Digesters and demographics: Identifying support for anaerobic digesters on dairy farms

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ABSTRACT

The dairy industry in the United States is amidst a long-running trend toward fewer, larger dairy farms. This development has created a backlash in some communities over concerns such as odor, waste management, and environmental degradation. Separately, anaerobic digestion has advanced as a waste management technology that potentially offers solutions to some of these issues, providing odor control and a combustible biogas among other things. These digesters require significant capital investments. Voluntary consumer premiums for the renewable energy produced have been used in some instances as a means to move adoption of such systems toward financial feasibility. This project employed a survey to measure Ohio consumers' willingness to pay a premium for renewable energy produced by anaerobic digesters on dairy farms. Cluster analysis was used to segment consumers by willingness to pay, age, education, income, self-identified political inclination, and a composite variable that served as a proxy for respondents' environmental stewardship. Four distinctive groups emerged from the data. Older, less educated respondents were found to have the least amount of support for digesters on dairy farms, whereas politically liberal, environmentally proactive respondents demonstrated the strongest support. Well-educated, affluent respondents and young respondents fell between these 2 groups. Most large dairy farms are generally met with fairly negative responses from their local communities; in contrast, this research finds some popular support for anaerobic digestion technology. Going forward, establishing a positive link between support for anaerobic digesters and for their use on large dairies could open up a new route for less-contested large dairy farm developments. Evaluation of community demographics could become an important part of finding an optimal location for a large dairy farm.

Key words: willingness to pay, anaerobic digestion, dairy

INTRODUCTION

The dairy industry in the United States is well into a long-term trend toward fewer, larger dairies. In 1989, there were just over 10 million dairy cows in the United States on 202,890 dairy farms; as of November 2009, there were almost 9.1 million head on an estimated 67,000 operations (NASS, 2010). These 2 decades alone witnessed a two-thirds decline in operations with only a 7% decrease in the national herd. This shift quantifies the increase of very large dairy farms relative to historical standards. In 2008, the latest year for which data are available, 730 dairies in the United States had more than 2,000 cows, a size category that was not recorded by the National Agricultural Statistics Service until 1998.

This meteoric increase in operation size has resulted in several new problems for the dairy industry. Today, managing public perception regarding animal treatment, waste management, odor, and environmental stewardship has become as much a part of dairy management as controlling feed costs and monitoring herd health. For many new or expanding operations, it is a struggle to site a facility that can earn and maintain public approval.

The trend in concentration of the dairy industry has also led to an increased emphasis on environmental management, especially as related to waste management. One manure management tool that has become increasingly visible in the industry is anaerobic digestion. Anaerobic digestion is a biochemical process in which manure is broken down by microbes, producing an almost odorless, almost sterile effluent and a flammable biogas. The effluent has the potential to be spread and managed in a more effective fashion, because there would be less concern regarding offensive odors, or pressed and reused as a replacement for bedding. The biogas can be burned to provide a clean renewable energy source.

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Because of its somewhat quixotic premise (i.e., turning waste products into clean renewable energy), it is reasonable to believe that some measure of popular and fiscal support for the technology might exist. A logical progression would then question whether such popular backing could then lead to support of the dairies themselves. Given these notions of popular support, 2 distinct research questions emerge. One, is there support among the larger community for anaerobic digestion technology? Two, if such support exists, does it extend to a large dairy using this technology? It is the first question that this research specifically addresses. In this paper, we describe a classification method for sorting observations. This method then is applied to a data set of Ohio consumers to characterize subsets of individuals based on their support for anaerobic digestion technology.

BACKGROUND

The principal question that this paper seeks to answer is this: what types of people would be most supportive of anaerobic digestion technology? More to the point, are there identifiable clusters of individuals that display enough affinity for anaerobic digestion that they may provide support to a large dairy that uses this technology? Conversely, are there individuals who would pose real opposition to this technology?

In addition to positive perception and vocal support (or at least the absence of dissent), some financial backing might be available from consumers. Many states now allow utilities to offer some form of green power pricing whereby consumers can pay some premium to support sustainable, renewable, or clean energy. The premium is transmitted back to the producer to assist in offsetting the capital costs of constructing new renewable energy generation. One example of this type of program is Central Vermont Public Service's Cow Power program. Central Vermont Public Service customers who join the voluntary program choose to buy 25, 50, or 100% of their electricity through the program and pay a \$0.04/kilowatt premium on this consumption. The premium is then paid to the dairy farms supplying the electricity (Central Vermont Public Service, 2009). Although most producers do not view their digesters as profit centers, the additional premiums along with any revenues and savings that could be generated by commodity energy sales or effluent recycling can serve to offset the large capital costs of constructing a digester.

Consumer support for environmentally friendly technologies, including renewable energy, has been established in the literature. There are some recurring attributes related to these consumers. Rowlands et al. (2003) found positive correlations between ecological

concern, political liberalism, education, income, and willingness to pay a premium for renewable energy. This study also found a negative correlation between age and willingness to pay. This negative correlation between age and willingness to pay and environmental consciousness is also reported in Borchers et al. (2007) and Granzin and Olsen (1991).

Even more important, perhaps, than demographic variables are the consumers' sociopsychological characteristics. Schwegler and Cornwell (1991), Arkesteijn and Oerlemans (2005), and Bhate and Lawler (1997) all found that sociopsychological factors were stronger predictors of willingness to pay for environmentally conscious products than the more common demographic variables such as age or income.

This project sought to identify these individuals by examining a data set of Ohio households for groups of consumers that have similar demographics, sociopsychological characteristics, and willingness to pay values. We used cluster analysis as a means of recognizing and isolating unique groupings of consumers, including those who may or may not be positive supporters of anaerobic digestion.

DATA

The survey from which the data for this project were taken was the Ohio Survey of Food, Agricultural, and Environmental Issues. It is a biennial survey conducted by The Ohio State University's Rural Sociology Program across the state to examine Ohioans' attitudes and concerns about current issues in food, agriculture, and the environment (Sharp, 2008).

The survey was administered in May of 2008. The sample was 3,500 Ohio households, with half of these (1,750) drawn from the 22 metropolitan counties and half (1,750) from the 66 metropolitan fringe and non-metropolitan counties (Adua and Sharp, 2009).

Selected households received a prenotification letter followed by the survey packet, which included a cover letter with two \$1 bills attached, the survey instrument, and a return envelope (Adua and Sharp, 2009). The instructions on completing the survey asked for either an adult female or adult male to complete the survey, with the request for a male or female being evenly split and randomly distributed among the questionnaires. Respondents were freely allowed to keep the money without completing the survey. Nonrespondents were mailed a reminder postcard, a replacement packet, and a second postcard at intervals of roughly 10 business days.

Of the 3,500 households in the initial sample, 318 were returned as undeliverable (Adua and Sharp, 2009). Another 29 were removed as not part of the

population, leaving an effective sample size of 3,153. A total of 1,521 usable surveys were returned, for an effective response rate of 48.2%. The average age of respondents was 54.22 yr. The average education of the respondents was 13.79 yr, corresponding to a high school diploma and some postsecondary education. The average political score was 4.43, just to the conservative side of moderate. The average household income for the sample was \$62,477.

METHODS

The cluster analysis in this project employed both agglomerative hierarchical clustering and agglomerative partitioning clustering methods, specifically a *k*-means algorithm. Cluster analysis can be sensitive to differences in the nominal magnitudes of employed variables because of the use of Euclidian distances to determine an observation's cluster. As a result, variables such as income, which could have nominal values in the thousands, can heavily influence the formation of clusters if the other variables have a much smaller range. To minimize this distinction, all the variables employed in this project were standardized to a normal distribution with a mean of 0 and a standard deviation of 1. Cluster analysis can also be sensitive to missing values, so only those observations that had values for all incorporated variables were used.

The cluster analysis was performed in 2 steps. First, the observations were clustered using hierarchical clustering. This step provided pseudo *t*-scores that illustrated the best-fit number of clusters. Once the appropriate number of clusters was determined, the observations were sorted using partitioning clustering.

Five variables were employed in this analysis. The 3 core demographic variables were age (measured in years), education (years completed), and household income (measured through a series of ranges). Respondents were asked to rate their political views on a scale of 1 to 7, with 1 being extremely liberal and 7 being extremely conservative. Consumers' ecological concern and engagement was measured using a composite variable labeled as the environmental stewardship score. This variable was created by identifying questions in the body of the survey that related to environmentally proactive actions and then eliminating those actions that could potentially have a financial or physiological benefit, such as walking instead of driving. The 5 remaining questions had payoffs that were psychological in nature only. They were recycling items for reuse, using tote bags when shopping, attending a meeting or hearing relating to an environmental concern, donating time or money to an environmental cause, and stopping use of a product because of environmental concerns.

The dependent variables in this analysis were willingness to pay a premium for electricity and willingness to pay a premium for natural gas generated from anaerobic digesters. Here, willingness to pay was used as the metric of support for anaerobic digestion. Willingness to pay is often measured through choice experiments in which several attributes are tested and the premiums for each are disentangled by estimating a representative model. This project was concerned with a single attribute, which simplified the analysis. In separate questions, respondents were asked to indicate the additional amount that they would be willing to pay each month for electricity or natural gas produced by anaerobic digestion. In this way, willingness to pay was directly measured as a premium selected by the consumer. The offered amounts were \$0, \$5, \$10, \$15, \$25, \$35, \$50, and more than \$50. The scaling on the offered amounts reflected the expected distribution of premium payments in that most consumers will chose to pay nothing or very little, with only a few consumers willing to pay considerable premiums. The distance between the smaller values provides a finer gradation to more accurately gauge the acceptable premium for those respondents.

The "more than \$50" category provided a challenge for analysis because it lacked the definitive value of the other choices and did not provide a space for respondents to write in their chosen value. There is no definitive standard for analysis with this type of data point. In a more extensive survey, it would be possible to conduct a follow-up survey over a sample of respondents in this category to gauge a representative value. For this analysis, a value of \$75 was assigned to the "more than \$50" response. This value was based on the logical progression of the offered values and author experience with similar analysis situations.

RESULTS

Respondents were clustered according to their willingness to pay values, age, education, average income, political persuasion, and environmental stewardship. The clusters developed for electricity and natural gas were very similar and provided some distinctive groups. These groups also appeared repeatedly in a related analysis that examined motivations for paying a premium for renewable energy. It should be noted that the clustering algorithm is designed to statistically differentiate groups; however, some groups may nonetheless be economically or demographically similar. Some clusters may also be the best fit for their included observations but lack a larger economic rationale. This analysis focuses on the socioeconomic groups that can be distinguished within the fitted clusters.

Table 1. Cluster analysis of consumers' willingness to pay for electricity from anaerobic digesters^{1,2}

Cluster no.	Variable						Cluster size	Cluster type
	Willingness to pay: electricity (\$/mo)	Age (yr)	Education (yr)	Political attitude ³	Income (\$/yr)	Environmental stewardship ⁴		
1	7.97	40.59	13.08	4.00	50,171	4.13	327	Youths
2	8.25	47.25	16.27	5.26	127,390	4.45	193	Educated wealthy
3	13.78	47.60	16.15	3.06	76,185	7.88	210	Liberal environmentalists
4	55.54	51.23	12.76	4.91	48,258	5.88	93	NA ⁵
5	5.72	66.01	12.69	5.01	38,404	5.01	397	Elders
6	69.59	45.16	16.19	3.83	118,213	6.21	46	Liberal environmentalists

¹Pseudo *F*-statistic = 206.55.²Cubic clustering criterion = 4.471.³Rated on a scale of 1 to 7, with 1 being extremely liberal and 7 being extremely conservative.⁴Rated on a scale of 1.5 to 12, with 1.5 being minimally engaged in environmental stewardship activities and 12 being deeply engaged in environmental stewardship activities.⁵NA = not assigned.

The respondents from the survey were combined into 4 separate groups: the elders, the youth, the educated wealthy, and the liberal environmentalists. These 4 clusters were the groups that emerged the most consistently. The names for these groups are simply descriptive monikers to more easily discuss the cluster and are in no way an editorial comment on the members of the groups themselves.

The results of the cluster analysis are reported in Tables 1 and 2. The cluster analysis was performed using SAS 9.1 (SAS Institute, Cary, NC). The pseudo *F*-statistic is comparable to the *F*-statistic found in standard regression as a measure of explanatory power of the included variables. The cubic clustering criterion examines the clusters' difference from points drawn from a uniform distribution. It is an empirical statistic developed to measure goodness of fit for the clusters based on the expected coefficient of determination, the observed coefficient of determination, the sample size, and the clusters' dimensionality (SAS Institute, 1983).

The Elders

The elders occupied a cluster that averaged 66 yr of age, the oldest cluster in the group. They were the least educated group as well, with an average of 12.5 yr of education. The Elders were also at the bottom end of the income scale, with mean cluster income averaging \$36,700. The cluster also had a tendency to be one of the most politically conservative clusters, although there was more variation for this variable. Similarly, the elders generally had one of the lowest environmental stewardship scores in each group, although more fluctuation existed here as well.

The elders distinguished themselves beyond their demographic characteristics in their attitudes toward anaerobic digestion and their willingness to pay for its attributes. This group always had the lowest willingness to pay of all unique clusters for electricity or natural gas. In each case, the group's willingness to pay was less than half of the average willingness to pay of the

Table 2. Cluster analysis of consumers' willingness to pay for natural gas from anaerobic digesters^{1,2}

Cluster no.	Variable						Cluster size	Cluster type
	Willingness to pay: natural gas (\$/mo)	Age (yr)	Education (yr)	Political attitude ³	Income (\$/yr)	Environmental stewardship ⁴		
1	7.14	37.85	13.60	3.81	50,072	4.30	287	Youths
2	63.98	49.61	13.91	4.53	71,053	5.87	113	Liberal environmentalists
3	13.79	47.93	16.07	2.96	70,247	8.18	151	Liberal environmentalists
4	5.82	57.48	13.63	6.15	56,018	4.51	239	NA ⁵
5	9.04	45.41	16.36	4.73	142,871	5.03	174	Educated wealthy
6	5.28	66.18	12.26	3.99	35,069	5.11	274	Elders

¹Pseudo *F*-statistic = 224.48.²Cubic clustering criterion = 11.795.³Rated on a scale of 1 to 7, with 1 being extremely liberal and 7 being extremely conservative.⁴Rated on a scale of 1.5 to 12, with 1.5 being minimally engaged in environmental stewardship activities and 12 being deeply engaged in environmental stewardship activities.⁵NA = not assigned.

sample as a whole. It is possible, and indeed likely, that this reluctance was attributed in some part to their relatively low incomes. However, the elders' low willingness to pay shows little interest in reducing their wealth through voluntary premiums or financial programs as a means to provide support for anaerobic digestion on Ohio dairy farms.

The Youths

The youths were a cluster that distinguished itself as being unique through its age, with middle-of-the-road characteristics in many other respects. The youths were consistently the youngest cluster developed, with a mean age of 39. They tended to be somewhat more liberal than most of the rest of the clusters, occupying a place just to the left of center in the self-reported scale of political tendencies. Their income averaged right at \$50,000/yr. Their mean education was 13.3 yr, reflective of some college education or degrees in a group of mostly high school educations. The other point of uniqueness for this group was its environmental stewardship scores. The youths consistently had the lowest environmental stewardship score of any of the other clusters.

The youths tended to trend closer to the center regarding willingness to pay. They never had the highest willingness to pay nor the lowest. As a result, this group is not currently an attractive cluster to target for support for anaerobic digestion. However, it is worth considering shifts that may occur as these individuals age: better educated members of the group might advance into the educated wealthy cluster whereas some of the more passionate but income-constrained members might move into the liberal environmentalists cluster as time passes.

Educated Wealthy

The educated wealthy cluster was the most educated cluster, with a mean education of 16.3 yr of education, and a well-paid one, with an average income of \$135,000/yr. The cluster trended toward middle age, at an average age of just over 46 yr, and was generally more conservative than other clusters. Their environmental stewardship scores were in the middle of the range of scores represented.

The potential cynicism of this group of individuals was reflected somewhat in their willingness to pay values. The willingness to pay values for the educated wealthy were below the mean values in the sample for both electricity and natural gas dependent variables. Potentially, these individuals could just have been premium weary in the sense that they pay or have been asked to pay premiums for numerous other items. How-

ever, these individuals do not represent the strongest potential base of support.

Liberal Environmentalists

The liberal environmentalists cluster was largely defined by its political views and environmental activism. This was the most interesting group in composition and is likely the most important group for providing support for anaerobic digestion. They were clearly the most politically liberal group and the most environmentally proactive. The cluster was somewhat less homogeneous than some of the other clusters. Regarding willingness to pay, 2 similar subgroups of the liberal environmentalists appeared, one of which was slightly more conservative, better paid, and less environmentally active. This subgroup appeared specifically in the electricity analysis. Overall, the cluster's average age was 47.8 yr. The group was well educated, with 15.6 yr of education, and fairly well paid, with an average income of \$77,000/yr.

The willingness to pay clusters for liberal environmentalists showed a divergence within the group. As a whole, the liberal environmentalists had higher willingness to pay values than the other clusters. However, within the liberal environmentalists, there was a group with somewhat higher than the norm willingness to pay and a group with markedly high willingness to pay. Unexpectedly, the lower value group was the more politically liberal and environmentally proactive.

From a digester support perspective, this cluster was the most important of the 4. Using willingness to pay as a metric, this group demonstrated the strongest active support for digesters. Furthermore, these individuals had the highest environmental stewardship scores, indicating that they were proactive in their interest. Anecdotally, the members of this cluster are often the most vocally opposed to large dairies. Reaching out to such a group could provide real leverage to large dairies that are in the process of locating and establishing their operations.

CONCLUSIONS

Large dairies face a real challenge in public opinion when it comes to establishing their operations. Concerns over odor, waste management, and environmental degradation can prove to be a serious obstacle to large dairy farms. Anaerobic digestion is a manure management tool that may offer some solutions to these issues. Furthermore, this technology produces clean renewable energy from waste materials.

Support for anaerobic digestion exists within the larger community. This backing exists not only in at-

titudes and preferences but in monetary measures as well. As described, distinctive groups demonstrate considerable support for anaerobic digestion. These individuals value the real and perceived benefits of this technology enough to be willing to pay a premium for it. In turn, this premium would be valuable in moving the installation of an anaerobic digester toward financially feasibility.

Given that approval for this technology exists, the next task is to establish whether it directly translates into support for dairy farms that install digesters. The approving subsets are identifiable, and a directed examination of their willingness to extend acceptance to large dairy farms could establish more positive reception paths for new dairies incorporating the digesters. For those dairy farms that currently have or are contemplating anaerobic digestion, it is critical to recognize the potential resources within the surrounding community that could alleviate some of the financial burden of installing and operating a digester.

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