



Modeling Anaerobic Digestion Based Ammonia Production

Although in its early stages, anaerobic digestion (AD) is currently being explored as a renewable energy source in Minnesota. Anaerobic digestion is the biological breakdown of manures and other materials into flammable gases which can be used for electric generation, heat, or as chemical feedstocks in industry. Often referred to as biogas, this gas can be purified to industrial quality and injected into natural gas pipelines. It contains energy-rich methane, hydrogen, and carbon monoxide, which are each gases that can be used as building blocks for other chemicals. With an abundant supply of animal manures and crop residue biomass in the state, anaerobic digestion has a potential to supply Minnesota with a significant amount of renewable energy for different uses.

One potential use for this biogas is the production of anhydrous ammonia. Conventional ammonia production uses natural gas captured during oil production to produce anhydrous ammonia. Using methane from the natural gas in a process called steam methane reforming, the energy in the methane molecules is used to bond nitrogen molecules from the air with hydrogen molecules from the methane. This is typically done in huge industrial scale facilities located near oil fields. However, this same technology can be used at a smaller scale with biogas. A diagram of how this could work is on the following page.

Because Minnesota has no fossil fuel resources, it imports hundreds of millions of dollars' worth of anhydrous ammonia based fertilizers each year. This research examined how a dairy-based biogas to ammonia plant might be designed and operate.

Modeling Assumptions

Dairy operation:

- Larger dairy system (5000 cow) to maximize biogas
- 300 Tons per day of manure
- 120 lbs manure (total mixed waste) per Animal
- 88% Moisture

Biomass requirements

- Corn Stover used as an added digestion feedstock
- 110,000 tons per year
- 300 tons per day
- 600 round bales per day (1,000 lbs each)
- 17 truckloads per day Transport (36 bales each)
- 22,000 Acres at 5 tons per acre
- Harvested every other corn crop for soil health

Other Inputs

- Low volumes of water
- Water recycled from digestate
- Most liquid from manure
- 40 MWhr of electricity per day

Animal/Crop Waste Handling

- 185 tons per day mixed digestate
- 53.5 tons Liquid
- Pumped using dragline application
- Injected with tractor
- 132.5 tons Solid
- 32 wagon loads per day
- (not accounting for application season)



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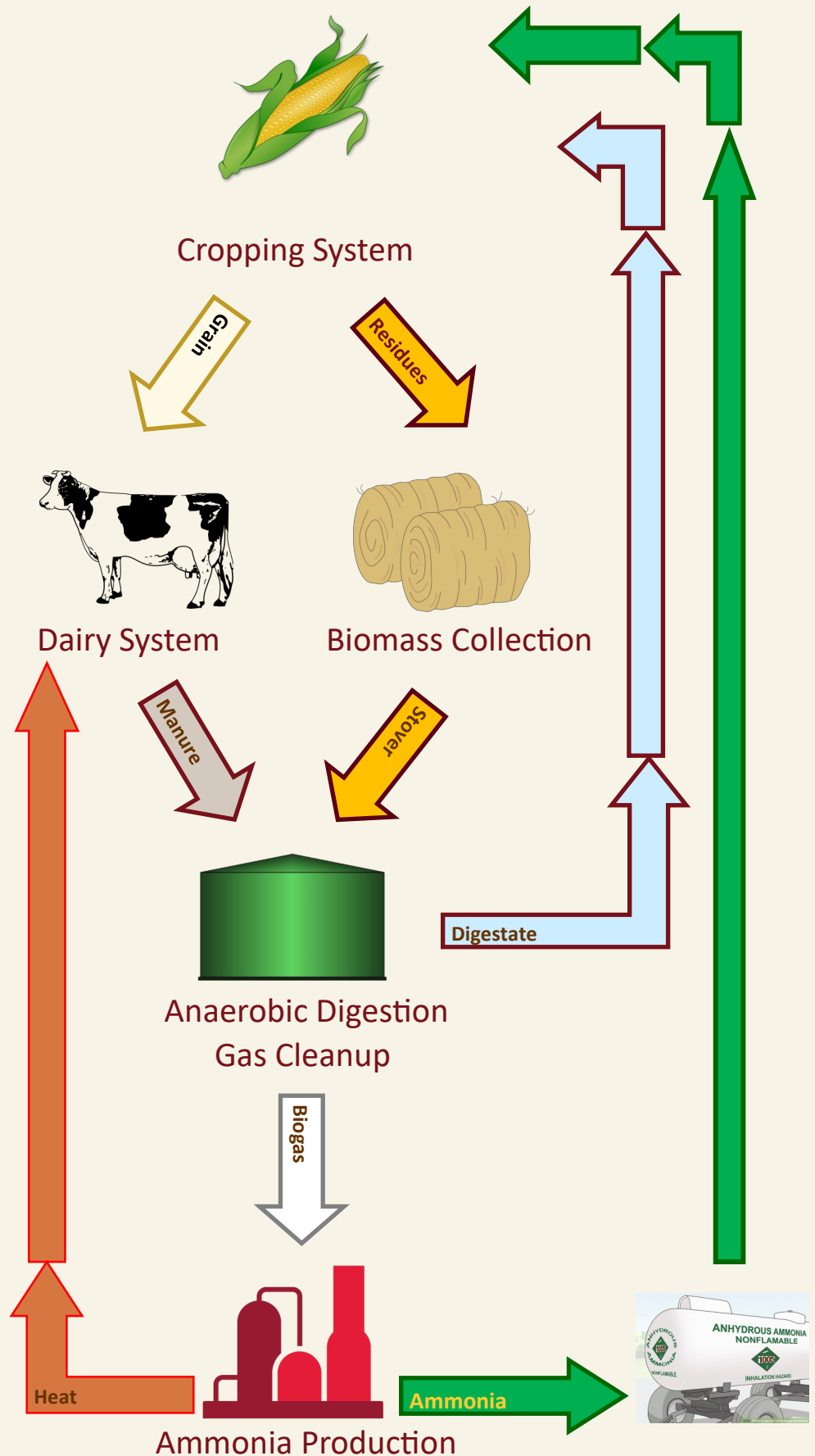
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Ammonia Production via Anaerobic Digestion

Figure 1. Overview of Anaerobic Based Anhydrous Ammonia Production.

The feedstocks used for ammonia production begin with crop production. Alfalfa and corn silage are the two predominant feed sources for cows in the system. Corn Stover is harvested after grain harvest. The large bales of stover are shredded and mixed with cow manure slurry. This mixture is put in a heated tank and microbes breakdown much of the hydrocarbons into methane, hydrogen, carbon monoxide (biogas), along with other impurities. The remaining components of the manure and stover (digestate) contain nutrients, and can be applied to crops as fertilizer. The biogas is piped to the ammonia production plant where it is used to make anhydrous ammonia by steam-methane reforming. The ammonia can then be used as a fertilizer or industrial chemical. Heat from this process may also be used for the anaerobic digestion process or in other places in the dairy system. It is not included in the current modeling work.



Project Economics

The current low cost of natural gas has significantly reduce the price of conventional anhydrous ammonia from where it was seven or eight years ago. Therefore, the economics of this smaller scale production are not currently viable. This could significantly change if ammonia prices returned to their previous higher levels. Another potential future incentive may be the environmental benefits of producing a 'green' renewable based ammonia. However for the moment, the system is not economically feasible.

The two primary costs for the system are the on-going purchases of biomass and capital costs for building the biomass digestion and ammonia production system. It was assumed that manure would be free and that auxiliary costs included in the facility would cover the additional expense of digestate application to cropping systems. It was assumed the dairy was an existing facility whose operation would not be substantially impacted by the ammonia production system.

Expenses

Facility Costs:

	Anaerobic digester
Base module cost	\$18,000,000
Contingency	\$3,000,000
Total module cost	\$21,000,000
Total plant cost	\$26,000,000
Auxiliary	\$7,800,000
Depreciation	15
Interest rate	10%
Total investment	\$34,000,000

Based on a twenty year lifespan, payback plant costs would be \$1.7 Million per year. It is hard to estimate the amount of cost in repairs and maintenance, but it would be a significant part of the economics. Skilled labor would also be required to operate a complex, high pressure, high temperature ammonia production system. General farm labor would be needed for application of digestate.

Feedstock Costs

The cost of corn stover biomass delivered to a central location would likely be between \$50 and \$90 per ton. If \$60 per ton is used for this model, the yearly biomass cost would be \$7,700,000 per year

Income

Ammonia

The facility is expected to produce about 21,000 tons per year (2.7 tons per hour). At \$600 a ton, The value of the ammonia is \$12,600,000 per year.

Potential Models for Organizing the Business

Depending on the situation, a number of potential models for the business structure could be used. For example, a one organization structure where one business does it all (Dairy-Biomass-AD/Ammonia-Digestate Handling). Or a divided model where a combination of groups (Dairy, Biomass- Digestate, AD/Ammonia) are all separate.



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Questions To Help Guide Discussions

General Questions

What level of need do you see for having local nitrogen fertilizer production? Currently? Future?

Is the environmental impact of the fertilizer used in agriculture important?

(Nitrogen fertilizer is roughly 35% of greenhouse gas footprint of corn)

Do the model assumptions look valid?

Dairy system?

Biomass? Ability to contract biomass harvesting?

Digestate waste? Land to apply digestate on?

Economics

How much labor or added workers would this type of facility require?

Would hiring labor be a benefit to the project, or a problem?

(mostly labor for biomass harvesting and digestate application)

What sort of return on investment would be expected.?

Interest by farmers and/or coop members

Will farmers/owners be interested in adopting the technology?

Would the complexity of the technology deter from investing in the technologies?

Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative - Citizen Commission on Minnesota Resources (LCCMR). Currently 40% of net Minnesota State Lottery proceeds are dedicated to growing the Trust Fund and ensuring future benefits for Minnesota's environment and natural resources.

