energy, 2010)**

***Qualco digester.***

The Qualco digester came online in December 2008 and is located in Snohomish County, on the former Department of Corrections honor farm in Monroe. The honor farm was donated to the Tulalip Tribes by the state. The digester was originally designed to be a community digester, however, it currently only receives manure from one dairy—the Werkhoven Dairy. The Werkhoven Dairy sends manure from 1,100 cows to the digester about a mile away via pipeline.

**Figure 21. Qualco digester flaring excess methane (Bartley, 2012)**

The digester is a hybrid-plug/flow-complete mix design and powers a 450 kW generator, however Qualco plans to add a 750 kW engine soon because it is generating more methane than it can run through the generator (Figure 22). The project cost $3.4 million. Revenue sources for the digester include electricity, RECs, carbon credits and tipping fees; electricity is currently sold to Puget Sound Energy. The separated solids and liquid effluent are applied to crops.

**Data Analysis**

Data were transcribed using Dragon Dictate 3.0 software. Themes were drawn from the transcribed interviews through a multistage data analysis technique obtained from the article "Techniques to Identify Themes" (Ryan & Bernard, 2003). The first stage of analysis involved reading through the interviews several times and color coding topics and keywords that appeared repeatedly among and within interviews; the second stage involved cutting and sorting the quotes into piles of similar nature; the third stage involved assessing which piles represented themes and sub-themes pertaining to the original research question: Why have Washington State dairy farmers been slow to adopt AD technology? Due to the open-nature of the interview questions and the small sample size, themes were identified not only by the number of people expressing an opinion but also according to the relevance of that opinion to digester development variables; therefore some themes may contain a low number of interviewees, but contain a substantial amount of information.

# Results and Discussion

## Introduction

Analysis of the interviews revealed similarities within each business model pertaining to motive for becoming active in the dairy digester industry, overall satisfaction with choice to become active, community digester potential, and potential for expansion. There were several unexpected points of interest that are highlighted in this section and noted for their importance, however they are beyond the scope of this thesis to explore in depth and further research is recommended. The similarities within business models, community component potential, and unexpected points of interest, are discussed according to business models.

While the non-profit partnership business model was the most environmentally motivated among business models, most of the interviewees commented on either nutrient management and/or food-processing waste disposal and therefore those responses are discussed collectively under environmental concerns. Lastly, potential restrictors of dairy digester development are discussed, including undervalued environmental outputs associated with ADs, the renewable energy policy framework in place in the state, and low and volatile electricity rates. The chapter closes with a brief section on the future outlook for dairy digesters in the state. Figure 23, below, is a model portraying the similarities within each business model, dissimilarities among business models, and overarching themes representative of all three business models.

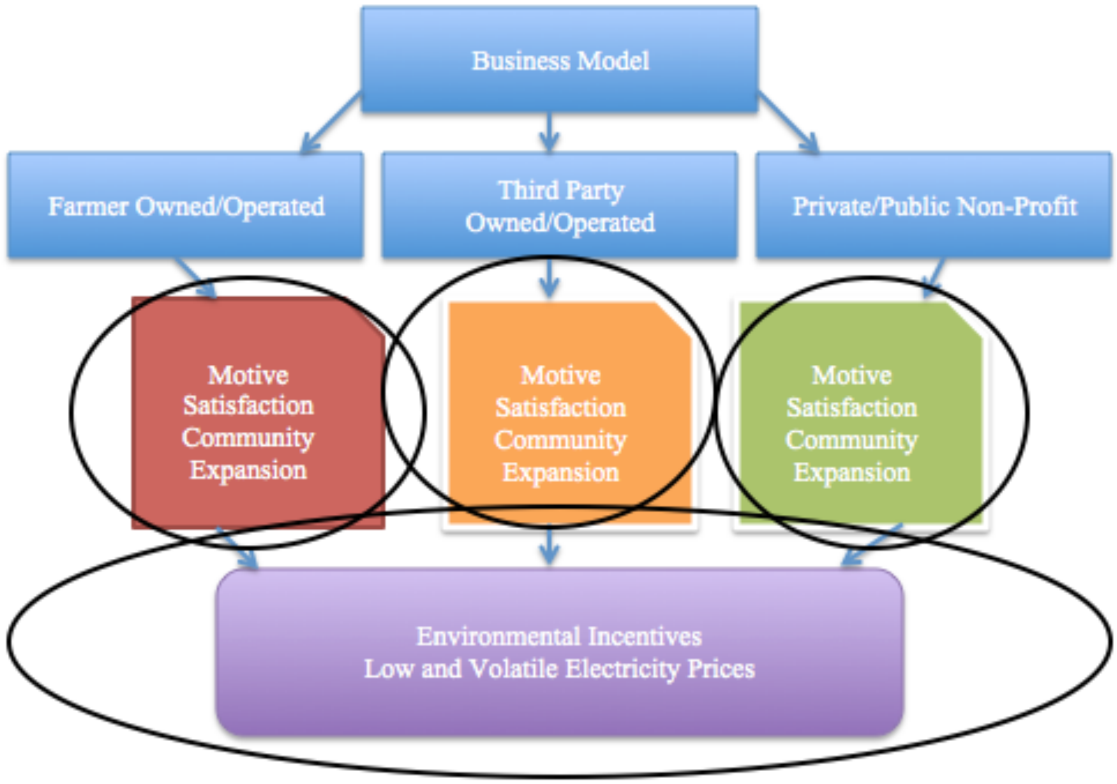


**Figure 22. Interviewee responses were similar within each business model but differed among the models. Overarching themes representative of all interviewees regardless of business model affiliation were identified.**

**Business Models**

As mentioned before, there are three distinct business models represented in the Washington State dairy digester industry: farmer-owned and operated digesters, developer-owned and operated digesters, and non-profit partnership digesters. In order to fully understand the state of the industry and all options available for future development, a discussion is warranted on the capacity that each business model has to satisfy its members, how satisfied they are with their choice to develop, their future outlook, and the potential for expansion. Additionally, as previously mentioned, one possible solution in some areas, in order to offset some of the capital costs associated with dairy digesters, is to have a community digester. Therefore, interview responses to questions pertaining to these issues are discussed according to business model in this section.

**Farmer-owned and operated.**

All three interviewees in the farmer-owned and operated businesses were primarily motivated to develop a digester for diversifying revenue streams. As one interviewee stated, “from a product business standpoint, the main interest is that dairy has been really bad the last 5 years. So, as a family, we had to say that if we want to stick around, we have to find ways to diversify other than just milk.” The motive to diversify is exclusive to this business model, and it brings up several questions. For example, if the economics of dairy farming are becoming more and more difficult, does it make sense to make a long-term investment in something that depends on dairy cow manure to operate? Furthermore, is investment in a digester necessary in order to be a successful dairy farm? Such questions are beyond the scope of this study; however further research into this subject may prove useful for farmers looking to become active in the dairy digester industry.

The main revenue streams from the digester in this model include electricity sales and tipping fees. The dairymen in this model were also satisfied with the bedding offsets associated with using the digested fiber from the separated solids out of the digester. One interviewee commented on the bedding offsets, saying they save on average $6,000/month. The savings from bedding offsets, as well as the potential for digested fiber marketability, is consistent throughout the literature (Bishop et al., 2010; Bishop & Shumway, 2009).

Even though the digested fiber market is not yet developed, one interviewee commented, "we have been talking about figuring out a way to sell that bedding whether it be a compost or to nurseries or something like that or other farms to use as bedding." Another interviewee stated, "we played with drying the manure a little bit, we got some systems in place that are able to dry it and pelletize it and use it as a biofuel or to use it as a fertilizer pellet. It may help some to kind of move some nutrients off site but, at this point, the return on investment hasn't been there to really go gung ho towards that." This model showed the least amount of motivation to pursue alternative revenue options, however it's very apparent, if the markets and technology available, these farmers would actively participate.

When asked if they would recommend a digester to farms with similar sized herds as theirs, all three interviewees said they would. However, there was a precaution one interviewee pointed out: "everybody's got to look at their situation and decide; it's not for everybody, there is management. Right now in order for them to pencil, they need the tipping fee income, and there's only a certain amount of that out there. As more digesters come, then that gets thinned out." This suggestion of a limited amount of food processing waste to generate tipping fees in a given area has not been addressed in the literature beyond the suggestion that digesters located in close proximity to urban areas are at a significant advantage (Coppedge et al., 2012a). It has been identified in feasibility studies that tipping fees may be the most important revenue source for a digester (Bishop & Shumway, 2009). This suggests there may be implications for potential developers and policy makers to consider when applying efforts into potential future digester projects. If a municipality decides to build a digester in a community where there are already digesters in operation, and there is a fixed amount of food-processing waste available, the resource base may get too thin and result in a crash of the industry in that area. Consequently, governments should keep this in mind when issuing permits and giving recommendations for potential digester projects.

Overall, the satisfaction among the farmer-owned and developed business model was high. When asked to rate their satisfaction with digesters on a scale of 1–10, answers ranged from 7–9. In hindsight, one interviewee commented, however, that, "I'm still really glad we did it but at the same time—I don't know what has changed—but it seems like this combined with some other things that happened, that it's added so much complexity to our operation that it's frustrating… At times simpler is better, but if you wanted a number I'd say seven." The added complexity associated with AD adoption on a dairy farm has not been addressed in the literature. Studies pertaining to this issue are warranted and may be beneficial for farmers who are contemplating becoming active in the industry.

The interviewees in this business model were motivated primarily by a need to diversify revenue streams. Farmers value the bedding offsets from not having to buy nearly as much cow bedding. Interviewees see the potential for possible future revenue streams with digested fiber, and would participate if the markets develop. Questions were raised regarding the complexity a digester may add to a dairy farm and the potential of decreased tipping fees and food processing waste availability if the digester industry were to expand. All interviewees in this model identified low and volatile electricity prices as being the primary restrictor of digester development in Washington State.

***Community digester option.***

Within the farmer-owned and operated business model, there are two different scenarios for incorporating a community digester component. First, multiple dairymen invest together in a digester where they would all contribute animal waste. Second, a farm owning a digester accepts additional manure from surrounding farms through some sort of formal agreement.

The first scenario is thought to be difficult. One interviewee suggested, "I think there is some room for community digesters, assuming all the other economics change, but it also forces you to depend on that dairyman also having the mentality that they're going to be here five years from now, and the way it sits in our area right now, you know do I really want to invest several million dollars in a project if the other guy I'm investing with may or may not be here five years from now? In other parts of the country you could say well, he might not be there but somebody else will be dairy farming there. In this area [that's] not necessarily true; if the land sells there's a pretty good chance it's going to a berry grower."

As for the second scenario, issues arise regarding transportation. One interviewee, in response to the question of accepting manure from nearby farms, responded, "yeah I would if we could get something to work out. You know, obviously there would be logistics getting the manure there and back. But, yes, I don't see anything wrong with that." Another interviewee commented that he had actually tried that in the past but, "we had enough ourselves, and we were trucking it in. It's not cost effective that way." The transport of manure has been identified in the literature as fairly expensive and, in most cases, not cost-effective for the amount of electricity which can be generated from the manure itself (Shumway & Bishop, 2009).

One interviewee argued, “from an operational standpoint it would be easy, but it is creating complexity with not a lot of reward. Working with neighbors is great, but it also creates another opportunity for conflict.” This was a surprising finding, considering that the farmers interviewed by Gremelspacher et al. (2010) found that good neighbor relations outweighed the potential for conflict when installing a community digester.

Farmers from the second scenario seemed willing to take in additional manure from surrounding farms as long as there was a need for it and a cost-effective method of transport from the source. However, it may carry with it a potential risk of undesired conflict within their community. The need for the manure and the economics pertaining to transport have been identified as problematic in the literature (Gremelspacher et al., 2010; Linderoth, 2006; Shumway & Bishop, 2009). The potential risk of conflict has not been addressed and further research should examine this prospect more closely.

**Developer-owned and operated.**

The developer-owned and operated business model, as described in the methods chapter, works with one or more dairy farms to develop a digester on their land with their manure. The developer covers all of the investment costs, day-to-day operations, and maintenance of the digester. The only thing asked from the dairymen is their cow manure and, in exchange, the dairymen usually receive pathogen-free bedding and a nutrient-rich effluent from the digester. Of the three individuals interviewed from this business model, one is a developer and two are dairymen who are currently contributing manure to a developer-owned digester.

When asked to rate his satisfaction with the choice to become active in the dairy digester industry on a scale of 1–10, the developer responded, “eight, maybe. You know, we’ve learned some hard lessons about how the world really works…for the first couple years you’re probably a nine or a ten, and then the deeper you get into it the more you start to see things that sort of just make you shake your head.” When asked about future expansion, the developer in this model commented that he sees potential, however, there is still a long road ahead. When asked what is currently restricting digester development, he commented on the current rates paid for electricity, saying “even if you got a digester for free these days you couldn’t make enough money on the electricity to afford to run it.”

The two dairymen from this business model who were interviewed for this study suggested their primary motivation for becoming involved was to receive the pathogen-free bedding from digester operations, and both seemed to be happy with the arrangement. When asked to rate their satisfaction to develop a digester on a scale of 1–10, one interviewee responded, “we’re pretty satisfied, it’s been pretty good. We’ve had some learning experiences, but probably an 8 or 9.” The other interviewee ranked his satisfaction as an 8, saying his main reason for participating was “to get the bedding back for bedding my cow stalls…the bedding is very expensive and it is not bacteria-free without being processed through a digester.”

For a third party to offer bedding and nutrient-rich effluent to the farmers in exchange for their manure seems like a good bargain for the farmer, however there were some concerns over the additional nutrients coming in from tipping fees. When asked to elaborate on a question about the nutrient-rich effluent, a contributing farmer responded, "they bring in a lot of extra stuff and I'm okay with that, but the problem is that stuff has to go somewhere—well it is ending up in my lagoons… Now it's three times as high [in nitrogen]. I have to have a way larger land base… It's great fertilizer, but you have to be able to handle it."

On the other hand, another interviewee seemed very content with the additional nutrients, saying "we have more than enough land." This same farmer, in response to the business model arrangement, shared that, "originally, we looked at doing it ourselves… [but] when the [developer] came to us we let them run with it because our goals will still be met with less headache." Concerns pertaining to added nutrients from accepting food-processing waste into digester operations are discussed further in the Nutrient Runoff section of this chapter.

When asked whether they would recommend contributing to a digester to other farmers with similar sized herds, both respondents said they would. One of the interviewees added, "looking back there is probably no way we could have done it on our own… It was a pretty expensive project, so I would recommend it." Additionally, the role of dairyman in this business model requires significantly less responsibility than the farmer-owned and operated model. Removing much of the associated complexity may be more appealing to some farmers.

Due to the relatively small number of interviews conducted with dairymen contributing to a developer-owned digester, coupled with no other published findings on the subject, it is uncertain whether these results are representative of the overall population of dairymen involved with this business model in Washington State or on a national level. However, this information is useful and informs us that this demographic is satisfied overall with their decision, they are receiving the benefits they anticipated, and they would recommend that other dairymen with similar sized herds contribute to a digester. With over 260 commercial-scale dairy farms in Washington State, coupled with a high satisfaction rating by these two interviewees, this business model has the potential to expand significantly.

***Community digester option.***

Community digesters within the developer-owned and operated business model were found to have significant advantages over community digesters within the farmer-owned and operated model, where digester owners were concerned about risks involved with investing with other farmers and the threat of potential conflict. In contrast, developer-owned and operated community digesters alleviate all of those concerns because a third party is responsible for managing the day-to-day operations, setting up the financing, and taking care of all the revenue streams. In effect, the developer and its affiliates take on all of the economic risk. The developer-owned and operated digester model in Washington also incorporates multiple partners in addition to multiple farms. To better understand what makes a digester a community digester in the perspective of a developer, one interviewee noted that it incorporates “multiple farms, multiple partners overall. One of our digesters is next to a greenhouse, which is supplying heat to a commercial greenhouse. Multiple partners is more complicated, but it’s what we think is the right thing to do.”

As a whole, this business model provides multiple farms with the benefits of bedding and nutrient-rich effluent without the nuisance of every day maintenance, capital costs, and volatile revenue streams. The model is community based and capitalistic by nature, so expansion of this model is primarily dependent on economic climate and the experiences of contributing dairymen.

**Non-profit partnership.**

Interviewees from the non-profit partnership business model had many different motives for becoming active in the dairy digester industry, as might be expected from a three-way partnership. However, a common theme among all of their motives was environmental concern and the determination to find solutions to environmental problems. Specific primary motives included improving fish habitat, preparing for future environmental regulations, demonstrating a new way of doing things, and improving the economics of farming.

One interviewee summed up his motive as, "we were looking at both sides of the equation. We wanted to reduce the amount of runoff from the farms going into the rivers… We also wanted to improve the economics of dairy farming to help keep the dairy farms here long-term." Another interviewee in this model also argued that dairy farms should be maintained over the long term, saying, "if you make [dairy farms] the enemy and you drive [dairy farms] out of business, whatever replaces them is going to be a lot worse than what [the dairy farms] are doing." This business model exemplifies how people are concerned with the environment, while the agricultural community may share some common ground when it comes to the potential environmental and economic benefits of AD application.

Another motive observed from the non-profit business model is related to future environmental regulations pertaining to the dairy industry. One interviewee described how he became involved, stating, "right around 2000, there was a lot of talk about regulations and setbacks of rivers and they were shooting all kinds of numbers around. You know, we run a business…and it's very difficult to plan for the future when you have no idea what the future was." Initially, this interviewee's main concern was to mitigate potential conflicts between the dairy industry and the listing of salmon as an endangered species in Washington State.

Another interviewee's response to the question about motivation for developing or participating in a dairy digester project was, "demonstrating a new way of doing things." The interviewee went on to elaborate, "I look at the technology, it's pretty straightforward… In this country you got dairy farms, but you got way beyond that—you got cattle feedlots, you got pig feedlots, you got chickens, you got everything under the sun [and] their manure is destroying places… All that stuff could be directed into digesters… You could argue that it could be five, ten, fifteen percent of the nation's energy needs but, more important than that, you're taking that stuff out of the environment…not destroying the Chesapeake Bay or the Puget Sound." This holistic perspective provided insight into the determination to find a solution to environmental concerns.

The partnership's main digester revenue streams are tipping fees and electricity sales. The benefits that they were anticipating prior to development include a new way of doing things, improving water quality for fish, improving the economics of farming, and a reduction in odor, and, as one interviewee put it "I think it has worked better than we anticipated."

When asked about possible future revenue streams, one interviewee responded, "we're always looking for other revenue streams…We produce far more gas than what we burn in the generator. We're really looking at shipping some of the gas back to the dairy [farm], which is about a mile away, and putting in a smaller generator there to basically produce all the electricity to run our farm, and with the excess heat, use that to heat water for cleaning purposes." Another potential revenue stream may incorporate, "experimenting with the compost and concentrating the nutrients in the liquid effluent to be able to export more of our excess nutrients to other farms. We don't want to start charging until we get a consistent product…but once we do we can market those nutrients." This business model is actively seeking ways to expand.

The dairyman in this model wears many hats, and has a unique agreement with his partners. As one interviewee described, "in exchange for the day-to-day maintenance of this facility, they get to use the rest of the property here for growing feed crops for their cows." Because this partnership is a non-profit, they can put their profits into research and development and habitat restoration. Additionally, since the farmer runs the day to day affairs, and is not necessarily concerned with turning a profit on the added substrates coming in, he can directly manage nutrients for optimal crop yield. The economic risk falls primarily on the partnership itself, which creates an even more cohesive relationship and strengthens the motivation to work together in order for all parties involved to meet their goals. Additionally, non-profit partnerships can help achieve their mission to improve the economics of dairy farming, improve water quality, and demonstrating a new way of doing things.

When asked if they would recommend this model to be replicated where similar partnerships could be developed, one interviewee responded, "absolutely, but the thing that has made this work…you got to find people that want to solve a problem. You have to find the right people from different groups to come together to say they want to solve this. It took a long time to develop enough trust and, in a lot of cases, friendship to make this thing work. It's easy to recommend it. To make it happen is not so easy." Another interviewee responded, "we've been going to different conferences and organizations talking about this because…we think the model we have here is one that can be used anywhere in the country."

Out of all of the business models, the satisfaction that the interviewees had for their choice to develop or participate in a dairy digester project were the highest in this group, ranging between nine and ten. One interviewee replied, "I'm almost totally satisfied. There are a lot of things you can say you were surprised by, or you didn't like or so on and so forth, but I personally take immense satisfaction in having been part of a project like this. And I will continue to be part of it as long as I can because it does shows us a new way of doing things."

***Community digester option.***

The non-profit partnership owned and operated model was started with a community component in mind. As explained by one interviewee, "one of our original goals was to have at least four farms tied in, but we need to expand before we can tie in new farms. Hopefully we can do that in the next five years." Another interviewee, when asked about expansion, replied, "we want to expand. We want to add several thousand more cows and we want to build more digesters." The determination to expand and to incorporate more dairy farms is likely attributed to the motives of the individuals involved and to the fact that the business model is a non-profit. This model appears to be ready for expansion and participants are interested in any and all types of additional revenue streams. This model shows great potential for successfully expanding under any economic conditions, due to its collaborative approach and its value-driven motives.

## Environmental Concerns

While the non-profit partnership was the most environmentally motivated business model, every interviewee expressed some concern or input on environmental issues such as nutrient management, greenhouse gas emissions, pathogen removal, and food-processing waste disposal. For at least four interviewees, the motives to develop a dairy digester had at least one environmental component, with some interviewees expressing multiple environmental motives. Nutrient management issues and converting food-processing waste into energy were the two most common concerns and are discussed below.

### Nutrient management.

Nutrient runoff from the dairy industry was a priority motive for at least three interviewees. One interviewee responded that one of his motives was "improving fish habitat by keeping more of the nutrients from being able to run off the fields into the rivers and streams. It's been an issue in our watersheds for probably 20-30 years. By monitoring the effluent out of the digester, they're able to match up where the nutrients go and do a better job of applying the nutrients we have. It looks like we're doing a good job." Based on interview data from this study, there has been a noticeable difference in water quality as a result of these digester operations.

Interviewees had mixed concerns regarding the liquid effluent as a fertilizer. The effluent contains nutrients with fast absorption rates, so plants are able to take them up very quickly. This fast turnover of nutrients may decrease nutrient runoff into the streams and rivers because it doesn't sit in the soils for long (Benedict & Redfern, 2013). In addition, the farmers receive a more productive fertilizer for their fields. There was some skepticism and dissatisfaction regarding the new nutrient-rich fertilizer. As one interviewee explained, "the verdict is still out on how that is going to work. Obviously, the revenue is there, but are there long-term costs that we're not factoring in there? The land needs nutrients, but how much nutrients? Are we hurting ourselves more than we're helping ourselves?" Another interviewee was distressed because "the fertilizer is good…but it's three times the strength of my regular manure…now I can only put so much on my fields because it's so high in nitrate." One interviewee responded that added substrates, "add some nutrients to the system, but some of the substrates (food-processing wastes) have more [nutrients] than others, so we are trying to manage around that and make it more stable to apply to the land… A lot of the stuff that we add into the digester is pretty much straight sugars; they have a lot of energy but they don't add any nutrients…so it kind of balances out." Additionally, that interviewee commented, "you know fertilizers are fairly expensive, we actually export a lot of the solids, and you know that may be a mechanism that we use to balance."

It seems that decreased nutrient runoff from dairy operations is a motive for some people to participate in dairy digester projects due to environmental concerns, and that digesters have been meeting their expectations in that sense. The farmers involved are receiving, based on the types of substrates added (food-processing wastes), a variably higher nutrient-dense effluent with an almost immediate absorption rate, which they can directly apply to the land. The added nutrients in the effluent seems to be a concern for some of the farmers, due to potential long-term effects, and at least one interviewee claimed he had to obtain more land in order to "take care of it." These issues may be remediated with the suggestions of exporting excess nutrients off-site for sale as a fertilizer, as well as by making changes to traditional nutrient management tactics.

Washington State University (WSU) has been researching nutrient recovery systems to better manage the nutrients coming out of the digesters (Coppedge et al., 2012a & 2012b). From the perspectives of some of the interviewees, the research is making good progress. One remarked, "with the work WSU has done by taking a closer look at the soils and how much nutrients they need and where, and by monitoring the effluent out of the digester, they're able to match up where the nutrients go and do a better job of applying the nutrients." By understanding the nutrient demand of the soils, researchers can then extract the remaining amount of nitrogen and phosphorus from the liquid effluent so that these nutrients may be sold.

**Food-processing waste disposal**

As mentioned earlier, to make the digesters more economical, digester operators can take in food-processing waste. This waste consists of a number of different organic materials, ranging from meat-packing-facility waste, to trap grease, to expired liquor. A digester is allowed up to 30% additional off-site feedstock from these sources (Coppedge et al., 2012b).

Three interviewees offered insights on the subject of food-processing waste disposal. One expressed, "when you add [food-processing waste into digesters], what predominantly provides most of our 30% of additional substrates allowed under the law, [and] a terrible thing in landfills...[the digesters] clean it up…take[s] it out of the environment. This is what people don't understand…all this crap that goes into a digester, that means it's not going into the environment…and it comes out as a useful and environmentally safe compost to go back out on your fields. That's a huge benefit."

The value associated with keeping food-processing waste from being buried in landfills has not been mentioned in the literature. Tipping fees are a relatively new contribution to a digester's economic feasibility, since the law allowing digesters to handle the additional waste only came into effect as of 2009 (Coppedge et al., 2012b). More research is needed to calculate the value that averted landfill waste may have on society and the environment.

## Potential Restrictors of Dairy Digester Development

As mentioned in previous chapters, there are several possible reasons why Washington State dairy farmers have been slow to adopt AD technology. Interviews with the farmers and developers in this study identified four potential causes: undervalued environmental outputs associated with ADs, the renewable energy policy framework in place in the state, and low and volatile electricity rates. Low and volatile electricity rates were found to be the most common and significant restrictor of dairy digester development identified among all interviewees. This section closes with policy recommendations and observations about the future outlook.

### Environmental incentives.

Four interviewees commented on the environmental incentive structure in Washington State as being a potential restrictor of digester development. As discussed in the literature review, there are two types of environmental benefits that can be monetized through credits in Washington State: carbon credits and renewable energy credits (RECs). Carbon credits encompass the amount of greenhouse gasses that the digester captures that would have otherwise been released into the atmosphere, and RECs capture the environmental benefits associated with the renewable electricity produced by digesters. Both environmental credits are thought of as distinct and separate from one another, and both are potential sources of revenue for digester developers.

When asked how important carbon credits and RECs have been for their operations, interviewees had mixed responses. All but one stated that carbon credits have not been a very appealing revenue option. As one interviewee described it, "the certification requirements are so cost prohibitive, what we're actually doing is collecting all the data that's saying we're burning this rather than letting it go [into the atmosphere], and then four years from now we would actually get certified. Then you could backdate some of those and that would be good for another seven years, and I think even then we make like maybe ten or fifteen thousand dollars over that seven years after the cost of getting certified." This directly reaffirms Gloy & Dressler (2010), who demonstrated that the time and effort required to become certified often outweigh the expected benefits.

Another interviewee responded, "well there are a number of problems… You get into a lot of complicated matters by bringing in the pre-consumer food waste and they have to kind of separate that out and figure out how much methane is being captured and that would have been released anyway. With cow manure alone that's [a] pretty straightforward calculation…but the pre-consumer food waste made it more difficult." This idea is not established in the literature and could prove problematic for dairy farms in Washington State to become certified. As mentioned, every dairy digester in the state takes in food-processing waste; in some cases it is their primary source of revenue. As the interviewee suggests, the offsets from the manure alone are fairly easy to calculate, however certification programs may not yet know how to carry out the necessary calculations for the additional food processing waste. Potential carbon market implications for the dairy digester industry compared to the RFP process are discussed in the renewable energy policy section, below.

RECs were part of every participant's revenue sources. However, as suggested in the literature (Gloy & Dressler, 2010), the renewable energy produced is not appropriately valued. One interviewee commented, "RECs are part of our revenue income; not sure what percent… Right now we are selling the electricity and the RECs to [the utility] as a joint package; they didn't want the energy without the RECs." This is interesting because RECs, like carbon credits, are designed for promoting renewable energy development. However, in this case, the purchasing utility wouldn't even buy the producer's electricity without them, according to the interviewee.

The literature also suggests that the renewable attributes of renewable electricity is only valuable if willing buyers are found, and it is the customer's willingness to pay that determines the value of renewable electricity (Gloy & Dressler, 2010). While there is some agreement in the literature as to the demographic variables and socio-psychological characteristics associated with a consumer's willingness to pay for renewable energy, green power programs in Washington State are obviously not working well for dairy digesters. The CVPS Cow Power Program, as mentioned in the literature review, represents a successful voluntary consumer-based pay program. The premiums that more than 4,600 CVPS electricity customers voluntarily pay generates about $470,000 per year, which helps maintain and develop dairy digesters (Wang et al., 2011). Clearly, the renewable value associated with the electricity produced from small-scale renewables is not being valued in Washington State. Based on the CVPS Cow Power Program's success, further research into the potential application of such a program in Washington State is warranted.

**Renewable energy policy framework.**

One interviewee commented on the request for proposal (RFP) process as being a restrictor of dairy digester development. The interviewee provided an example, "a [utility] needed green power starting in 2020, so they put out a RFP and they said we need 100MW of green power and we need it started in 2020. Anybody can bid, but the companies that are going to win that bid are companies that are going to come to them with a large, low-cost project that's fully permitted, that are not to start up 'till 2020, and they're going to win the bid. The project that is 1/100$^{th}$ [that size] can't possibly be as inexpensive as a huge project and can't afford to wait 'till 2020. RFPs are not designed for small projects." This interviewee's comment directly echoes Lipp's (2007) comment that the RFP process often excludes small-scale renewable energy developer participation.

This same interviewee showed concern that the problems inherent in the RFP process may prove to be an example of what could happen with a mandatory carbon market. The interview suggested, "if the demand is for just large amounts of carbon credits that will be supplied by the cheapest source, which will probably be forests and landfills, …dairy farms are always going to be at a disadvantage because there are just more things that you have to keep track of and more things that are reducing your offset yield and you just can't make them as big. So, if a couple years down the road you hear the dairy industry complaining about carbon offsets, it's because they're getting their butt kicked by bigger and simpler carbon offset projects."

Gloy & Dressler (2010) suggested a similar implication, due to the high capital costs involved. The offsets produced by ADs would be much higher than other agricultural operations that are able to produce the same offsets at a lower cost. As noted previously, dairy digesters are very capital intensive and, if they are competing for carbon offsets in a mandatory carbon market, we may witness problems similar to those inherent in the RFP process. The uncertainties inherent in the above suggestions warrant further study before it can be accurately assessed whether a mandatory cap and trade program would be in the best interest of the dairy digester industry.

**Low and volatile electricity rates.**

The problem of low and volatile electricity rates was the most common reason given for why Washington State dairy farmers have been slow to adopt AD technology; this was cited by every interviewee. As mentioned in the literature review, power purchase agreements (PPAs) are currently one of the only stable sources of income for a digester owner. This is important because, when a farmer seeks out a lender for a loan to build a digester, the PPA in Washington State serves as a proof of income over a long period of time. Therefore, the prices that utilities offer to pay for the electricity produced by a digester directly affects the lender's decision to approve or deny a loan.

When asked if there are financing options available for farmers who want to build a digester, one interviewee answered, "the short answer is not really. They're very expensive to put in, and, at best, they invest relatively low market—and because of the inequities on how the electricity is treated, it puts it at another disadvantage. Until those questions are addressed, I'm not sure that digesters are going to be very economical."

When asked about electricity rates, every interviewee replied that they are getting worse. One interviewee exclaimed, "I think we have to sign a new contract and our belief is that this new contract may be 20-25% lower rates." Another interviewee replied "our contract expires at the end of this year and at that point we're going to see an almost 50% drop in what we'll get paid for electricity." It is clear from the interviews that electricity rates are not only low, but are in a steady state of decline.

One interviewee responded to how policies might be altered to better facilitate digester development by remarking, "one of the policies that we have often mentioned is forcing all utilities to provide standard offer contracts for digesters for small renewables… Those projects would have to be long-term and fixed-price." Because of the current policy, the same interviewee argued, "if you want to build a digester, you go to your utility and you ask them, so what will you pay me—and for how long? They'll say, we don't know—and we won't know for a year, if ever. You can't do business like that. So if every utility in the state just had a contract that said you can sign this for 10 or 15 years and here's the price, it wouldn't even have to be $.30/kWh like they have in Germany."

As described in the literature review, Germany and many other countries have successfully spurred rapid dairy digester development with use of a fixed-price feed-in tariff (FIT) policy that bases the fixed-price on the cost of technology plus reasonable profit. The literature suggests that this is currently the most effective policy for spurring AD development (Couture & Cory, 2009). FIT policy is not popular in the United States, though some states have been and are continuing to implement FIT-like policies into their RPS policy (Couture et al., 2010). The majority of these FIT/RPS hybrid policies are considered to have achieved limited success due to the lack of some fundamental elements inherent in European-style FIT polices (Couture et al., 2010; Lipp, 2007; Ragwitz et al., 2007). This element of the study is crucial in understanding how to promote smaller renewable energy development here in Washington State.

Unfortunately, a feed-in tariff is politically unlikely in Washington State. As one interviewee explained, "I think to have a real digester business, somehow there has got to be a way. The feed-in tariff would be the easiest way…that's why, in Germany, you've got a lot of farmer-owned digesters and a lot of community-owned digesters…[however] the price of a feed-in tariff would send politicians running and screaming in the other direction, so…I just don't think it's politically possible."

The reality for the implementation of a true European FIT policy is debated in the literature (Cory et al., 2009). Nevertheless, the FIT implemented in Vermont's Sustainably Priced Energy Enterprise Development Program (SPEED) in 2010 has so far been a successful way to implement FIT policies into an existing RPS framework (Wang et al., 2011). The FIT rate approved by the Vermont Public Service Board is $0.141/kWh for a long-term, fixed-price for dairy digesters. This rate, coupled with the CVPS Cow Power Program premium of $0.04/kWh, offers digester owners $0.181/kWh for the renewable electricity they produce (Wang et al., 2011).

This study found that the low and volatile electricity rates are the most common response as to why Washington State dairy farmers have been slow to adopt AD technology. This study suggests that the SPEED Program be reviewed and analyzed for potential application into the Washington RPS policy framework.  Additionally, because of the CVPS Cow Power Program's success and similarity with the SPEED Program, a study would be warranted on Washington consumer willingness to pay rates similar to those paid in the CVPS program.

**Future Outlook**

When asked where they see dairy digester development five to ten years from now, the interviewees generally agreed that the industry is stagnant right now and will remain "exactly where it is right now," as one interviewee indicated, unless something changes.  "Maybe in five years we'll see another round of development, but I don't see any digesters on the horizon."  Another interviewee responded, "with the current electricity rates that I'm hearing out there right now, not a whole lot—not in Washington—unless that market changes."  According to this study, the most effective way to spur AD development is through renewable energy reform that includes subsidized electricity rates.

# Conclusion

## Findings

Through interviews with dairy farmers and developers active in the dairy digester industry, this study attempted to address what factors are inhibiting the adoption of AD technology by Washington State dairy farmers. The results of this study suggest that, while many potential answers to this question were identified, the most common answer among interviewees was low and volatile electricity rates. Based on the results and the literature reviewed, this study suggests that a fixed-price, cost-based, technology specific feed-in tariff policy, similar to Vermont's Sustainably Priced Energy Enterprise Development Program (SPEED) be considered by policy makers for potential application in Washington's renewable energy policy framework.

## Future Research

Further studies are needed to analyze the SPEED Program and the CVSP Cow Power Program to better inform policy makers of their potential application in Washington State renewable energy policy. Additionally, it would be beneficial to survey the Washington dairy farmer community with a questionnaire similar to the one mailed out by Gremelspacher et al., (2010). A survey specifically drawn from this study's themes could assess the potential interest that the dairy farmer community may have in participating with either of the three business models represented in Washington State.

While this study has addressed many points of interest, there were several unexpected findings that were highlighted in the results and discussion chapter that were beyond the scope of this study, such as food-processing waste availability, the complexity an AD may add to a dairy community, and carbon market effects on ADs. Further research into these subjects would expand our understanding of the limitations and potential of future AD development, and may encourage the promotion and adoption of ADs throughout Washington State and possibly the nation. ADs have the potential to be a solution to many of the environmental problems we face as a society today, and will likely continue to face in the future.

**Anaerobic Digesters as a Solution**

As previously mentioned, there are many environmental concerns associated with the dairy industry including GHG emissions from traditional manure lagoons, eutrophication of waterways, and the spread of harmful pathogens. This section briefly covers these concerns and how application of AD technology onto dairy farms may provide a solution to both environmental issues and dairy farmer economics.

As noted in the introduction, GHG estimates from livestock production accounts for approximately 18% of global GHG emissions—contributing about 50% of total methane (CH4) emissions (Kebreab, Clark, Wagner-Riddle, & France, 2006). Through application of the eight ADs currently operating in Washington State, the manure from 14,000 dairy cows, or approximately 6% of the total dairy cow population is being processed through ADs. Because Washington State has a relatively large dairy industry of approximately 250,000 dairy cows, AD technology has the potential to significantly reduce GHG emissions from dairy farms in Washington State.

Commercial dairy farms produce large amounts of waste in a relatively small area. Animal waste applied to land can contaminate ground and surface water leading to eutrophication and human health problems (EPA, 2012b). Additionally, eutrophication of waterways has been shown to lead to highly undesirable changes in ecosystem function and structure in freshwater, marine, and terrestrial systems (Smith, Tilman, & Nekola, 1999). The nitrogen content of liquid effluent after anaerobic digestion has been shown to have a faster absorption rate by crops, which not only is preferred by farmers but may reduce the amount of nutrient runoff into nearby waterways (Benedict & Redfern, 2013).

While currently the digestion process alone does not reduce the amount of nutrients in the effluent, nutrient recovery systems being developed can serve as a method of separating out nitrogen and phosphorus from the effluent (Benedict & Redfern, 2013). A system patented by WSU and installed at the Vander Haak Dairy in Whatcom County, Washington has been shown to recover up to 80% of phosphorus and nitrogen from the digested effluent (Benedict & Redfern, 2013). ADs integrated with nutrient recovery systems have the potential to aid dairy farmers in nutrient management techniques, which would decrease eutrophication concerns and potentially increase crop yield. Additionally, nutrient recovery systems may offer dairy farmers an additional source of income from the sale of nutrients to areas of the country that are nutrient deficient.

Untreated manure can contain over 150 pathogens or disease causing microorganisms which has been shown to pose health risks to both humans and animals (Saunders, Harrison, Fortuna, Whitefield, & Bary, 2012). Even though most dairies are required to treat their manure under the Dairy Nutrient Management Act, in order to lower the pathogen concentrations (Liu, Shumway, & Collings, 2003), they still pose a threat as many pathogens, including enterococci, *E. coli,* fecal streptococci, and *Salmonella,* have been shown to exhibit regrowth after being land applied. Treatment of manure through anaerobic digestion has been shown to be an effective method of reducing harmful pathogens from the manure (Saunders et al., 2012).

The application of ADs on dairy farms has the potential to significantly reduce GHG emissions, eutrophication of waterways, and both human and animal health risks associated with harmful pathogens. Additionally, as discussed in the previous chapter, farmers who seek ways to diversify their revenue streams or offset the cost of bedding for their cows may benefit from developing their own digester or by participating in a digester operation. The results from this study indicate a potential synergy between the environmental problems we face as a society and dairy farming economics. Due to Washington State's relatively large dairy industry coupled with WSU's AD research and development, Washington has the potential to be a leader towards a cleaner, healthier, and more sustainable renewable energy future.

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# Appendix A. Generic Set of Questions asked of Interviewees

1. How did you first hear about dairy digesters?
2. How do you think the majority of Washington State dairy farmers feel about dairy digesters?
3. What were your main reasons for developing a digester?
4. What dairy associated benefits were you anticipating from digester operations?
   - Now that your digester is operational, are your expectations being met?
5. What revenue streams were you expecting prior to development?
   - Are your expectations being met now?
6. Are you receiving additional feedstock from surrounding dairies?
   -What is their role in the operation, just to provide manure in exchange for waste management?
   -Are they content?
   -Would you be able to operate without them?
   -Would you recommend participation to dairy digesters by other farms in similar situations?
   -Do you feel there is a difference in satisfaction of farmers who contribute from surrounding farms from farmers who have an on-site digester?
7. If you had the capacity and infrastructure, would you accept additional manure from other nearby farms?
8. Do you feel there is a difference in satisfaction of farmers who contribute from surrounding farms from farmers who have an on-site digester?
9. What were some of your major concerns prior to developing?
10. Are there any additional revenue streams you're looking at for the near future?
11. Through your experience, do you feel there are a lot of funding options available for renewable energy development projects such as digesters in Washington State?
12. Were there any major roadblocks for you during the development stages?
13. Have there been any major hurdles during the operational stages?
14. Would you recommend AD to other farms with similar sized herds as yours?
15. On a scale of 1-10, how satisfied are you with your choice to develop a digester?

16. How much of an impact did environmental concerns play into your choice to develop a digester
17. How important have RECs and Carbon Credits been for your operation?
18. Where do you see dairy digester development five – ten years from now?
19. What in your opinion is restricting dairy digester development/adoption the most in WA?
20. Do you have any recommendations, policy or regulatory, for the promotion and facilitation of dairy digester development in Washington State?
21. Do you feel there is a different attitude on the success of dairy digesters among third-party owners, farmer/owned operated, and public private partnerships?
22. Is there anything else you would like to share about your experience with AD development?