Opportunities, Constraints, and Research Needs for Co-digestion of Alternative Waste Streams with Livestock Manure in Minnesota

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Section 1: Introduction

Anaerobic manure digestion (AD) is a technology that has been around for centuries, but only until recently has it become a main stream technology in the United States. Anaerobic digestion was developed and modified by a number of researchers in Europe and Asia to address the treatment of human wastes and to produce gas cooking and heating, and energy use (Persson et al, 1979). Many larger scale digesters receiving manure and other waste streams have been installed in the last 30 years throughout Europe. India has installed thousands of very small ADs, along with some larger industrial applications (Persson et al, 1979) (Lusk, 1998). In the United States, the adoption of AD has been very slow and has been hindered by high capital costs and past system failures. In just the last 5 years, a critical mass of ADs has been implemented on farms across the country. These systems tend to focus on the digestion of dairy manure and have been located on-site of relatively large farms. Unlike Europe, centralized ADs have only been developed in a few special circumstances in the United States.

In the State of Minnesota, there are currently only two farm scale ADs that are fully operational, with both of them located on dairy farms. Interest is high among livestock producers who would like to install an AD, but the interest has not matched the implementation of the technology. Alternative biomass waste streams to combine with manure in the AD process may be one strategy to move the development of this technology forward in Minnesota. Minnesota has an abundance of biomass, whether naturally occurring or bi-products of industrial processes, that may be suitable for addition to AD systems. The amount of energy produced by AD of manure in Minnesota is only a small fraction of the entire energy use of the State (Hinds, 2003), but co-digestion of manure with alternative waste streams will help enhance this renewable energy generation technology.

The purpose of this report is to identify potential waste streams in Minnesota that could be combined with manure to enhance biogas production and increase revenues of an AD system. Canada (Monreal, Barclay, and Rousselle, 2004) and Australia (Lake, 1996) have looked at this topic abroad and some Midwestern States in the U.S. are also beginning these types of investigations. This report investigated current research and information pertaining to this topical area and has identified research and knowledge gaps that exist. No new research, whether economic, technical, or scientific, was undertaken for the preparation of this report.

Section 2: Criteria for Mixing Manure with Alternative Waste Streams

The focus of this report is on the alternative waste streams that can be co-digested with manure. Manure AD is becoming more prevalent in the United States and there is a great potential for its use by Minnesota's animal agriculture industry.

The following section gives a brief overview of various aspects of AD.

What is Anaerobic Manure Digestion?

Anaerobic manure digestion is a biochemical process by which organic matter is decomposed by bacteria in the absence of oxygen, producing methane and other byproducts. The complete mixture of this gas is called biogas. Biogas can be used for heating, as fuel for engine generators that produce electricity, or flared into the atmosphere. Biogas consists of a mixture of methane, carbon dioxide, and other trace gases (ex. hydrogen sulfide).

The following is the chemical formula for AD (Frear, Fuchs, Wallman, 2004):

Organic Matter + H20 + Bacteria (Acidogenic/Methanogenic) → CH4 + CO2 + NH3 + H2S

Anaerobic digestion occurs in sealed vessels (digesters) that do not contain oxygen. Two types of digesters used to digest animal manure and other compatible waste streams are: mesophilic and thermophilic. Mesophilic AD is accomplished at temperatures of approximately 30-35 Celsius (body temperature) and requires a retention time of the digestate for 15-30 days in the digester. Thermophilic AD occurs at higher temperatures that typically exceed 55 Celsius. Thermophilic AD has a shorter retention time (12-14 days) and may be able to destroy a larger number of pathogens (European Anaerobic Digestion Network, 2005). The drawbacks of thermophilic are that they are sometimes more costly to run and more complicated than thermophlic digesters.

What Factors Impact the Production of Biogas from Manure and Other Organic Waste Streams?

The digestion of manure and the biogas produced is variable depending upon factors such as the type of manure (liquid vs. solid), animal species, and the type of feed the animals are consuming. This variability of the AD of manure will also be variable depending on the types of other organic waste streams that are being co-digested. The rate and efficiency of the anaerobic digestion process is controlled by the following factors (Burke, 2001):

- The type of waste being digested,
- Its concentration,
- Its temperature,
- The presence of toxic materials,
- The pH and alkalinity,
- The hydraulic retention time,
- The solids retention time,
- The ratio of food to microorganisms,

- The rate of digester loading,
- And the rate at which toxic end products of digestion are removed.

What Waste Characteristics are Important for AD and Biogas Production?

The most important constituents of wastes for AD are to have high levels of volatile solids, such as celluloses and hemi-celluloses. Most volatile solid compounds convert to biogas readily through the AD process. Although, lignin does not break down very well through AD, hence waste streams with high lignin content are may result inefficient AD and low biogas production. The more efficient the biogas production, the higher the methane content of the biogas will be. Biogas is typically 55-65% methane and 35-45% carbon dioxide (Burke, 2001).

What are the Drawbacks of Co-digestion of Different Waste Streams?

There are numerous constraints and obstacles for co-digesting manure with alternative waste streams. Economic, political, regulatory, and technical barriers have to be considered when determining the feasibility of using a particular waste stream with manure.

Rudolf Braun developed the following list of constraints for co-digestion of wastes in his paper *Potential of Co-digestion, limits and Merits* (Braun, 2002):

- Increased digester effluent chemical oxygen demand (COD)
- Additional Pretreatment requirements
- Increased mixing requirements
- Wastewater treatment requirements
- High utilization degree required
- Decreasing availability and rates
- Hygienisation requirements
- Restrictions of land use for digestate
- Economically critical dependent on crop costs and yield

There is a lack of literature, specifically in the United States, that characterizes the digestibility of a number of the waste streams described in the previous section of this report. In the mid-1990s, the State of Michigan developed a report of the potential for using agricultural wastes for biomass energy (Falvey, 1996). This report was fairly favorable to their potential, but did not go into specifics about manure digestion and waste streams that could be used effectively together for co-digestion. Studies need to be conducted in States like Michigan and Minnesota to determine which waste streams are suitable for AD with livestock manures. Future research is needed to fully understand if these wastes indeed are feasible for livestock producers to use with manure digesters. One of the most important aspects to consider are what waste streams will help enhance biogas production of AD with manure. In some cases, high strength biological wastes added to a manure AD system may be problematic for the integrity of the digester. Also, the consistency and frequency of the wastes entering the manure AD is important and could be detrimental to the entire system is not managed correctly.

Economics is a key factor that may inhibit the use of certain waste streams for being used in a livestock AD system. The margins in modern agriculture are very tight and economics plays a large role in every decision a farmer makes. One of the most underlying limiting economic factors will be transportation costs. For example, in a livestock operation, transportation of manure to fields for land application is carefully incorporated into the size of the operation, method of application, and manure storage type and size.

Some waste streams will need further treatment (sterilization) or permitting before they can legally be used on a livestock operation. These types of wastes may have significant benefits for co-digestion with manure, but may have additional added costs and may require a higher level of management by the livestock producer. Most of the work investigating wastes, such as offal from slaughter plants, have been undertaken in Europe and other counties. Because of that fact, further analysis would need to be taken to determine if this type of waste could realistically be incorporated in the manure AD system in Minnesota.

What are the Benefits of Co-digestion of Different Waste Streams?

Manure is a valuable resource to Minnesota farmers, whether it is used as a fertilizer or for producing energy. AD is one of many types of treatment systems that can enhance the value of the manure. A report from the South Jutland University Denmark presents a number of benefits of with AD of manure and co-digestion of bio wastes (Holm-Nielsen and Al Seadi, 1998):

- Cost savings for farmers
- Improved fertilizer efficiency
- Reduced greenhouse gas emissions
- Cost effective and environmentally sound waste recycling
- Reduction of Odors
- Reduction of flies
- Potential pathogen reductions
- Renewable Energy production

In addition, Braun has documented the benefits of co-digestion of multiple substrates, such as manure and other waste streams (Braun, 2002):

- Improved nutrient balance and digestion
- Equalization of particulate, floating, settling, acidifying, etc. wastes, through dilution by manure or sewage sludge
- Additional biogas collection
- Possible gate fees for waste treatment
- Additional fertilizer (soil conditioner) reclamation

- Renewable biomass (“Energy Crops”) disposable for digestion in agriculture

The economic benefit of increased biogas production from the co-digestion of manure with other waste streams is probably the largest benefit. Research has shown that some waste streams have the ability to enhance biogas production from AD systems with manure (citation). Because of the limited amount of research for this area, it important that future studies be undertaken to further quantify the synergistic effects of other waste streams on biogas production from manure digesters. Economic benefits are not limited to increased biogas production. Tipping fees collected by farmers taking these other waste streams could also be another source or revenue for the livestock operation. There are also cost savings to businesses and industry producing these alternative waste streams. Digesting these waste streams with manure as a means of waste treatment in some cases will be much less expensive than treating the waste by other methods.

Manure management is very important for livestock operators in Minnesota. Manure digestion has many inherent benefits that make the manure easier to handle, enhance the fertilizer value, and reduce the odors. Adding other waste streams to improve any of these properties will be a benefit to the livestock producer. In some instances, livestock producers with AD systems also have incorporated manure composting into their operation. The manure composting may occur after the digestion process. If composting is an economic and environmental initiative of the operation, it may be possible to add certain waste streams to the manure that will aid in the composting process.

What are the Primary Waste Streams that can be digested with Manure?

The following are the major identified sources (see section 3 for more detail) of organic waste streams that could be combined with manure in AD:

- Food Industry
- Grain Industry
- Paper and Pulp Industry
- Domestic Wastes
- Livestock Wastes
- Crop Residues

Most manure digesters in the US have only one source of substrate; animal manure from dairy, swine, or poultry. In other countries with a more mature AD industry and more constraints on disposal of organic wastes, mixing or co-digesting manure with other types of waste streams has been common place. In the US, dairy manure has been the prominent source for manure digestion. Manure from swine and poultry has been digested also, but success has been limited. With more livestock operations undertaking manure digestion, alternative waste streams for co-digestion may be important in their development and feasibility.

Section 3: Sources of Waste Streams in Minnesota Potentially Suitable for Manure Digestion

Minnesota is blessed with numerous biomass resources that can be used for a variety of purposes, such as fuel for cars and trucks and biogas for producing electricity and heat. Minnesota Governor Tim Pawlenty has signed into law measures that will double the amount of ethanol in gasoline in Minnesota. "This bill strengthens our rural economy, improves our air quality and reduces our unhealthy dependence on foreign oil," said Governor Pawlenty, "It also puts our state at the leading edge of a very promising industry. We truly are on our way to becoming the Saudi Arabia of renewable fuels (May 10, 2005)". For Minnesota to be successful in implementing a larger number of AD on livestock operations across the State, it will be important that other waste streams than manure be identified and incorporated into these future systems. This section reviews a number of wastes streams, or more appropriately referred to as "resources", that may have potential for co-digestion with manure.

<u>Food Industry</u>:

Breweries: Anaerobic digestion of brewery waste may be a potential option for digestion with manure. In Minnesota, there is a modest brewery industry that remains, but the majority of the industry is located in the Twin Cities metropolitan area. The Schells Brewery in New Ulm, MN is located in a more rural area and may be a possible source of brewery waste. Brewery waste can be rather dilute and this may be a drawback for its use as a waste stream to combine with manure for AD. The Anheuser-Busch company, which has a large fluidized bed digester it uses for AD of their brewery waste, the total solids was about 1%. In this instance, the digester provides a cost savings by producing energy on-site and also by reducing the effluent concentration that is sent to the waste water treatment plant (Riggle, 1996). For this type of waste to be feasible farms to combine with manure in AD, it would be important to determine: 1) availability of the waste in MN, 2) dilution of the substrate, 3) transportation costs involved, and 4) type of digester needed for AD.

Potato Processing: Minnesota has a long history with the potato production industry and is a leading production State of this commodity. Potatoes are produced in the Red River Valley, Central, and Southwestern MN. Potato waste, which varies in type and consistency, could be used as waste stream to combine with manure for AD. Wastes such as spoiled potatoes, rejected potato chips, and wastewater are possibilities. The limiting factors for use of this waste stream would be: 1) proximity to livestock farms to the processing facilities, and 2) the consistency of the waste stream. In the recent past, there was a proposal to design an AD for a Minnesota dairy farm that would include this waste stream, but this project never came to fruition.

Sugar Beet Processing: The Sugar Beet industry in MN is located primarily in the Red River Valley and in SW part of the State. Wastes such as spoiled sugar beets and byproducts of the sugar refining process could be potential waste steams for AD with manure. Like the potato industry, it would be important to have livestock operators in close proximity to the processing plants. The density of livestock operations is much higher in SW MN than the Red River Valley, so a feasibility analysis would need to be conducted to determine if this waste stream is plausible. Another issue, which would relate to potatoes as well, is ensuring that the material in the waste stream was void of inert materials such as soil. Inert materials accumulate in digesters and eventually compromise the integrity of the AD system if it is not managed properly.

Dairy Processing: Minnesota is the 7th largest producer of milk from dairy cows in the United States, with h approximately 6,500 dairy farms. Dairy farms are located throughout the State, but the largest concentrations are in Southeastern and Central Minnesota. Minnesota has a significant dairy processing industry that produces fluid milk, butter, cheese, yogurt, ice cream, and other dairy products. With this variety of products being produced, an equal variety of waste streams associated with dairy processing may be available for AD. Dairy processing facilities are located in both major population centers and in rural areas of the State. Currently, some dairy processing plants are using AD for treating their own wastes on site, which reduces their treatment costs and effluent discharges to waste water treatment plants. Also, at least one dairy processing plant is producing ethanol from their waste streams (Riggle, 1996). The nature of dairy wastes, with high volatile organics and biochemical oxygen demand (BOD), makes them ideal for AD.

One advantage to dairy processing plants is the relatively close proximity of some plants to livestock operations that potentially could install manure digesters. To further the understanding of the scope to which dairy processing waste could be used for AD with manure, the following information should be analyzed: 1) geographic information system (GIS) analysis of location of livestock facilities to dairy processing plants, 2) ratio of manure to different dairy processing wastes in AD that result in optimum biogas production and digestate treatment, and 3) economic costs of transporting dairy processing wastes to on-farm manure digesters.

Meat Processing and Rendering Facilities: Minnesota has meat processing plants for the swine, chicken, turkey, and beef industry. Processing facilities are predominantly in southern MN, with another contingent of poultry processing facilities in Central and North Central, MN. In Europe, wastes from meat processing plants and slaughter houses (abattoirs) are commonly mixed with municipal sludge and manure waste streams in biogas plants (Braun, 2002). One of the main concerns with digestion of this type of waste stream is animal disease transmission. This has been amplified by the proliferation of bongiform encephalitis (BSE) in the United Kingdom and other countries. Therefore, it is necessary to pasteurize the wastes at an elevated temperature after AD to ensure that digestate is free of diseases and pathogens that may be harmful to animal populations.

Catering, Institutional, Domestic, and Restaurant Wastes: This waste stream is another source of wastes that may have potential for AD with manure. Comprised mostly of wastes produced through the food preparation process, these organic waste streams are becoming increasingly problematic for disposal in landfills and treatment by WWTPs.

This is most notable in Europe, which has resulted in separate collections just for this waste stream (CADDET Centre for Renewable Energy, 2000). Many European countries have incorporated this waste stream into AD from biogas plants, some of which are using manure. Researchers from Cornell University in New York State have conducted a study that has looked at the inclusion of food waste with manure and have documented the observed benefits (Scott and Ma, 2004). Research conducted in Switzerland found that the addition of vegetable waste improved and accelerated the AD process (Edelmann, Engeli, and Gradenecker, 2000). In Minnesota, it will be important to understand the amount of theses wastes that could be available for AD with manure and if it would be economically feasible to do so.

<u>Grain Industry</u>:

Ethanol Plants with Wet and Dry Distillers Grains: The ethanol industry has been in development over the last twenty years. Minnesota has a number of ethanol plants and will be potentially adding more and larger plants in the next few years. From the process of distilling ethanol from corn, a product called distillers grain is produced. There are many uses for distillers grain, the most prominent use is for animal feed. Distillers grain is sold as feed in both a wet and dry form. Because many livestock operations are already using distillers grain for feed, it may have the potential as an additional waste stream for a manure digester. Economic analysis of using distillers grain as strictly an AD waste stream, versus an animal feed has not been determined. Also, the performance of distillers grain as an additional to an AD system needs to be investigated.

Damaged Grains: In Minnesota, a small percentage of grain (corn, soybeans, and small grains) is damaged and determined to be unfit for sale. This may be because of improper storage, fire, or other unforeseen circumstances. This grain is usually disposed of by land application to agricultural fields or by putting it into a landfill. Because of this waste streams limited value, it may be an economical waste to digest with manure. There is a need to determine if further treatment is needed for the damaged grain before it enters a digester. Because the condition of the damaged grains is variable, this could impact the consistency of biogas production from this waste stream.

Biodiesel Plants: In Minnesota, biodiesel production is in its infancy, but there are plans for the development of this industry in the near future. Bio-products from the biodiesel production process may a waste stream to digest with manure. Distance from livestock facilities, digestibility of the bio-products, and the cost of hauling the waste will all be factors in determining if this is viable AD waste stream.

Soybean Processing: Minnesota is one of the largest producers of soybean oil and meal in the United States. Investigations on the technical and economic feasibility of using the bi-products from this industry for AD with manure need to be made.

Grain Milling Wastes: The grain milling industry has historically been a very important part of Minnesota's economy. This industry was exemplified with the flour mills industry located in Minneapolis, MN in the early 1990's. This industry continues to be a major industrial sector in Minnesota and is another source of organic waste streams that could be used to co-digest with manure. Location to animal agriculture (transportation costs) and the biological strength of wastes from this industry will be important in determining the viability of using this waste for AD with manure.

Paper and Pulp Industry:

Newspaper and Recycled Paper: Newspaper and recycled paper is an abundant waste stream source that is ubiquitous across the State of Minnesota. In Minnesota, the Haubenschild Dairy has used newspaper bedding as a supplemental waste stream for their manure digester. More research is needed to determine the synergistic effects co-digesting newspaper with manure.

Paper Mill Processing: Minnesota has a significant paper milling and logging industry. It is not apparent that paper mill waste is a good source for AD. This industry is located in Northern MN, where livestock operations that would have the potential for manure digestion are not very prevalent. If this waste stream is plausible for AD with manure, the economics of transporting this waste stream to livestock facilities would need to be determined.

Domestic Wastes:

Human Waste Sludge: In United States, as well as in Minnesota, it is common for municipal waste sludge to be treated with AD. The biogas collected is used for both creating electrical energy and for driving boilers for heating. The co-digestion of manure and human sludge has been accomplished in Europe. This has not been the case in the United States. Analysis is needed that looks into the scientific and political reasons (health concerns, regulations) in Minnesota that would allow or prohibit the co-digestion of human sludge and manure.

Yard Wastes: Yard wastes from gardens and grass clippings from lawns are two waste streams that have potential for AD. Both of these waste streams are available seasonally in MN. Currently, an increasing percentage of this material from residential areas is collected, composted, and reused. This material has been used for AD in European biogas plants. One of the issues associated with this waste is inert material such as soil and wood chips, can be problematic for AD. Also, the energy value of this waste may potentially be low, and the cost of transporting this material will need to be analyzed.

Livestock Wastes:

Mixing Manure from Multiple Species: The majority of AD systems being incorporated into livestock operations in the Midwest are being deployed on dairy operations. In Minnesota, two dairy farms are currently use AD and a handful more will be starting up manure AD systems in the coming years. Dairy manure is very suitable for AD and has been a successful venture for a number of dairy farmers. Minnesota has a strong dairy industry, but also has very robust swine and poultry industries as well.

Swine and poultry manure has more challenges for AD than does dairy manure and the use of alternative wastes streams for co-digestion with manure is very important. There is a need to determine the efficacy of mixing swine and poultry manures together or to mix with other species of manure (dairy, beef) to increase the feasibility of AD.

Residue from Poultry Manure Incineration: Minnesota's first poultry manure incineration plant is going on-line in the very near future. It is not know whether the residual wastes produced from the incineration process is a valuable waste stream to be digested with manure.

<u>Crop Residues</u>:

Corn Stover: Nearly half of Minnesota's cropland is planted into corn. With this large amount of corn being harvested, a large amount of corn stubble (stover) is left behind. This stubble is very important for protecting the soil from erosion from soil and wind. In recent years, the interest in harvesting some of this material for energy production has increased. It is believed that some stubble can be removed without reducing the environmental benefits it provides to the soil. Ethanol production is one of the main ideas for an end use to corn stubble. Analysis is needed to determine the cost effectiveness, technical feasibility, and environmental impact of mixing corn stubble with manure for AD.

Alfalfa or other Legumes: Alfalfa is grown primarily in regions of Minnesota where dairy are prevalent. Alfalfa is not just an important feed for livestock in Minnesota, but is also very good for the environment. Alfalfa is very good at helping reduce soil erosion on steep sloping land and it also helps build soil structure. With losses in cattle numbers in recent years, the amount of alfalfa in Minnesota has steadily decreased. Anaerobic digestion of alfalfa with manure could potential help in developing a new market for this crop and help restore the number of acres planted to it in the future. Research has been conducted that found that alfalfa did increase the biogas production of manure when it was co-digested with it (Kaparaju et al., 2002) Economic and scientific analysis is needed to determine if this is a feasible concept on working farms.

Switch Grass and Small Grains: In Iowa, the Bluestem Biomass process is an example of the use of a native grass for the production of biogas through AD. This is a promising project that may shed light on the efficacy of mixing this type of biomass with manure for AD. For small grains such as wheat and oats, the stubble left behind after harvest may be an optional resource for co-digestion with manure. Small grains are grown primarily in the Red River Valley in NW Minnesota and in areas where cattle are raised. The feasibility of using this material as a co-digestate will depend on many economic factors of collecting and transporting the material. Using the material as bedding, at least for cattle operations, should help with the economics of using it for AD.

Section 4: Research Needs

Anaerobic digestion of manure has been around for centuries and research has been increasing in this field. Unfortunately, there is little research that has been done on working farms in Midwestern states on alternative waste streams for co-digestion. In order for AD to continue to develop in Minnesota, it is important that on-going research is undertaken and keeps in line with the implementation of the technology.

The following are focus areas for research on co-digestion of alternative waste streams with manure from livestock operations in Minnesota:

- **Analyze Available Substrates:** There is a lack of technical research on a variety of available waste streams and their ability to be digested with or without manure. Continued work, beyond this report, is needed to identify available substrates and waste streams for co-digestion with manure.
- **Conduct Bench-top Studies with Small Scale Manure Digesters:** Initial research should involve lower-cost bench-top studies to look at the efficacy of alternative waste streams. These types of studies will allow for experimental control and reproducibility of testing.
- **Conduct Real World Tests with Operational Digester:** Continue to cooperate with farmers on research on manure digesters in Minnesota. Also, determine the plausibility of constructing a research manure digester at the University of Minnesota campus or at one of the Research and Outreach Centers.
- **Economic Analysis:** The University of Minnesota Applied Economic Department has been continually working on economic analysis pertaining to the adoption of AD by Minnesota livestock producers. It is important that this research continues and that economic benefits and constraints for introducing alternative wastes for co-digestion of manure be considered.
- **Decision Matrix Development:** A user friendly decision tool or matrix would be very helpful to assist livestock producers in determining what types of waste streams would be most compatible for mixing with specific types of animal manures.
- **Producer Adoption:** Producer surveys and outreach efforts need to be undertaken to determine which alternative waste streams livestock producers with AD systems are willing to work with.
- **Policy Implications:** The regulatory community (US EPA, MPCA, BAH, MDH, MDA) must be involved in determining what waste streams legally can be used by livestock producers on their farms. Permitting and reporting requirements need to be documented and assimilated into a guidance document on use of alternative waste streams in AD.
- **Funding Resources:** Funding sources for research need to be identified and time-lines for application for funds need be outlined. Also, cost share and grant funds for manure digesters must be documented and winnowed into a central document.
- **Continue CERTs Project Work:** It is important that the Clean Energy Resource Teams (CERTs) initiative continue and that the information compiled by this

group is updated and amended periodically. Through this effort, researchers will be better to connect with agricultural producers that may be interested in AD.

The University of Minnesota and the Minnesota Department of Agriculture will be cooperating on a future LCMR project that will be focusing primarily on the feasibility of multiple farm anaerobic manure digestion systems. Within this study, a limited amount of research will be conducted looking at a few wastes streams that may be beneficial to multiple farm manure digesters in Minnesota.

Section 5: European Model and Examples of Co-Digestion of Manure in Biogas Plants

In Europe, the development of biogas plants that co-digest manure with other wastes has been aggressive over the last two decades. This has resulted because of economic, social, and environmental pressures. The Kyoto Protocol, which requires counties to meet 1990 levels of green house gases, is a very significant driver (Ireland EPA, 2005). In counties like Denmark, with a relatively large livestock population and with a small land base, the development of biogas plants was needed. Many of these plants have been subsidized by their national government in order to make them economically viable. The following is a summary of some of the efforts co-digesting manure with alternative waste streams to produce biogas from a few counties in Europe:

Denmark: Denmark has been a world leader in AD development and implementation, especially for generating manure to electricity systems. One of the driving forces in Denmark is their goal of having 33% of their total energy produced derived from renewable energy sources by the year 2030. It is believed that that the biogas production in Denmark will be increasing by a factor of 10 by the year 2020. Manure is estimated to be about 80% of the biogas potential in Denmark (Anegelidaki and Ellegaard, 2005).

Co-digestion of manure with other organic wastes is common place in Denmark. It is the experience in Denmark that co-digestion of wastes help increase biogas production, which in turn results in a greater energy yield. Manure acts as a beneficial carrier substrate for other types of wastes streams and if beneficial for the following reasons: 1) manure is a good solvent for drier waste streams, 2) manure acts a pH buffer, 3) manure contains nutrients needed for bacterial growth, and 4) manure is helpful in diluting concentrated waste streams (Anegelidaki and Ellegaard, 2005).

As of 2000, there were 20 biogas plants that were operational in Denmark, which mostly involve the digestion of animal manures. These AD systems use both mesophilic (37 Celsius) and thermophilic (53 Celsius) systems for producing biogas and do not resemble counterpart systems being installed in the U.S. for livestock operations. Some of the individual AD systems are primarily a mesophilic system with a final thermophilic phase to reduce pathogens in the waste stream. The University of Southern Denmark has compiled data on individual biogas plants and has developed a very good publication that details how each plant works (Al Seadi, 2000).

United Kingdom: The United Kingdom (UK), like Denmark, has had government initiatives driving the AD and renewable energy industry. Notably, the “Climate Change Levy” and the “Renewable Obligation” (Monnet, 2003) are UK energy initiatives that are helping the development of AD. Although, the application of AD in the UK has not been as wide spread as other European countries. Regulations are driving the use of renewable energy and environmental beneficial technology like AD. One area of focus is the co-digestion of manure with animal bi-product wastes. The UK has promulgated strict regulations for the disposal of animal bi-products in the wake of the Mad Cow Disease outbreak in the early 2000’s. These regulations impact AD of this material to ensure that the digestate is free of any dangerous pathogens (Monnet 2003) (Papadimitriou and Stentiford, 2003). In addition, greenhouse gas reductions in the Kyoto protocol and other directives of the European Union on waters quality have put pressure on the UK to work toward developing more AD systems (Ireland EPA, 2005).

Sweden: The use of AD in Sweden has increased greatly in the 1990s. Like the UK and other European counties, regulation is the impetus behind the adoption of this technology. Specifically, the ban on the land filling of organic wastes, phosphorus reduction regulations, and the Kyoto protocol requirements for Sweden has given AD an outlet for those waste steams to be handled and processed (Nordberg, 2002). Also, the inability to use animal bi-products in feed in Sweden has made slaughterhouse and associated wastes available for AD. Manure is the primary feedstock for most of the biogas plants, so other waste streams co-digested are secondary substrates (Nordberg and Edstrom, 2002). A good example of a Swedish AD plant is the Kristianstad plant that processes a number of wastes. This plant takes in organic wastes such as municipal household organics, distillery bio sludge, abattoirs (animal slaughter plants), liquorice, vegetable wastes (carrots, potatoes), and manure (swine, cattle, poultry). All of these waste streams are processes and co-digested in very efficient manner. The digestate is land applied to near-by farmer fields (Caddet Centre for Renewable Energy, 2000).

Germany: Germany, along with other counties in Europe, has been using AD plants for manure since WWII (Lusk, 1998). As of 2000, Germany had a total of 44 biogas plants that have a processing capacity of 1.2 Million metric tons of bio-waste streams. In total, Germany processes 8 million metric tons of bio wastes, but 85% of those wastes are composted rather than treated through AD. Most of the larger biogas plants in Germany use co-digestion of animal waste, human sewage, and food and processing wastes. Typically, a low solids waste stream is used for these types of plants (Kranert and Hillebrecht, 2000). This is in contrast to Austria which has numerous biogas plants, but there is very little if any co-digestion taking place (Holm-Nielsen and Al Seadi, 1998). Biogas plants that utilize a variety of waste streams will have both an AD and a composting element in the bio waste processing scheme. For example, the Biogenes Zentrum Peine biogas plant built in the late 1990's separates waste streams high in lignin and cellulose that do not digest well and they are composted. Waste streams more suitable for AD are separated and digested (Kranert and Hillebrecht, 2000).

Section 6: Applied Concept in Minnesota: Haubenschild Dairy

The Haubenschild Dairy, near Princeton, MN, milks approximately 800 (900) cows and has been successfully operating an anaerobic manure digester system since 1999. The manure digester is a plug-flow system and the biogas that is collected is run through a CAT 3406 engine generator set that produces 130kW of electricity. Since the outset, the Haubenschild Dairy has co-digested manure with shredded newspaper. The newspaper is first used as bedding and incorporated with the manure before it enters the digester. The new paper is brought to the farm in bulk from the local (who is it) and is finely shredded into bedding with a conventional bale shredder. In recent years, the Haubenschild Dairy has also been taking small amounts of dairy processing waste and incorporating that into the manure digestion stream.

The Haubenschild Dairy has far exceeded the biogas production per cow that was initially projected for the dairy. University of Minnesota researchers believe that this has occurred because of three things: 1) Haubenschild dairy's management of the digester, 2) the precise herd and feed management, and 3) the use of the shredded newspaper as bedding. The University of Minnesota researchers believe that the synergistic effects of the manure and the shredded newspaper combined in the manure digester have resulted in the above normal biogas production at this facility. If additional funding becomes available, a small research study may be undertaken to scientifically document this finding.

Section 7: Conclusion

Minnesota is a leader in renewable energy and is in support of AD systems for livestock operations. For Minnesota to continue its leadership role in AD, it is important that additional livestock operations incorporate AD into the management systems in the near future. To do so, it may be necessary for livestock operations to digester other waste streams with their manure. Economic, environmental, and social issues will guide the use of alternative waste streams with AD of manure. This report is one of many steps needed to help understand this issue and give guidance to livestock producers in Minnesota.

The major findings of this report are:

- Europe is leading the world in AD of manure and alternative waste streams.
- Minnesota industries produce an abundance of organic waste streams that have the potential for use in AD with manure from Minnesota livestock farms.
- There is very limited research and documentation that specifies which waste streams are the most technically and economically feasible for AD with manure.
- The potential economic impact of fully utilizing alternative waste streams with AD of manure seems to be great, but economic analysis must be done to quantify this information.
- Research needs specified in this report must be examined and prioritized by stakeholders involved in AD in MN.
- Livestock producers need readily accessible information on alternative waste streams for AD with manure.

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Works Cited

Al Seadi, T. 2000. *Danish Centralized Biogas Plants – Plant Descriptions*. Bioenergy Department, University of Southern Denmark.

Angelidaki, I. and Ellegaard, L. 2005. *Anaerobic Digestion in Denmark: Past, Present, and Future.* Water Science and Technology.

Braun, R. 2002. *Potential of Co-Digestion: Limits and Merits*. (Publisher???)

Burke, Dennis A. 2001. *Dairy Waste Anaerobic Manure Digestion Handbook: Options for Recovering Beneficial Products From Dairy Manure*. Environmental Energy Company (www.makingenergy.com), Olympia, WA.

Caddet Centre for Renewable Energy. (2000) *Co-digestion of Manure with Industrial and Household Waste.* Technical Brochure No. 118.

Edelmann W., Engeli H, Gradenecker M. 2000. *Co digestion of organic solid wastes and waste waters*, proceedings: II International Symposium on anaerobic digestion of solid wastes, Barcelona, June 1999 in IAW: Water, Science & Technology., #41/3, pp. 263-273.

European Anaerobic Digestion Network. 2005. Website: www.adnett.org.

Flavey, M. 1996. *The Potential of Cogeneration from Manure, Crop Residues, and Food Processing Wastes in Michigan.* Michigan Public Service Commission, Biomass Energy Program.

Frear, C., Fuchs, M., and Wallman, J. 2004. *Bioenergy Inventory and Assessment of Eastern Washington: If it's Organic it has Value*. Harvesting Clean Energy Conference IV, Portland, OR, January 20-21, 2004.

Hinds, P. 2003. *Minnesota's Potential for Electricity Production Using Manure Biogas Resources*. Minnesota Department of Commerce, State Energy Office.

Ireland Environmental Protection Agency. 2005. *Anaerobic Digestion: Benefits for Waste Management, Agriculture, Energy, and Environment.*

Holm-Nielsen, J.B. and Al Seadi, T. 1998. *Biogas in Europe: a General Overview*. Bioenergy Department, South Jutland University Center.

Kaparaju, P., Kalmari, E., Kalmari, J., Luostarinen, S. and Rintala, J. 2002. *Co Digestion of Energy Crops and Industrial Confectionery By-products with cow manure; batch-scale and farm-scale evaluation.* Water Science Technology 45(10):275-280.

Kranert, M. and Hillebrecht, K. 2000. *Anaerobic Digestion of Organic Wastes – Process Parameters and Balances in Practices.* Institute of Waste Management and Environmental Monitoring, University of Applied Sciences Braunschweig/Wolfenbuttel Germany.

Lake, M. 1996. *Energy from Wet Wastes: NSW Government Gets Behind Co-Generation.* UNEP, Environmental Centre, University of Queensland.

Lusk, P.D. 1998. *Methane Recovery from Animal Manures: A Current Casebook.* Resource Development Associates, Washington, D.C.

Monnet, F. 2003. *An Introduction to Anaerobic Digestion of Organic Wastes.* Remande Scotland.

Monreal, C.M., Barclay, J., and Rousselle, G. 2004. *Energy Co generation from Agricultural and Municipal Wastes National Program.* Agriculture and Agri-Food Canada, Ottawa, Ontario.

Nordberg, A. (2002). Treatment *of Animal Waste in Co-digestion Biogas Plants in Sweden*. Swedish Institute of Agricultural and Environmental Engineering.

Nordberg, A. and Edstrom, M. (2002). Waste *Management in Northern Europe: Experiences from the Linkoping Biogas Plant*. Swedish Institute of Agricultural and Environmental Engineering.

Papadimitriou, E.K. and Stentiford, E.I. 2003. *Processing Standards for the Composting and Anaerobic Digestion of Feed stocks Containing Catering Waste.* Presentation #15 at ECN/ORBIT e.V. Animal-By-Products Regulations Workshop 2003, United Kingdom.

Persson, S.P., Bartlett, H.D., Branding, A.E., and Regan, R.W. 1979. *Agricultural Anaerobic Digesters: Design and Operation*. Penn State University, University Park, Pennsylvania.

Riggle, D. 1996. *Anaerobic Digestion for MSW and Industrial Wastewater.* Biocycle, November 1996.

Scott, N and Ma, J. 2004. *Potential of Using Food Wastes in Farm-based Anaerobic Digesters*. Department of Biological and Environmental Engineering.