BURNS McDONNELL

DANE COUNTY

Final Report

Community Manure Treatment Feasibility Study

PROJECT NO. 169859
FINAL REVISION
JULY 2, 2025

Contents

Executive Summary

Burns & McDonnell formally kicked off the Community Manure Treatment Feasibility Study (Study) with the Dane County Land & Water Resources Department on April 2nd, 2024. The intended objective of the Study was to determine the feasibility of developing a community digester facility that would reduce phosphorus loading within the Yahara River Watershed while maximizing biogas and beneficial nutrient streams. Phosphorus loading into the Yahara River Watershed is not only a concern for Dane County but for the State of Wisconsin and the agriculture industry as well.

Over the course of the study, bi-weekly meetings were held between the Burns & McDonnell project team and the Dane County Land & Water Resources Department. Additionally, an Agricultural Technical Working Group was formed of several farmers and industry professionals working within Dane County. Four meetings with the Agricultural Technical Working Group were held during the duration of the project on May 30th, 2024, August 21st, 2024, November 13th, 2024, and March 12th, 2025. Each meeting allowed the people that would be most impacted by this project to provide valuable feedback and insights to shape the Study.

The Study was divided into four separate tasks, detailed below:

Task #1 – Manure Processing Facility Design and Siting Study

The objective of Task #1 was to determine a suitable location for a manure processing facility within Dane County and to create a preliminary design basis that addresses facility components, process flow diagrams for various systems (AD, RNG, and nutrient recovery), various biogas processing equipment, nutrient recovery technologies, by-product markets, and drying systems. The Site Selection Report can be found in Section A, and the Design and Cost Estimate Basis can be found in Section B.

Task #2 – By Product Market Analysis

Task #2 involved identifying various nutrient recovery technologies/equipment, markets, and possible revenue sources for the byproducts generated. The Nutrient Recovery Report, including a technology decision matrix, is included in Section C.

Task #3 – Business Structure Analysis

Burns & McDonnell's consulting team assessed four different business structures, public ownership, private ownership, cooperative, and public-private partnership, for the community digester project. The advantages and disadvantages of the various structures as well as the economic impact for farmers were included in the analysis. The Business Structure Analysis Report can be found in Section D.

Task #4 – Economic Cost Analysis

Using the information developed in Task #1, Burns & McDonnell created a pro forma and economic analysis that includes capital costs, utility demand and consumption, hourly thermal usage and utility rates, and O&M costs. A sensitivity analysis was also performed with regards to potential market incentives, natural gas prices, byproduct markets, and renewable fuel credit prices. The Economic Impact Report can be found in Section E.

Section A – Site Selection Report

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Dane County Community Digester Siting Report

Dane County Land & Water Resources Department

Site Selection Summary
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1.0 INTRODUCTION

Dane County is exploring options to reduce the nutrient runoff that flows into the Yahara River and ultimately into Lake Mendota, Lake Monona, and other bodies of water in and nearby Wisconsin's capital city, Madison. These lakes have seen considerable nutrient loading from the agriculture operations within the county. The excess nutrients, particularly phosphorus, from cow manure, its field application, and the associated runoff have caused seasonal algae blooms in several lakes within the county. These algae blooms lead to reduced oxygen levels for fish and plant species, water quality concerns, and additional conditions that can be harmful to human health. Burns & McDonnell is collaborating with the Dane County Land & Water Resources Department to determine feasible locations within the county to site community anaerobic digesters with the goal of reducing nutrient runoff into the county's waterways, primarily the Yahara River.

This report will give an overview of seven (7) possible project townships within Dane County, Wisconsin, outline the selection process, and give a final recommendation on the most suitable townships for siting a community anaerobic digester.

The seven (7) possible project townships were selected over the other County of Dane townships based on the number of cows and farms contained within each, founded on the farm data received from Dane County. Once selected, the seven (7) townships were compared based on several criteria. The site selection criteria focused on the physical characteristics of the township. The criteria include:

- Land Availability
- Population Density
- Utility Availability
- Environmental & Permitting Considerations
- Cow & Farm Availability

2.0 CRITERIA OVERVIEW

2.1 Land Availability

The land availability criteria focus on the available land space and logistical infrastructure necessary to support a community digester within a township. The criteria include:

- Land Availability – defined as land zoned for agriculture
- Vehicle Access – defined as the types of highways and roads within a township
- Interstate, Rail, or Major Highway Access
- Grading Considerations

2.2 Population Density

The population density criteria focus on the number of people living within a given township. It is generally considered best practice to site digesters away from cities or towns.

2.3 Utility Availability

The utility availability criteria focused on the proximity or ease of access that a township has to utilities. The criteria include:

- Availability of 3-Phase Power
- Availability of Natural Gas Pipelines

3-Phase power is crucial for operating a digester facility's motors and electrical equipment. Renewable natural gas (RNG) is the likely product of these sites and requires specific distribution equipment. Given the possibility of an RNG facility, proximity to a natural gas pipeline was included as a site selection criterion.

2.4 Environmental & Permitting Considerations

When siting a community digester, it is important to consider environmental impact and subsequent permitting concerns that could present issues and impact installation timelines. The criteria include:

- Proximity to Navigable Lakes, Ponds, Rivers, or Streams
- Potential Wetland Impacts
- Distance to Groundwater
- Nutrient Loading (TMDL) – Percentage of Township Land within the Watersheds of Interest that is under a TMDL (Headwaters Yahara River watershed, Lake Kegonsa-Yahara River watershed, Lake Mendota-Yahara River watershed, and Lake Monona-Yahara River watershed)
- Floodplains – Percentage of Township Land Susceptible to Flooding
- County Zoning

2.5 Manure Availability

The manure availability criteria determine if there is a suitable number of cows and farms within a township to support a community digester. The criteria include:

- Head of Cows per Township
- Ratio of Cows/Farms
- Number of Farms

3.0 DATA REVIEW

To determine which of Dane County's townships would be most suitable for a community digester, GIS data was provided by Dane County and collected from public databases. The following data was compiled and analyzed for each township:

- Total Land Area
- Land Area within a Floodplain
- Land Area Zoned for Agriculture
- Wetland Area
- Waterbody Area
- HUC 10 Watershed Boundaries
- Population Data
- Groundwater Depth
- Topographic Maps
- Number of Farms*
- Head of Cows*

**Dane County provided data about farms within the county and the number of cows at those farms. It was noted that the Dane County did not have complete information about the number of farms or cows within the county. Burns & McDonnell added 200-300 facilities that were determined to most likely be dairy farms, but ultimately, the complete number of cows within the county was estimated (based on available data) for this study.*

4.0 TOWNSHIP EVALUATION

Based on discussion with the Dane County staff and members of the agricultural engagement committee, seven (7) townships were selected for evaluation. Five (5) of the townships selected are within the watersheds of interest (Headwaters Yahara River watershed, Lake Kegonsa-Yahara River watershed, Lake Mendota-Yahara River watershed, and Lake Monona-Yahara River watershed) and had a large number of cows. See Appendix B for detailed maps of the watersheds of interest boundaries, a heat map showing cow populations, utilities, transportation, and floodplain/wetlands in each township. Two (2) of the townships lay outside of the watersheds of interest but contain many cows.

All relevant data within each of these criteria areas were captured and quantified within the site selection ranking matrix. Utilizing the data, quantitative scores were assigned based on site qualifications. These scores were multiplied by an importance factor for each criterion. Each criterion score was then added together to develop the final score for each site.

Table 4-1 below details the townships being evaluated.

Table 4-1: Township Overviews

Township	Head of Cows	Land Area (acres)
Town of Sun Prairie	5,047	8,400
Village of Windsor	6,553	17,711
Town of Montrose	4,583	21,774
Town of Vienna	7,594	22,216
Town of Medina	3,050	21,282
Town of Dane	3,775	22,392
Town of Springfield	4,966	23,003

Table 5-1 below provides the final score from the site selection matrix desktop evaluation and a final recommendation for each site. The scores were developed using a ranking of 0 through 3 (3 being the best score) based on each criterion listed in the Matrix shown in 2.0 Criteria Overview. The 0-3 ranking is multiplied by an importance factor (agreed upon with Dane County and Agricultural Technical Working Group) for each criterion that provides weighting to the overall score based on the importance of the criteria being evaluated. The final scores for each criterion are then added to provide a final overall score out of 102 total points available for each site.

4.1 Town of Sun Prairie

The Town of Sun Prairie is a viable township for siting a community digester. A majority of the land area is zoned for agriculture, there is sufficient transportation infrastructure, and there is a suitable number of cows and farms within the township. However, much of the land area is not within the watersheds of interest and a high percentage of the land area is within a floodplain. See Table 4-2 below for more information.

Table 4-2: Town of Sun Prairie Criteria

CRITERIA		SUMMARY	SCORE
Land Availability	Land Availability	• 71.4% of land zoned for agriculture	9/9
	Vehicle Access	• State/US Highway only at the border of the town	6/9
	Interstate, Rail, or Major Highway Access	• Has rail along the WI-19 corridor; I-94 at south side of the township	6/3
	Grading Considerations	• Mostly flat, with a small portion that is hilly	4/6
Population Density	Population Density	• 73 people per sq. mile	4/6
Utility Availability	Availability of 3-Phase Power Lines	• Power available	9/9
	Availability of Natural Gas Pipelines	• Wisconsin Gas - substantial facilities in the area	9/9
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	• 0.17% of land is a waterbody	3/3
	Wetlands Impacts Nearby	• 8.8% of area is a wetland	4/6
	Distance to Groundwater	• 10" to groundwater	6/6
	Nutrient Loading (TMDL)	• 1.7% of land within the Yahara River Watershed	3/9
	Floodplains	• 14.5% of land within a floodplain	1/3
	County Zoning	• Opted out of county zoning	1/3
Manure Availability	Head of Cows per Township	• 5,047 head of cattle	6/9
	Ratio of Cows / Farms	• Ratio of 336	6/6
	Number of Farms	• 15 farms	4/6
		Total Score	77/102

4.2 Village of Windsor

The Village of Windsor is recommended as a suitable township for a community digester. This township scored the highest in the environmental & permitting considerations criteria, has abundant land available for development, and has sufficient transportation infrastructure. The Village of Windsor does have the highest population density of all seven (7) townships evaluated. If the Village of Windsor is selected for a community digester, it will be important to engage the local community. See Table 4-3 below for more information.

Table 4-3: Village of Windsor Criteria

CRITERIA		SUMMARY	SCORE
Land Availability	Land Availability	• 66.4% of land zoned for agriculture	9/9
	Vehicle Access	• State/US Highways throughout the township	9/9
	Interstate, Rail, or Major Highway Access	• Has I-90 and Rail	3/3
	Grading Considerations	• Mostly flat, with a small portion that is hilly	4/6
Population Density	Population Density	• 316 people per sq. mile	2/6
Utility Availability	Availability of 3-Phase Power Lines	• Power available	9/9
	Availability of Natural Gas Pipelines	• Madison Gas and Electric - entire area with some higher-pressure distribution lines	9/9
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	• 0.73% of land is a waterbody	2/3
	Wetlands Impacts Nearby	• 4.3% of area is a wetland	6/6
	Distance to Groundwater	• 5" to groundwater	4/6
	Nutrient Loading (TMDL)	• 94.6% of land within the Yahara River Watershed	9/9
	Floodplains	• 4% of land within a floodplain	3/3
	County Zoning	• Within county zoning	3/3
Manure Availability	Head of Cows per Township	• 6,553 head of cattle	6/9
	Ratio of Cows / Farms	• Ratio of 243	4/6
	Number of Farms	• 27 farms	4/6
		Total Score	86/102

4.3 Town of Montrose

The Town of Montrose scored the lowest of all the townships evaluated and therefore is not recommended as a potential township for a community digester. Its location on the southwest side of Dane County means that no part of the township is within the watersheds of interest and contains a relatively low number of cattle. There is also no major interstate or rail access within the township. Furthermore, there is very little natural gas pipeline infrastructure in the township. More details on township scoring can be found in Table 4-4.

Table 4-4: Town of Montrose Criteria

CRITERIA		SUMMARY	SCORE
Land Availability	Land Availability	• 63.8% of land zoned for agriculture	9/9
	Vehicle Access	• Only WI state trunklines	9/9
	Interstate, Rail, or Major Highway Access	• No interstate or Rail	0/3
	Grading Considerations	• Hilly portions	2/6
Population Density	Population Density	• 33 people per sq. mile	6/6
Utility Availability	Availability of 3-Phase Power Lines	• Power available	9/9
	Availability of Natural Gas Pipelines	• Madison Gas and Electric - very northern edge with limited capacity lines	3/9
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	• 0.65% of land is a waterbody	2/3
	Wetlands Impacts Nearby	• 9.5% of area is a wetland	4/6
	Distance to Groundwater	• 5" to groundwater	4/6
	Nutrient Loading (TMDL)	• 0% of land within the Yahara River Watershed	0/9
	Floodplains	• 14.3% of land within a floodplain	1/3
	County Zoning	• Within county zoning	3/3
Manure Availability	Head of Cows per Township	• 4,583 head of cattle	3/9
	Ratio of Cows / Farms	• Ratio of 143	2/6
	Number of Farms	• 32 farms	6/6
		Total Score	63/102

4.4 Town of Vienna

The Town of Vienna scored the highest of all seven (7) townships evaluated and, as such, is recommended for a community digester. The town contains the highest number of cattle, is almost completely within the watersheds of interest, and has suitable transportation infrastructure. It is important to note that there is already a community digester, the Waunakee Facility, in the Town of Vienna. If another community digester is sited in the township, it is important to site it in another part of the township to avoid competition with the Waunakee Facility. More details on township scoring can be found in Table 4-5.

Table 4-5: Town of Vienna Criteria

CRITERIA		SUMMARY	SCORE
Land Availability	Land Availability	• 79.4% of land zoned for agriculture	9/9
	Vehicle Access	• No US highways; 1 WI trunkline in SW corner	6/9
	Interstate, Rail, or Major Highway Access	• I-90 and rail in SW corner of the township	3/3
	Grading Considerations	• Mostly flat, with a small portion that is hilly	4/6
Population Density	Population Density	• 47 people per sq. mile	6/6
Utility Availability	Availability of 3-Phase Power Lines	• Power available	9/9
	Availability of Natural Gas Pipelines	• Madison Gas and Electric - entire area with some higher-pressure distribution lines	9/9
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	• 1.87% of land is a waterbody	1/3
	Wetlands Impacts Nearby	• 4.9% of area is a wetland	6/6
	Distance to Groundwater	• 5" to groundwater	4/6
	Nutrient Loading (TMDL)	• 96.3% of land within the Yahara River Watershed	9/9
	Floodplains	• 2.1% of land within a floodplain	3/3
	County Zoning	• Within county zoning	3/3
Manure Availability	Head of Cows per Township	• 7,594 head of cattle	9/9
	Ratio of Cows / Farms	• Ratio of 122	2/6
	Number of Farms	• 62 farms	6/6
		Total Score	89/102

4.5 Town of Medina

The Town of Medina is not recommended as a township for a community digester. The township scored the second lowest, as it is not located in the watersheds of interest, has the lowest number of cattle, and contains the highest percentage of wetlands. More details on township scoring can be found in Table 4-6.

Table 4-6: Town of Medina Criteria

CRITERIA		SUMMARY	SCORE
Land Availability	Land Availability	• 62.1% of land zoned for agriculture	9/9
	Vehicle Access	• No US highways; 2 WI State trunklines	9/9
	Interstate, Rail, or Major Highway Access	• I-94 on south border of the township; Rail access	3/3
	Grading Considerations	• Flat	6/6
Population Density	Population Density	• 40 people per sq. mile	6/6
Utility Availability	Availability of 3-Phase Power Lines	• Power available	9/9
	Availability of Natural Gas Pipelines	• Wisconsin Gas - substantial facilities in the area	9/9
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	• 0.99% of land is a waterbody	2/3
	Wetlands Impacts Nearby	• 15.7% of area is a wetland	0/6
	Distance to Groundwater	• 5" to groundwater	4/6
	Nutrient Loading (TMDL)	• 0% of land within the Yahara River Watershed	0/9
	Floodplains	• 16.8% of land within a floodplain	0/3
	County Zoning	• Within county zoning	3/3
Manure Availability	Head of Cows per Township	• 3,050 head of cattle	3/9
	Ratio of Cows / Farms	• Ratio of 92	2/6
	Number of Farms	• 33 farms	6/6
		Total Score	71/102

4.6 Town of Dane

The Town of Dane is not recommended as a township for a community digester. The township is relatively hilly and has no interstate or major highway access, although it does contain rail infrastructure. Only about 1/3 of the Town of Dane is located within the watersheds of interest. More details on township scoring can be found in Table 4-7.

Table 4-7: Town of Dane Criteria

CRITERIA		SUMMARY	SCORE
Land Availability	Land Availability	• 69.5% of land zoned for agriculture	9/9
	Vehicle Access	• US Highway in SW corner; 1 WI State Trunkline	6/9
	Interstate, Rail, or Major Highway Access	• No interstate access; Rail access	2/3
	Grading Considerations	• Very hilly	0/6
Population Density	Population Density	• 28 people per sq. mile	6/6
Utility Availability	Availability of 3-Phase Power Lines	• Power available	9/9
	Availability of Natural Gas Pipelines	• Madison Gas and Electric - entire area with some higher-pressure distribution lines	9/9
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	• 0.69% of land is a waterbody	2/3
	Wetlands Impacts Nearby	• 4.6% of area is a wetland	6/6
	Distance to Groundwater	• 5" to groundwater	4/6
	Nutrient Loading (TMDL)	• 35.4% of land within the Yahara River Watershed	6/9
	Floodplains	• 5.1% of land within a floodplain	2/3
	County Zoning	• Within county zoning	3/3
Manure Availability	Head of Cows per Township	• 3,775 head of cattle	3/9
	Ratio of Cows / Farms	• Ratio of 74	2/6
	Number of Farms	• 51 farms	6/6
		Total Score	75/102

4.7 Town of Springfield

The Town of Springfield is a viable township for siting a community digester. Most of the township is located within the watersheds of interest, but about 7% of the township is located within a floodplain. The township is also relatively hilly, leading to a slightly reduced overall score. Also of note is the presence of an existing digester facility on the outskirts of the town of Middleton, WI, which is already operating within the township. More details on township scoring can be found in Table 4-8.

Table 4-8: Town of Springfield Criteria

CRITERIA		SUMMARY	SCORE
Land Availability	Land Availability	• 69.9% of land zoned for agriculture	9/9
	Vehicle Access	• US highway and WI state trunkline	9/9
	Interstate, Rail, or Major Highway Access	• US-12 is divided highway through township; No rail access	2/3
	Grading Considerations	• Hilly portions	2/6
Population Density	Population Density	• 81 people per sq. mile	4/6
Utility Availability	Availability of 3-Phase Power Lines	• Power available	9/9
	Availability of Natural Gas Pipelines	• Madison Gas and Electric - entire area with limited higher-pressure distribution lines	6/9
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	• 0.96% of land is a waterbody	2/3
	Wetlands Impacts Nearby	• 5.1% of area is a wetland	4/6
	Distance to Groundwater	• 10" to groundwater	6/6
	Nutrient Loading (TMDL)	• 87.3% of land within the Yahara River Watershed	9/9
	Floodplains	• 7.1% of land within a floodplain	2/3
	County Zoning	• Opted out of county zoning	1/3
Manure Availability	Head of Cows per Township	• 4,966 head of cattle	3/9
	Ratio of Cows / Farms	• Ratio of 71	2/6
	Number of Farms	• 70 farms	6/6
		Total Score	76/102

5.0 RECOMMENDATIONS

Each township is assigned a recommendation status: recommended, viable, or not recommended. Recommended townships are best suited for a community digester. Viable townships have characteristics that make a community digester possible but present, or lack, features that result in a lower site selection matrix rating. Townships that are not recommended lack characteristics that would support a community digester.

Table 5-1: Site Selection Recommendations

SITE	MATRIX RATING	RECOMMENDATION STATUS
Town of Sun Prairie	77	Viable
Village of Windsor	86	Recommended
Town of Montrose	63	Not Recommended
Town of Vienna	89	Recommended
Town of Medina	71	Not Recommended
Town of Dane	75	Not Recommended
Town of Springfield	76	Viable

The top scoring and recommended townships are the Town of Vienna and the Village of Windsor due to the available transportation infrastructure, utility availability, ideal environmental conditions, and high number of farms and cows. Additional information for the Town of Vienna and the Village of Windsor can be found in Section 4.4 and Section 4.2, respectively.

The townships of the Town of Springfield and the Town of Sun Prairie are viable but fall short in certain areas as compared to the Town of Vienna and the Village of Windsor. The Town of Springfield scored lower on the manure availability criteria due to a lower number of cows and ratio of cows to farms. The Town of Sun Prairie scored lower in the environmental and permitting consideration criteria due to only 1.7% of the land area being within the watershed of interest, 14.5% of the land area being within a floodplain, and opting out of county zoning.

The Town of Montrose, Town of Medina, and Town of Dane are not recommended based on a combination of land availability, manure availability, and environmental and permitting concerns. The challenges for these townships are discussed in detail in Sections 4.3, 4.5, and 4.6.

APPENDIX A - SITE SELECTION MATRIX

Appendix A - Site Selection Matrix

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Site Evaluation Matrix
Dane County
Project No. 169859

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State: Wisconsin

Category	Criteria	Imp. Factor	Town of Sun Prairie Notes	Ranking	Score	Village of Windsor Notes	Ranking	Score
Site Development								
Land Availability *Available Space and Transportation Infrastructure to Site a Community Digester*	Land Availability	3	71.4% of land zoned for agriculture	3	21	66.4% of land zoned for agriculture	3	25
	Vehicle Access	3	State/US Highway only at the border of the town	2		State/US Highways through twp	3	
	Interstate, Rail, or Major Highway Access	1	Has rail along the WI-19 corridor; I-94 at south side of twp	2		Has I-90 and Rail	3	
	Grading Considerations	2	Mostly flat, with a small portion that is hilly	2		Mostly flat, with a small portion that is hilly	2	
Population Density	Population Density and Growth	2	73 people per sq. mile	2	4	316 people per sq. mile	1	2
Utility Availability *Distance to Utilities*	Availability of 3-Phase Power Lines	3	Power available	3	18	Power available	3	18
	Availability of Natural Gas Pipelines	3	Wisconsin Gas - substantial facilities in the area	3		Madison Gas and Electric - entire area with some higher pressure distribution lines	3	
Environmental & Permitting Considerations *Distance to Environmentally Sensitive Areas*	Navigable Lake, Pond, River, or Stream Nearby	1	0.17% of land is a waterbody	3	18	0.73% of land is a waterbody	2	27
	Wetlands Impacts nearby	2	8.8% of area is a wetland	2		4.3% of area is a wetland	3	
	Distance to Groundwater	2	10" to groundwater	3		5" to groundwater	2	
	Nutrient Loading (TMDL)	3	1.7% of land within the Yahara River Watershed	1		94.6% of land within the Yahara River Watershed	3	
	Floodplains	1	14.5% of land within a floodplain	1		4% of land within a floodplain	3	
	County Zoning	1	Opted out of county zoning	1		Within county zoning	3	
Manure Availability								
Manure Availability *Cattle and farm availability*	Head of Cows per Township	3	5,047 head of cattle	2	16	6,553 head of cattle	2	14
	Ratio of Cows/Farms	2	Ratio of 336	3		Ratio of 243	2	
	Number of Farms	2	15 farms	2		27 farms	2	
Total Score			77			86		

Category	Criteria	Imp. Factor	Town of Montrose Notes	Ranking	Score	Town of Vienna Notes	Ranking	Score
Site Development								
Land Availability	Land Availability	3	63.8% of land zoned for agriculture	3	20	79.4% of land zoned for agriculture	3	22
	Vehicle Access	3	Only WI state trunklines	3		No US highways; 1 WI trunkline in SW corner	2	
	Interstate, Rail, or Major Highway Access	1	No interstate or Rail	0		I-90 and rail in SW corner on twp	3	
	Grading Considerations	2	Hilly portions	1		Mostly flat, with a small portion that is hilly	2	
Population Density	Population Density and Growth	2	33 people per sq. mile	3	6	47 people per sq. mile	3	6
Utility Availability	Availability of 3-Phase Power Lines	3	Power available	3	12	Power available	3	18
	Availability of Natural Gas Pipelines	3	Madison Gas and Electric - very northern edge with limited capacity lines Wisconsin Gas - would be difficult to connect	1		Madison Gas and Electric - entire area with some higher pressure distribution lines	3	
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	1	0.65% of land is a waterbody	2	14	1.87% of land is a waterbody	1	26
	Wetlands Impacts nearby	2	9.5% of area is a wetland	2		4.9% of area is a wetland	3	
	Distance to Groundwater	2	5" to groundwater	2		5" to groundwater	2	
	Nutrient Loading (TMDL)	3	0% of land within the Yahara River Watershed	0		96.3% of land within the Yahara River Watershed	3	
	Floodplains	1	14.3% of land within a floodplain	1		2.1% of land within a floodplain	3	
	County Zoning	1	Within county zoning	3		Within county zoning	3	
Manure Availability								
Manure Availability	Head of Cows per Township	3	4,583 head of cattle	1	11	7,594 head of cattle	3	17
	Ratio of Cows/Farms	2	Ratio of 143	1		Ratio of 122	1	
	Number of Farms	2	32 farms	3		62 farms	3	
Total Score			63			89		

Category	Criteria	Imp. Factor	Town of Medina Notes	Ranking	Score	Town of Dane Notes	Ranking	Score
Site Development								
Land Availability	Land Availability	3	62.1% of land zoned for agriculture	3	27	69.5% of land zoned for agriculture	3	17
	Vehicle Access	3	No US highways; 2 WI State trunklines	3		US Highway in SW corner; 1 WI State Trunkline	2	
	Interstate, Rail, or Major Highway Access	1	I-94 on south border of twp; Rail access	3		No interstate; Rail access	2	
	Grading Considerations	2	Flat	3		Very hilly	0	
Population Density	Population Density and Growth	2	40 people per sq. mile	3	6	28 people per sq. mile	3	6
Utility Availability	Availability of 3-Phase Power Lines	3	Power available	3	18	Power available	3	18
	Availability of Natural Gas Pipelines	3	Wisconsin Gas - substantial facilities in the area	3		Madison Gas and Electric - entire area with some higher pressure distribution lines	3	
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	1	0.99% of land is a waterbody	2	9	0.69% of land is a waterbody	2	23
	Wetlands Impacts nearby	2	15.7% of area is a wetland	0		4.6% of area is a wetland	3	
	Distance to Groundwater	2	5" to groundwater	2		5" to groundwater	2	
	Nutrient Loading (TMDL)	3	0% of land within the Yahara River Watershed	0		35.4% of land within the Yahara River Watershed	2	
	Floodplains	1	16.8% of land within a floodplain	0		5.1% of land within a floodplain	2	
	County Zoning	1	Within county zoning	3		Within county zoning	3	
Manure Availability								
Manure Availability	Head of Cows per Township	3	3,050 head of cattle	1	11	3,775 head of cattle	1	11
	Ratio of Cows/Farms	2	Ratio of 92	1		Ratio of 74	1	
	Number of Farms	2	33 farms	3		51 farms	3	
Total Score			71			75		

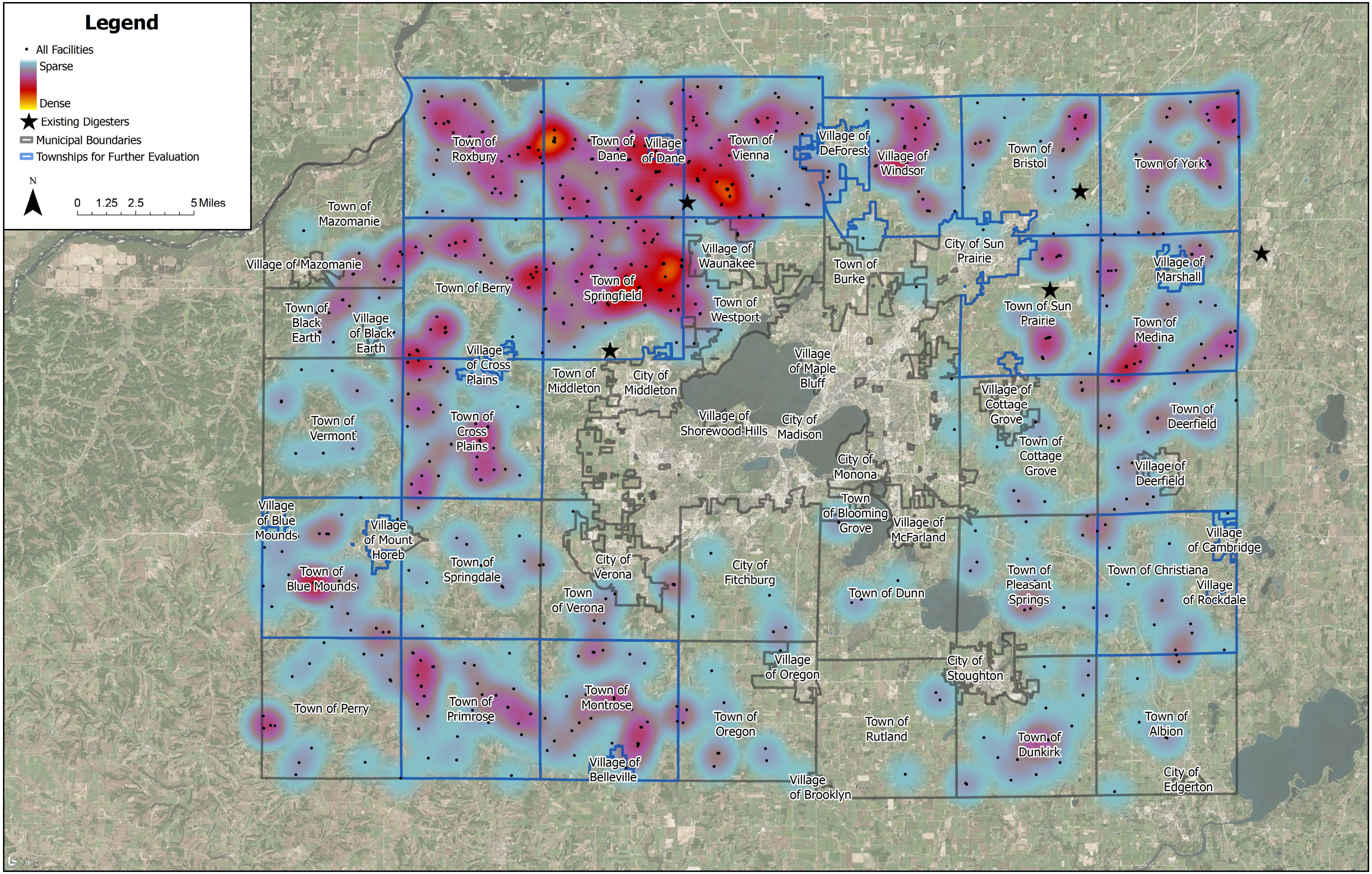
Category	Criteria	Imp. Factor	Town of Springfield Notes	Ranking	Score
Site Development					
Land Availability	Land Availability	3	69.9% of land zoned for agriculture	3	22
	Vehicle Access	3	US highway and WI state trunkline	3	
	Interstate, Rail, or Major Highway Access	1	US-12 is divded highway through twp; No rail access	2	
	Grading Considerations	2	Hilly portions	1	
Population Density	Population Density and Growth	2	81 people per sq. mile	2	4
Utility Availability	Availability of 3-Phase Power Lines	3	Power available	3	15
	Availability of Natural Gas Pipelines	3	Madison Gas and Electric - entire area with limited higher pressure distribution lines	2	
Environmental & Permitting Considerations	Navigable Lake, Pond, River, or Stream Nearby	1	0.96% of land is a waterbody	2	24
	Wetlands Impacts nearby	2	5.1% of area is a wetland	2	
	Distance to Groundwater	2	10" to groundwater	3	
	Nutrient Loading (TMDL)	3	87.3% of land within the Yahara River Watershed	3	
	Floodplains	1	7.1% of land within a floodplain	2	
	County Zoning	1	Opted out of county zoning	1	
Manure Availability					
Manure Availability	Head of Cows per Township	3	4,966 head of cattle	1	11
	Ratio of Cows/Farms	2	Ratio of 71	1	
	Number of Farms	2	70 farms	3	
Total Score			76		

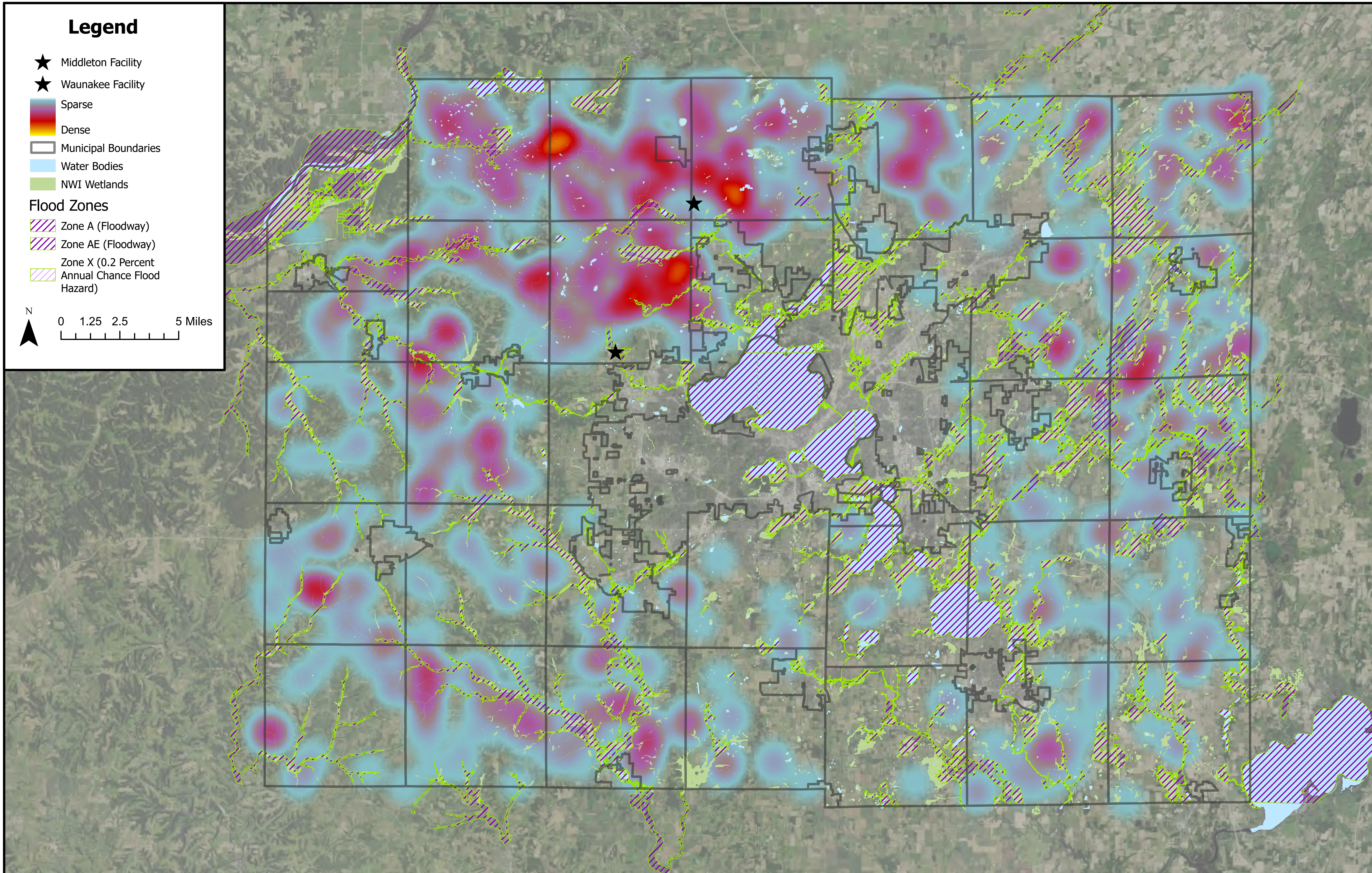
Notes:
1. The importance factor is assigned based on the importance of the criterion being evaluated to establish a viable demonstration site location.
2. The importance factor and the ranking are multiplied to provide the score for each criterion. All scores are added to provide the total scoring shown at the bottom.
3. The rankings for each criterion is further defined in Appendix C - Matrix Ranking Criteria.

Appendix A - Matrix Ranking Criteria

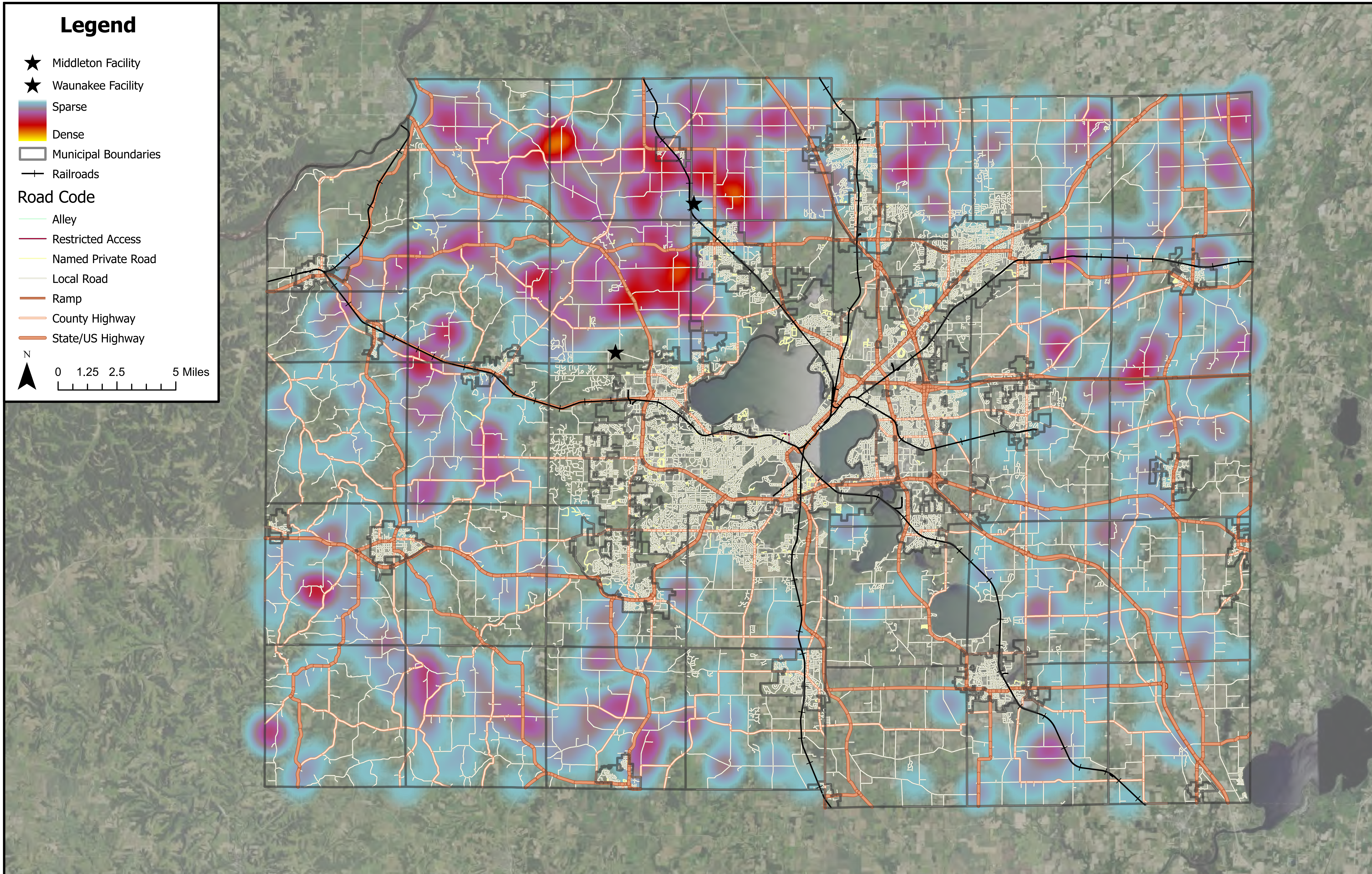
BURNS & McDONNELL			**Ranking Criteria**
State: Wisconsin	**Criteria**	**Imp. Factor**	
Host Site Development			
Land Availability *Available Space and Transportation Infrastructure to Site a Community Digester*	Land Availability	3	% of land zoned for agriculture, 3 > 60%, 2 = Between 60% - 40%, 1 = Between 20% - 40%, 0 < 20%
	Vehicle Access	3	3 =State/US Highway, 2 = County Highway, 1 = Local Roads
	Interstate, Rail, or Major Highway Access	1	3 = Yes; 1 = No; If the township has one and not the other, 2 can be used.
	Grading Considerations	2	3 = Flat; 2 = mostly flat; 1 = flat portions, some hills; 0 = mostly hilly
Population Density	Population Density and Growth	2	3 => 50 people/sq. mile; 2 = Between 275 - 50 people/sq. mile; 1 = Between 275 - 1700 people/sq. mile; 0 =< 1700 people/sq. mile
Utility Availability *Distance to Utilities*	Availability of 3-Phase Power Lines	3	3 = Yes; 0 = No
	Availability of Natural Gas Pipelines	3	3 = multiple (5+) pipelines available, 2= several (3-4) pipelines available, 1 = pipelines (1-2) available, 0 = no pipelines in the area
Environmental & Permitting Considerations *Distance to Environmentally Sensitive Areas*	Navigable Lake, Pond, River, or Stream Nearby	1	% of land that is a body of water, 3 < 0.5%, 2 = Between 0.5% - 1%, 1 = Between 1% - 2%, 0 > 2%
	Wetlands Impacts nearby	2	% of land that is wetland, 3 < 5%, 2 = Between 5% - 10%, 1 = Between 15% - 10%, 0 > 15%
	Distance to Groundwater	2	3 => 10'; 2 = Between 10-5'; 1 = Between 5"-3'; 0 =< 3'.
	Nutrient Loading (TMDL)	3	% of land within the Yahra Rivershed. 3 > 85% reduction in Yahara Watershed, 2= Between 30% - 85% reduction in Yahara Watershed, 1 < 30% reduction in the Yahara Watershed. 0= No improvement of the Yahara Watershed
	Floodplains	1	% of land within a floodplain, 3 < 5%, 2 = Between 5% - 10%, 1 = Between 15% - 10%, 0 > 15%
	County Zoning	1	3 = Yes; 1 = No
Manure Availability			
Manure Availability *Cattle and farm availability*	Head of Cows per Township	3	3 = > 7,500 head; 2 = Between 7,500 - 5,000 head; 1 = Between 5,000 - 1,000 head; 0 = < 1,000 head
	Ratio of Cows/Farms	2	3 => 300; 2 = Between 300 - 150; 1 = Between 150 - 50; 0 =< 50
	Number of Farms	2	3 = > 30 farms; 2 = Between 30 - 15; 1 = Between 15 - 10; 0 = < 10

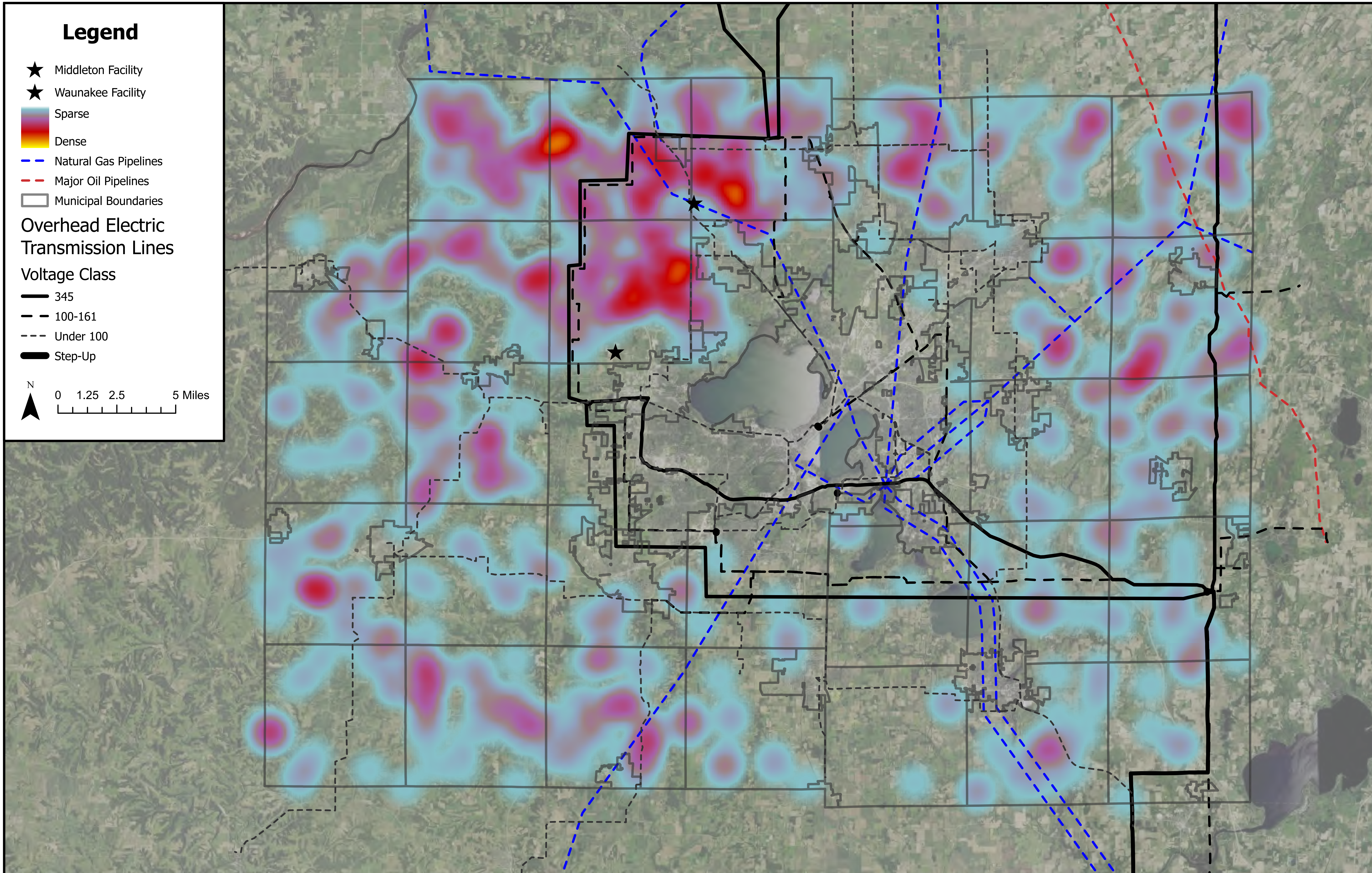
APPENDIX B - COUNTY GIS MAPS


Legend
All Facilities
Sparse
Dense
Existing Digesters
Municipal Boundaries
Townships for Further Evaluation
N
0 1.25 2.5 5 Miles
Town of Roxbury
Town of Dane
Village of Dane
Town of Vienna
Village of DeForest
Village of Windsor
Town of Bristol
Town of York
Town of Mazomanie
Village of Mazomanie
Village of Waunakee
Town of Burke
City of Sun Prairie
Village of Marshall
Town of Berry
Town of Springfield
Town of Westport
Town of Sun Prairie
Town of Black Earth
Village of Black Earth
Village of Cross Plains
Town of Medina
Village of Maple Bluff
Town of Middleton
City of Middleton
Village of Cottage Grove
Town of Vermont
Town of Cross Plains
Village of Shorewood Hills
City of Madison
Town of Deerfield
Town of Cottage Grove
City of Monona
Village of Deerfield
Village of Blue Mounds
Village of Mount Horeb
Town of Blooming Grove
Village of McFarland
Village of Cambridge
Town of Blue Mounds
Town of Springdale
City of Verona
City of Fitchburg
Town of Pleasant Springs
Town of Christiana
Village of Rockdale
Town of Verona
Town of Dunn
Village of Oregon
City of Stoughton
Town of Perry
Town of Primrose
Town of Montrose
Town of Oregon
Town of Rutland
Town of Albion
Town of Dunkirk
Village of Belleville
Village of Brooklyn
City of Edgerton



Legend
Middleton Facility
Waunakee Facility
Sparse
Dense
Municipal Boundaries
Water Bodies
NWI Wetlands
Flood Zones
Zone A (Floodway)
Zone AE (Floodway)
Zone X (0.2 Percent Annual Chance Flood Hazard)
N
0 1.25 2.5 5 Miles


Legend
Middleton Facility
Waunakee Facility
Sparse
Dense
Municipal Boundaries
Railroads
Road Code
Alley
Restricted Access
Named Private Road
Local Road
Ramp
County Highway
State/US Highway
N
0 1.25 2.5 5 Miles


Legend
Middleton Facility
Waunakee Facility
Sparse
Dense
Natural Gas Pipelines
Major Oil Pipelines
Municipal Boundaries
Overhead Electric Transmission Lines
Voltage Class
345
100-161
Under 100
Step-Up
N
0 1.25 2.5 5 Miles


Legend
Middleton Facility
Waunakee Facility
Municipal Boundaries
Watershed of Concern
Water Bodies
HUC10 Watersheds
Allen Creek
Badfish Creek
Black Earth Creek
Blue Mounds Branch
Blue Mounds Creek
City of Spring Green-Wisconsin River
Crawfish River
Headwaters Crawfish River
Headwaters Sugar River
Headwaters Yahara River
Koshkonong Creek
Lake Kegonsa-Yahara River
Lake Koshkonong-Rock River
Lake Mendota-Yahara River
Lake Monona-Yahara River
Lake Wisconsin-Wisconsin River
Little Sugar River
Maunesha River
Otter Creek-Wisconsin River
Ridgeway Branch-East Branch Pecatonica River
Story Creek-Sugar River
West Branch Sugar River
N
0 1.25 2.5 5 Miles
Town of Roxbury
Town of Dane
Village of Dane
Town of Vienna
Village of DeForest
Village of Windsor
Town of Bristol
Town of York
Town of Mazomanie
Village of Waunakee
Town of Burke
Village of Mazomanie
Town of Berry
Town of Springfield
Town of Westport
Village of Marshall
Town of Black Earth
Village of Black Earth
Town of Sun Prairie
Town of Medina
Village of Cross Plains
Village of Maple Bluff
Town of Middleton
Village of Cottage Grove
Town of Vermont
Town of Cross Plains
Village of Shorewood Hills
Town of Deerfield
Town of Cottage Grove
Village of Deerfield
Village of Blue Mounds
Village of Mount Horeb
Town of Blooming Grove
Village of McFarland
Village of Cambridge
Town of Blue Mounds
Town of Springdale
Town of Verona
Town of Dunn
Town of Pleasant Springs
Town of Christiana
Village of Rockdale
Village of Oregon
Town of Perry
Town of Primrose
Town of Montrose
Town of Oregon
Town of Rutland
Town of Dunkirk
Town of Albion
Village of Belleville
Village of Brooklyn

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Section B – Design and Cost Estimate Basis Report

Design and Cost Estimate Basis Report

Dane County Land & Water Resources Department
Project No. 169859

Final Report
2/17/2025

Table of Contents

1.0 PROJECT OVERVIEW

1.1 Project Description

The Dane County Land & Water Resources Department has tasked Burns & McDonnell with performing a feasibility study for a community manure digester facility (Facility) within Dane County, Wisconsin to reduce nutrient runoff to waterways, specifically Lake Mendota and Lake Monona. Local dairy farmers will provide the manure for the community digesters located at the Facility Site. Via anaerobic digestion, the manure will produce biogas that will be either upgraded to renewable natural gas (RNG) for injection into a pipeline or burned in engines to generate electricity and heat in a combined heat and power (CHP) biogas engine.

It is expected that based on the estimated manure collected that the anaerobic digesters will be able to produce at a rate of 1,521 scfm of biogas, equating to about 1,156 MMBtu of daily energy production. The biogas prediction provided was estimated using industry assumptions and similar project experience. The actual energy production will be based on a specific mass balance when the candidate dairy farms are identified, if the county ultimately decides to pursue this venture.

1.1 Process Description

Dairy manure from the participating dairies will be collected, delivered, and deposited into the receiving pits at the Facility by the dairies. The sand laden manure from sand bedded dairies will be entered into a sand separation system while all other bedding types will be dropped off directly into the main manure reception pit. The comingled manure within the manure reception pit will be diluted to meet pumpability requirements in the Facility utilizing recirculation water from the Facility's primary screw press separator effluent. The manure will then be pumped into the anerobic digesters. The biogas produced from the anerobic digesters will be pumped through an H_2S removal system, then, due to it being fully saturated with water at this stage, must go through a moisture removal (dehydration) system prior to the biogas either being burned in a CHP (combined heat and power or biogas engine) to create electricity or upgraded via a biogas upgrader system. The biogas upgrader system removes CO_2 and other trace gases from the biogas, bringing it to pipeline quality prior to injection into a natural gas pipeline. In the event of the biogas being used to make electricity via engines, the removal of CO_2 and trace gases from the biogas is not necessary.

A set of screw presses with a dissolved air flotation (DAF) tank will be utilized to recover most of the phosphorus from the digester effluent (digestate). The effluent (liquid portion) from the screw presses will be sent on to the DAF system. The DAF will produce a nutrient dense wet cake, holding a large portion of the manure digestate's phosphorus, and an effluent stream. The effluent from the DAF will either go to an ultrafiltration (UF) system with reverse osmosis (RO) to separate the residual dissolved solids in the effluent or directly to the Facility's storage lagoon.

After the primary separation (screw presses), the solids from the digestate will be delivered back to the participating dairies (in varying forms based on the different options that will be covered below) and recycled for various applications meeting each individual farm's Nutrient Management Plan (NMP). The liquid digestate from either DAF or UF-RO system, depending on which is selected, will be placed in an onsite lagoon for storage until being taken back to the dairies. The UF-RO system will produce clean water which can be discharged into a waterway and a concentrated waste stream that will ultimately be sent back to the participating dairies in amounts corresponding with the amount of manure they supplied the Facility.

The process and technology selected above was assembled via a combination of industry experience between the engineers and companies involved, feedback from local county dairy farmers, and conclusions stemming from the Nutrient Recovery report previously assembled for this study. The processes and technology selected may be further adapted or modified as the project proceeds, however, the overall technology and processes have been chosen.

1.2 Site Layout

The proposed Facility will likely be located within or on the shared boarder between the Village of Windsor or the Town of Vienna. An exact location has yet to be determined. For the layout of the Facility, it was primarily designed around the high amount of traffic that a single facility taking in hundreds of thousands of gallons of manure a day would experience. The estimated manure flow into the Facility on a daily basis would be approximately 580,000 GPD, roughly 73 tanker trucks a day. It is likely that not all of the manure will be hauled via tanker truck, but the above calculations show that the Facility layout had to allow for high volumes of traffic, focusing on keeping all of it moving as it dropped-off manure, collected bedding sand or manure solids, loaded up digestated concentrate, or collected finished compost/recovered nutrient soil amendment.

The buildings were placed along the Facility access roads in such a way to allow for the trucks dropping manure at the Facility to focus in the front of the Facility, while the trucks picking up material will be at the back of the Facility. Looping access roads and dual access to the high commodity items (compost, bedding fiber/sand, and digestate effluent concentrate) are all built into the layout. The loadout for the lagoon will also be located at the large compost building. It is assumed that the selected location of the Facility will be situated on roadways rated for the heavy machinery and trucks required to deliver manure to and take products away from the Facility without damaging any public roadways. The preliminary Facility layout that can be reviewed in Appendix A.

1.3 Cost Estimate

Please see Appendix D for a high-level cost estimate of the execution of this project. The estimate also does not include the cost for bringing power to the Facility site location. The nature of this study does not include specific timeframes, so costs should be considered high-level and preliminary.

2.0 PROCESS BACKGROUND

2.1 Introduction

This Design Criteria report will be used to define the process design parameters for selecting and sizing the necessary process equipment and cost estimate for the proposed Facility.

2.2 Overall Facility Design Assumptions

All assumptions utilized in the design of the Facility are listed below:

- Available land, up to 40 acres, can be found between the two chosen townships (Windsor and Vienna), selected in task 1 of the Dane County Community Digester feasibility study, to build a single community digester for dairies within its vicinity to bring their manure to for processing and nutrient recovery/control.
- Dairies will bring their manure to the community digester and take away bedding/nutrients/compost/effluent concentrate, logistics of this step is left to the farms at this point of the study.
    - This assumption is to simplify the logistics of handling the manure for the sake of the high level of this study. As the study proceeds and farm candidates are selected, full logistics and costs/costs sharing can be developed.
    - It is assumed that the roads in and around the facility would be of a high enough grade as to allow the heavy machinery on it that would delivery manure to and take product away from the facility.
- All farms will be collecting their manure daily and transporting it to the Facility's manure reception pits.
    - This is an important assumption in terms of the manure quality assumptions used in this report, affecting daily total manure volume and gas production estimates.
        - Manure quality is characterized as the total solids, volatile solids, and biomethane potential of the manure. As excreted, manure has a well-known potential energy content. The more it is handled outside of the digester i.e. separating sand or long residence in an open pit, the net biogas production is negatively affected. This is due to facultative bacteria beginning to breakdown the manure's volatile solids before it is in a tank where the biogas it produces can be collected.

- The Facility will be located near a utility owned gas line that can be used to inject the finished RNG product into and to provide brown gas (utility pipeline supplied natural gas) for heating, electricity production, etc. to the Facility as needed.
    - This assumption is made to minimize the cost to transport the finished RNG product to an injection point and to avoid costs associated with virtual pipeline transportation of the RNG at this stage in the feasibility study. A virtual pipeline setup may be required in the final project but that will not be known until land is selected and can be avoided if land near a gas utility pipeline is selected.
- The dairies will take back their share of the post nutrient recovery process effluent.
    - This assumption is made to simplify the model at this stage of the feasibility study. This is also a common approach used in similarly run facilities.
- The manure will be received at the Facility in three forms broken out into an assumed percentage of each received below.
    - Sand laden (from the dairy using sand as cow bedding material).
        - Assumed to be 25% of all of the manure received.
        - Assumed to be collected via scraping or vacuum truck.
        - Assumed that all sand separation operations will be performed on the manure as it received at the community digester, not at the participating dairies.
        - It is assumed that none of the participating sand bedded dairies have sand separation equipment of their own.
    - Fiber laden (from the dairy using recycled manure fiber as cow bedding material).
        - Assumed to be 65% of all of the manure received.
        - Assumed to be collected via scraping or vacuum truck.
    - Flush flume (diluted manure from using a flush flume to collect the scraped manure from the free stall barns).
        - Assumed to be 10% of all of the manure received.
            - Flush flume manure will be assumed to be using recycled manure fiber bedding.
- The total amount of raw manure received at the community digester is based off dairy herd data received from Dane County. The entire assumed herd size of 20,000 cows are assumed to be wet cow equivalents (WCE), Holstein basis. This means that all cows are corrected to produce 21 lbs. of dry solids a day at 12% total solids, equating to 21 gallons of manure a day.

    - Dairies will tend to have herds comprised of milking cows, dry cows, and calves of varying breeds. Each of these types of cow and cow types will produce different amounts of manure on a daily basis. Since the herd breakdowns are unknown at this level of the study, the entirety of the herd is assumed to all be milking cows (WCEs).
- Manure collection efficiency is assumed to be 100% at all of the participating dairies.
    - Many dairies will have portions of their herd's manure that aren't collectable. This is particularly common in smaller dairy operations. To simplify this at this stage of the study, this assumption was applied.
- Each of the participating dairies will add their parlor flush water into the manure that they will send to the Facility.
    - Flush flume dairies use their parlor flush in their manure flush flume collection systems.
        - This is a common practice amongst dairy farms but is not always the case.

2.3 Nutrient Recovery Option Specific Assumptions

The three options listed below were assembled using findings from the previously submitted Nutrient Recovery report with input from Dane County and Digested Organics. All options will recover 60% or more of the phosphorus in the manure so that it can be either utilized as a crop nutrient or allocated out of the sensitive watersheds within Dane County.

Option 1: All recovered manure fiber (except the fiber required by the dairies bedding on recovered manure fiber) and DAF float/wet cake is composted, with compost going back to the dairies (as NMPs allow) and marketed to Dane county residents. Any remaining will be moved out of the watershed.

- The dairies will have allowance in their NMP to take the bulk of the composted solids back after processing to be used as a soil amendment.
    - The dairies will take back the bulk of the composted solids created and anything outstanding, due to dairy NMP limits, will need to be taken out of the county/watershed. Due to the high level of this study, the above assumption will be used.
- Fiber from existing nearby digester facilities will be taken in and composted.
    - This includes the existing digester facilities in Waunakee and Middleton, WI.

Option 2: All recovered manure fiber (except the fiber required by the dairies bedding on recovered manure fiber) and DAF wet cake will be pelletized and returned to the dairies as allowed by their land nutrient plans, to Dane County residents, and sold/moved out of the county.

- The dairies will take their share of the post nutrient recovery process' effluent for land application.
  - The dairies will be able to take back what their NMPs allow. Anything in excess will need to be moved out of the watershed/county.
- Fiber from existing nearby digester facilities will be taken in and pelletized.
  - This includes the existing digester facilities in Waunakee and Middleton, WI.

Option 3: All recovered manure fiber is dried and returned to the dairies for cow bedding. All of the DAF wet cake will be pelletized and returned to the dairies as allowed by their land nutrient plans, to Dane County residents, and sold/moved out of the county.

- The dairies will take their share of the post nutrient recovery process' effluent for land application.
  - The dairies will be able to take back what their NMPs allow. Anything in excess will need to be moved out of the watershed/county.
- All of the participating dairies will switch to fiber bedding and all of the fiber bedding produced at the Facility will be returned to the dairies.
  - This assumption was made to make this option viable for returning the separated manure fibers back to the dairies for cow bedding.
- Fiber from existing nearby digester facilities will be taken in and provided to the dairy farms for bedding.
  - This includes the existing digester facilities in Waunakee and Middleton, WI.

All of the options discussed above do not include land spreading requirements for the participating dairies, specifically those having excess phosphorus concentrations in their soil. This is due to there being no "land spreading requirements" that can be applied other than not applying any phosphorus to the land with excessive concentrations. That is, the only way to reduce excess phosphorus in the soil is with roots from crops that are harvested. The roots must remove the phosphorus and then the crop is harvested, and the process continues until the optimum soil phosphorus level is achieved. Crops such as rye, oats, wheat, and barley in addition to buckwheat, reed sudangrass/sorghum, cover crops, brassicas, etc. can be utilized. These must be fully removed from the field to remove the phosphorus. To this end, many of these crops can also act as energy feeds to the digester. The application of the resultant digestate must obviously be directed away from the high phosphorus areas within the county.

3.0 GAS PROCESS DESIGN BASIS

The table below shows the gas flow, as calculated using the herd data provided to Burns and McDonnell, and general biogas quality and characteristics that can be expected for the biogas produced by the Facility's digester system.

Table 1: Mass Balance

	Unit	Raw Biogas (dry)[1]	
		Nominal	Min-Max
Flow:	scfm	1,431	1,200 – 1,700
Pressure:	psig	0.11	0 – 0.18
Temperature:	°F	100	85 – 120
CH_4:	%	55	54 – 62
CO_2:	%	41.4	36 – 44
N_2:	%	0.5	0 – 2
O_2:	%	0.1	0 – 0.5
H_2S:	ppmv	2,500	1,500 – 6,000
H_2O:	Lb/MMscf	Saturated	-

1. Values derived from internal biogas production calculations.

4.0 MANURE HANDLING DESIGN BASIS

4.1 Summary of Manure Receiving and Quality

The manure volume used for the design of the Facility is based off county dairy herd data supplied to Burns & McDonnell by Dane County. This data and the chosen location for the community digester site are discussed in the siting selection report that is also a part of this study. For further information regarding the herd data and location selection, please see the Dane County Community Digester Siting Report. This data was paired down to show the highest herd percentage townships within Dane County and upon selecting the two townships with the highest available dairy herd numbers, Windsor and Vienna townships, it was decided, with Dane County's input, that one community digester facility be designed to handle both township's dairy cow herds. These two townships, located beside each other on the north central side of Dane county, provide an ideal location to build a single facility to handle both townships, keeping logistics simpler for the dairies to reach the facility. One large facility was also chosen over two smaller facilities (one in each of the townships) to keep the costs lower, allowing the single facility to purchase larger sized equipment as opposed to having two smaller facilities with similarly sized equipment.

When both Vienna and Windsor township's herds are combined, a total herd size of 20,000 dairy cows is the result. This number will be treated as a total wet cow equivalent (WCE) for the design of the Facility. A wet cow equivalent is defined above in Section 2.2. Using this as a starting place, the raw manure produced was then adjusted for the different manure collection and cow bedding styles that are commonly used at Wisconsin dairies. This included using recovered manure fiber and sand as bedding choices and scrape/vacuum, and flush flume systems for collection of the manure from the free stall barns. It was further assumed that the fiber bedded, sand bedded, and flush flume dairies would represent 65%, 25%, and 10% of the systems used, respectively. Using this assumption, the total manure collected was adjusted accordingly to match this breakdown.

Table 2: Collective Feedstock Summary

Parameter	Value	Units
Total Wet Cow Equivalents[1]	20,000	Head
Percent of Cows from Flush Flume Farms	10	%
Percent of Cows from Sand Bedded Farms	25	%
Percent of Cows from Fiber Bedded Farms	65	%
Total Solids[2,4]	8.1	%
Total Volatile Solids[2,4]	81.8	%
Manure Feed Rate[1,3]	579,625	GPD

1. These values were assumed based off direction from Dane County staff.
2. These values were calculated using an internal biogas estimating tool and the assumptions stated in the section above.
3. Assumes a manure collection efficiency of 100%.
4. The TS and VS values are post-delivery to the Facility and sand separation. They reflect the weighted average expected within the community digester's reception pit daily.

Adjustments were made to the incoming total solids of each of the manure types. The sand laden manure will need to have the sand separated out of it at the Facility. It is possible to remove the sand at each of the dairies, but this process adds water to the manure, raising its total weight and subsequently its costs to move to the Facility. Also, if a sand separation system is run incorrectly, the resulting manure can have excess water and its quality, from a gas production standpoint, can be greatly reduced. Given these reasons, the sand laden manure will be delivered directly into a sand separation system at the Facility. The sand will be recovered and the resulting, post separation manure will be delivered into the reception pit with the other manure streams. The recovered sand will be stacked and returned to the participating dairies that use sand as bedding. The sand separation process will dilute the manure, as this is a requirement of the sand recovery process. This has been factored into the received sand laden manure's total volume, as received daily and added into the total daily manure feed rate.

The recovered fiber bedded manure and flush flume collected manure will be trucked in and deposited directly into the digester reception pit. This manure does not need further processing upon reception and is ready to go into the digester system. It was assumed here that the flush flume manure is on fiber bedding and not sand for simplicity.

Breaking the total daily manure volume into these different categories allows the overall quality of the manure to be corrected for the different bedding and collection styles. After adjusting, the weighted total solids (TS) of the reception pit daily came to 8.14% TS. The weighted volatile solids (VS) content of the reception pit came to 81.8% VS of the TS. These values are important to know for biogas production calculations and can be seen listed out in Table 2 above.

4.2 Reception Pit

There will be one manure reception pit at the Facility that receives all of the manure from the farms. The total combined volume of the pit is sized for an eight (8) hour retention period prior to being transferred into the digesters. The pit will hold 200,000 gallons and have a footprint of 55' by 60' and be 8' deep.

Table 3: Raw Manure Pit Size

Parameter	Value	Units
Proposed Size	200,000	gal

The characteristics of the raw manure feedstocks play a significant role in the sizing of the reception pit. Scrape and vacuum manure from the farms will be thick and on the verge of unpumpable upon arrival at the facility. The thicker the manure is, the harder it will be to keep agitated and therefore pumpable. If the manure were to be put into a pit without sufficient agitation it would set up and become very difficult to pump/remove from the pit. Given this, the larger the reception pit, the harder it will be to keep the manure agitated. There will be thinner manure being introduced from the sand separation system and digestate/effluent can be recycled back to thin out the pit some but there might not be enough of the thinner manure to sufficiently dilute the manure within the pit and recycling too much digestate/effluent leads to a reduction in the reception pit's incoming manure availability volume. In summary, if the reception pit were any larger than proposed above, sufficient agitation of the pit would be unachievable, and operations of the facility would be greatly affected.

4.3 Anaerobic Digesters

Table 4: Anaerobic Digester Information

Parameter	Value	Units
Working Digester Volume (ea.)[1]	1,500,000	gal
Hydraulic Retention Time (HRT) (Min / Max)[2]	20.7	days
Biomethane Potential	400	m^3 biogas / Metric ton of VS
Methane Percentage in Biogas	55	%
Biogas Production	1,431	scfm

1. There will be eight digesters on site resulting in a total working volume of 12,000,000 gallons.
2. Based on the manure intake shown in Table 3.

Based off the feedstock summary referenced in Table 2 and the digesters sized above, a total of 1,431 scfm (1,088 MMBtu) of biogas will be produced daily at the Facility.

4.4 Final Concentrate Lagoon

The onsite lagoon will hold the liquid digestate after the solids have been separated out. The lagoon will hold the liquid concentrate product from the ultrafiltration – reverse osmosis process. This concentrate will be sent back to the dairies in amounts corresponding to the dairy's manure contribution to the facility. The lagoon was sized for a 30-day retention time. For conservative sizing, it was assumed that the lagoon would receive 395,000 gallons per day of liquid digestate. The lagoon is currently sized to be 425' by 250' and 15' in depth.

Table 5: Digestate Lagoon Size

Parameter	Value	Units
Proposed Size	11,860,674	gal

5.0 BIOGAS TREATREATMENT DESIGN BASIS

This section discusses the minimum amount of treatment required to meet the inlet gas requirements for either biogas upgrading to RNG for injection into a pipeline or electricity and heat generation in a CHP (combined heat and power) biogas engine.

5.1 Blower System

The raw biogas blower takes the low pressure (<0.5 psi) biogas and increases it to 2.5 to 5 psi (the exact pressure depends on the downstream equipment selected). The blower is essential to take the gas up to the pressure requirement needed by the H_2S removal vessels. Once pressurized, the biogas will be sent to the H_2S capturing media beds for treatment.

5.2 H_2S Removal

Based on previous project experience, it has been estimated that the H_2S concentration of the gas will be between 1,500 ppm and 6,000 ppm. Common options for removal of H_2S include non-regenerative adsorptive media (activated carbon, iron oxide), and regenerative systems (use chemical compounds and/or biology to remove H_2S). Based on the anticipated biogas flow rates and H_2S concentrations, a regenerative system is recommended for this application to reduce long-term operational costs when compared to media. Burns & McDonnell has included the costs of a regenerative system in our cost estimate, which is provide in Appendix D.

5.3 Moisture Removal

H_2S removal generally requires the biogas to be moist to remove the hydrogen sulfide from the gas, but the downstream equipment desires very little, if any moisture. Due to this, a dehydration system is necessary to reduce the moisture in the biogas. Sometimes this system is built into a compressor skid system or can be a standalone system.

5.4 Biogas Use

The biogas produced by the anaerobic digester system at the Facility will be broken into two options: electricity generation and RNG production. Both are discussed in the sections below.

The excess or off spec gas from either the CHP or RNG process will be combusted in a flare onsite. This is essential to reduce pressure in the system if the CHP or RNG systems are out of service for any reason, otherwise the excess biogas would vent to atmosphere via pressure relief safety valves installed on the digester tanks. A flare is an essential piece of equipment for any anaerobic digester facility.

5.4.1 Electricity Production

Biogas can be used to create both heat and electricity using a CHP biogas engine. The heat can be used to heat the digesters while all the electricity is typically sent to the local utility grid and purchased by that utility via a PPA (power purchase agreement). While less common, some projects utilize a portion of the electricity generated on-site and send the excess electricity generated to the local utility grid. Historically, dairy biogas to CHP projects were a very common way to utilize biogas, but more recently, new biogas to electricity installations are far less common. Biogas CHP projects are costly to maintain and many utilities currently prefer to purchase cheaper intermittent sources of renewable electricity (such as wind or solar) for approximately half of the cost that biogas-based electricity projects require to break even.

The exhaust for the CHP will also require special air permitting and annual emissions source testing. On the other hand, the heat created by the CHP being used to heat the digester tanks presents a sizeable heating savings and it is very marketable to be able to say that the digester system is powering local homes and businesses.

For this Facility, the raw biogas would be scrubbed of its H_2S and dehydrated before being sent to a CHP plant with approximately 6 megawatts (MW) of electric generating capacity. At this capacity range, reciprocating engines are recommended for the production of electricity; furthermore, a N+1 prime mover configuration is recommended to afford for maintenance activities. Caterpillar and Jenbacher are the two most predominantly used reciprocating engine manufacturers in the biogas to electricity industry. Both companies offer engines that are approximately 1.5 MW in capacity, for a total plant capacity of 7.5 MW (assuming N+1). Based on recent estimates for other similarly sized projects, Burns & McDonnell believes that a biogas to electricity CHP plant would cost approximately $20 Million - $40 Million depending on the building requirements, post-combustion emissions control requirements, electrical interconnection requirements, and heat recovery requirements. *This electricity CHP plant cost range includes only the costs of biogas pretreatment/conditioning, engine generators, post-combustion controls (if required) building enclosure, electrical switchgear, electrical interconnect, and heat recovery and distribution infrastructure.*

5.4.1.1 Fuel Cells

Fuel cells are an alternative to CHPs for converting biogas to energy. This is an emerging technology within the biogas space that can take the biogas and convert it directly to energy without producing exhaust. Conversely, these require the biogas to be thoroughly scrubbed, requiring expensive H_2S removal technologies that take the amount of H_2S in the biogas to orders of ppb (parts per billion) as opposed to the standard required by CHPs and RNG of ppm (parts per million). Fuel cells also don't produce heat that can be used by the AD system, like the CHPs do. This technology would slot in in place of the CHP and can be explored further as the community digester facility project gets away from feasibility and closer to actuality.

5.4.1.2 Emerging Biogas to Electricity Market Based Options

5.4.1.2.1 eRINs

A notable provision in the December 2022 draft of EPA's Renewable Fuel Standard (RFS) "Set Rule" included credits derived from the charging of electric vehicles, or eRINs. Specifically, eRINs would have allowed for inclusion of biogas-derived renewable electricity generated domestically or internationally that was used within the conterminous United States. However, proposed provisions related to the generation of RINs from qualifying renewable electricity sources were not included in the final rule released in 2023. Biogas industry groups remain optimistic that approved rules governing the production / procurement of eRINs will materialize in the years to come. Additional discussion on the RFS is provided below under the RNG Markets section.

5.4.1.2.2 Time-Matched Renewable Electricity

The matching of electricity generation to consumer consumption on 24/7 hourly basis typically involves buying the electricity from the same regional area where the consumer's electricity consumption occurs (also referred to as 24/7 Carbon-free Energy). Twenty-four seven hourly matching seeks to drive investments in the technologies required to realize a zero-carbon electricity grid by optimizing carbon free electricity procurement from a time and location perspective. Hourly matching of electricity is a consumer-focused approach to purchasing electricity generation that matches to the consumer's hourly electricity consumption. The matching of electricity generation to consumer consumption on 24/7 hourly basis typically involves buying electricity from the same regional area where the consumption occurs on the electricity grid. It is an approach that seeks to optimize the impact of procurement from a time and space perspective.[1]

On December 26, 2023, the Department of the Treasury and the IRS issued proposed regulations relating to the credit for production of clean hydrogen and the election to treat clean hydrogen production facilities as energy property. Beginning in 2028, the Inflation Reduction Act's Clean

[1] 24/7 Hourly Matching of Electricity | US EPA

Hydrogen Production Tax Credit (Section 45V) requires hourly matching (as currently proposed the electricity would need to be generated in the same hour as the electricity utilized by the hydrogen production facility to produce hydrogen). The IRS and Treasury are soliciting comments on the proposed transition period, the predicted timelines for the development of hour-tracking mechanisms, and the predicted timeline for market development for hourly energy attribute certificates (EACs).

Time matched renewable energy is starting to gain adoption from voluntary renewable energy buyers (i.e. google and Microsoft), but expansion of mechanisms to make the approach accessible to more purchasers is needed, which are contemplated herein:

- Consumer awareness
- Accessibility
- Data tracking
- New technology[2]

Additional resource: 24/7 Hourly Energy Matching & Tracking | M-RETS (mrets.org)

5.4.2 RNG Production

Upgrading biogas to RNG has become the leading use of biogas over the last decade due to the high value of the RNG. It requires more biogas process steps than when utilizing a CHP or fuel cells, but the value of the upgraded gas is significantly higher than the value of the electricity created by the CHP/fuel cells. Also, upgrading the gas does generate limited sources of heat that could be used to heat the AD tanks, but that practice is typically not employed. For the Facility, the biogas would be scrubbed of its H_2S, dehydrated, and compressed before being upgraded via a pressure swing absorption (PSA) or membrane system. For this application, either a PSA or membrane system would typically achieve the desired quality of RNG required for pipeline injection. After upgrading, the gas is compressed again and further dried, if required, before either injection into a pipeline or virtual pipeline offloading facility. The proposed Facility is presumed to be sited within a few miles of a natural gas pipeline, so direct injection could be utilized, saving money on trucking the gas and the associated equipment required to do so.

[2] The State of 24/7 Carbon-free Energy: Recent Progress and What to Watch | World Resources Institute (wri.org)

5.4.2.1 RNG Markets

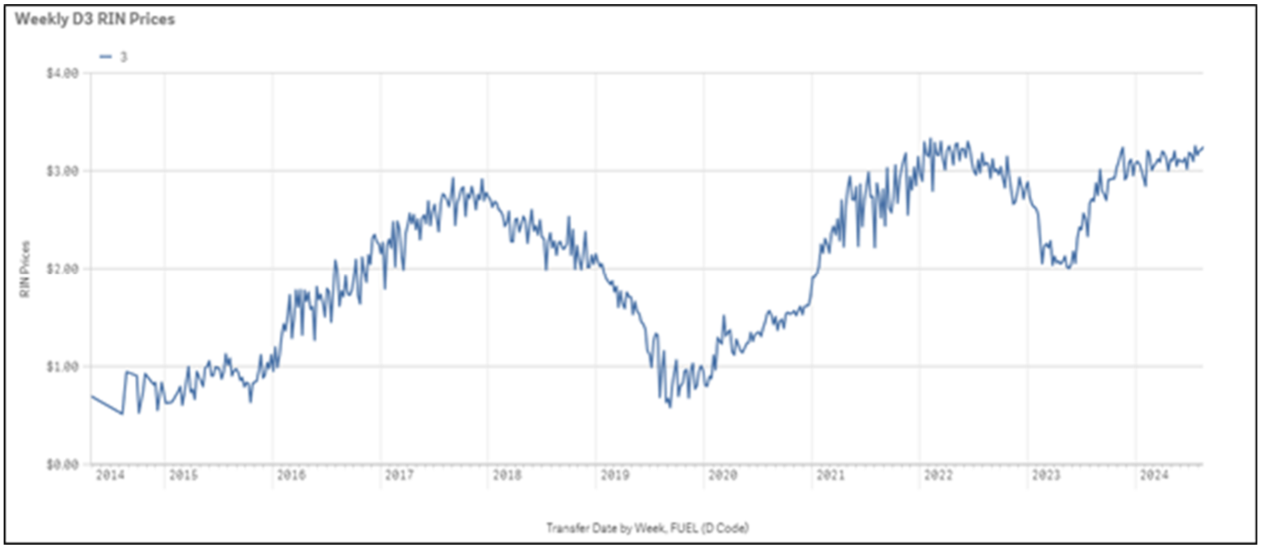
5.4.2.1.1 Federal Renewable Fuel Standard

The Federal Renewable Fuel Standard (RFS) was established under the Energy Policy Act of 2005, which was later expanded under the Energy Independence and Security Act of 2007. The RFS is administered by the United States Environmental Protection Agency (EPA), with the primary goals of reducing dependence on foreign oil and promoting biofuel use for reduction of emissions. Fuel credits are generated by using biofuel for transportation purposes and are assigned a Renewable Identification Number (RIN) by the EPA for each gallon of gasoline equivalent of renewable fuel produced. Refiners that produce gasoline or diesel fuel, and importers that import gasoline or diesel fuel into the United States, are required to purchase RIN credits if they do not produce or import enough biofuels to meet the annual requirements set by the EPA. Refiners and importers are referred to as an “obligated party” under the RFS.

There are several different categories of renewable fuels within the RFS. Biofuels are assigned a renewable fuel category, or D-Code based on the source and requirements for the fuel pathway. Biogas from a digester can fall into the D3 or D5 RIN categories depending on the feedstocks digested. D3 RINs are defined as cellulosic biofuels, which include RNG derived from WWTP sludge, landfill gas, and animal manures. D5 RINs are defined as advanced biofuels, which include RNG derived from waste digesters and can include the biogas generated through co-digestion of WWTP sludge and other high strength organic wastes (HSOW) such as fats, oils, grease (FOG) or food biproducts from industry. This would come into play if the digester facility being discussed were to take in any additional waste streams such as fats, oils, and grease. Since the focus of this study is on dairy manure, the focus will be on D3 RINs at this time, especially given that the value of a D3 RIN is higher than a D5 RIN, however, the addition of high strength organic waste can greatly increase the quantity of gas produced in an anaerobic digester.

The value of the RINs fluctuates with demand and generally increases when EPA sets renewable fuel obligations higher than market-driven biofuel consumption. The EPA tracks the historical RIN price data and makes it publicly available. Figure 1 depicts the EPA reported D3 RIN prices from 2014 through 2024. This variability is a risk to any potential or operational RNG project reliant on RIN credit sales. However, the RFS has demonstrated overall stability as more and more projects come online, showing continued demand for the increased supply of RNG. Current market prices are around $3.00-$3.50 per gallon gasoline equivalent (GGE) for dairy based RNG (cellulosic biofuel, D3 RIN), which equates to roughly $30+ per MMBtu.

Figure 1: EPA Reported D3 RIN Prices from 2014 – 2024



5.4.2.1.2 State Low Carbon Fuel Standards

In addition to the RFS, there are several states with standards that serve to reduce the carbon intensity of transportation fuels and further incentivize the use of RNG through Low Carbon Fuel Standards (LCFS). The existing programs in the U.S include California, Oregon, New Mexico, and Washington. Additionally, there is a growing number of other states where Low Carbon Fuel Standards are being considered. In most instances, projects are allowed to benefit from both federal RIN credits as well as state LCFS program credits. The generation and sale of credits from a given state's LCFS program may help with project economics. Under LCFS programs, individual projects typically apply for and receive a project specific carbon intensity score based on methane avoidance and production related emissions (energy consumption, methane recovery, etc.) and can vary widely, but are typically on the order of $15-$30 per MMBtu based on recent market prices and project specific carbon intensity scores.

5.4.2.1.3 Voluntary RNG Markets

Voluntary buyers such as private companies and natural gas utilities may also purchase the RNG through a voluntary long term offtake agreement. Voluntary buyers (buyers not associated with the transportation markets [RFS, LCFS]) are increasingly participating in the purchase of RNG.

A growing number of utilities are investing in voluntary RNG offtake agreements through cost recovery mechanisms and/or for sale to residential, commercial, and institutional customers. Some examples of utilities that are investing in RNG include Spire, Southern California Gas Company, Duke Energy (Piedmont), Pacific Gas and Electric Company, Black Hills Energy, Summit Utilities, Nicor, Northwest Natural, CenterPoint Energy, and Vermont Gas (to name a few).

Some regulated natural gas utilities are also now creating non-regulated development companies, under their parent companies, to self-develop RNG facilities and meet decarbonization goals. The non-regulated entity uses capital from the parent company to support the construction and operation of RNG facilities. Once the Facility is operational, the RNG can be sold as credits in the RFS program or other voluntary markets. Current voluntary market pricing for dairy derived RNG ranges from $25-$50/MMBtu.

6.0 NUTRIENT RECOVERY AND BY-PRODUCT GENERATION

This feasibility study looked at three (3) different options regarding the handling and processing of the post digestion slurry. These options will be discussed in the sub sections below but first, the similarities between all three will be presented. All three of the options utilize a screw press for primary solids recovery, a DAF (dissolved air floatation) system for further solids recovery (referred to as wet cake), and an optional ultrafiltration and reverse osmosis system to treat the effluent from the DAF. Please note that for this study, Burns & McDonnell brought in the Digested Organics group, who assembled a portion of the design work for the nutrient recovery side of the Facility. Due to this, the DAF unit selected is their own design, called a SRDU (solids removal and dewatering unit), so when DAF is mentioned, it is referring to their SRDU technology.

The screw presses and DAF systems will be utilized for each option discussed below. Screw presses present an affordable, operator friendly solution for primary solids separation of the manure digestate (post digestion). These presses will be run in parallel and will recover a solid product in the 35% total solids range. DAF systems are commonly used for secondary separation in wastewater and dairy manure nutrient recovery. They are simple systems that can be sized for considerable flow rates and run in parallel with other DAF systems.

The optional UF-RO system would further remove nutrients from the DAF effluent stream that would be sent back to the dairies while creating clean water with the potential to be discharged back into the environment with a WPEDS permit. This UF-RO system would cut down on the volume of final concentrate sent back to the dairies by extracting more clean water out of it. These systems are great for recovering more clean water, but they come at a cost in the range of $12 to $30 million, depending on which technology provider is used. The Terraflow UF-RO system, for example, would be able to recover more nutrients and produce more clean water than the standard UF-RO system, but comes at a significantly higher cost. This can be seen in the mass balance for the three options assembled by Digested Organics and attached to this report in Appendix C. Discharging to surface water can also take a considerable amount of time to secure a WPEDS permit, which could delay the project. The final effluent would ideally be dischargeable via a WPEDS permit while the concentrate would go to the Facility storage lagoon where it can be returned to the participating dairies in the appropriate quantities based on how much manure they supplied the Facility. The dairies would then land apply their share of the concentrate. If the optional UF-RO technology isn't used, the effluent from the DAF would be sent to the storage lagoon and given back to the dairies, just in larger volumes than with the UF-RO.

All options will also include a post digestion recovered fiber dryer. This will take the primary recovered manure solids and dry them for use as bedding by the dairy farms that bed with them. For the third option, all the primary separated solids will be dried, but for options 1 and 2, only a portion of the primary separated solids from the screw press will need to be recovered for the dairies that bed on recovered manure solids. The biggest difference between options 1 & 2 and option 3 will be the sizing of the dryer required.

The differences and focus of each option are discussed in the sub-sections below.

6.1 Composting

The first option explored is the composting of all of the solids recovered from the digestate, both from the primary screening with the screw presses and the wet cake produced by the DAF system. This would take a considerable amount of space to perform as it would produce in the range of 146,000 tons of compostable solids annually, but would create a hearty soil amendment that the dairies could use for improving their soil health, that the Dane County residents would have access to for private use, and that could be hauled out of the watershed, taking the phosphorus out with it.

The equipment to perform the composting would be relatively simple, as a conveyer system would be utilized to initially stack the solids in the composting building. Composting is comprised of three processes: anaerobic, aerobic, and fungal. The anaerobic step is completed by the digester while the aerobic and fungal steps are completed within the composting barn. The compost would need to be turned periodically but would require little interaction outside of that for a total composting time of around 1 month. The dairies would be able to collect the completed compost from the Facility in the quantities that their nutrient plans allowed them to land apply, local residents could pick up bulk or bagged compost, and bulk or bags could be sold to neighboring county residents and/or companies as needed. Composting is a simple solution but will require a considerable amount of time and storage space before the reclaimed fiber and nutrients can be sent out of the Facility.

6.2 Recovered Nutrient Granularization (Fertilizer Pellets)

This option would take the recovered solids from the screw presses, combine it with the wet cake from the DAF system, and pelletize it, producing roughly 146,000 tons of soil amendment granules annually. This product would be stored in the same storage barn space that was proposed for the compost in the first option but would require less overall space. The resulting soil amendment pellets can be given back to the dairies in quantities that meet their land nutrient plans, bagged and given to residents of Dane County, and sold in either bags or bulk to out of county parties. The pellets produced would contain a significant portion of the phosphorus from the manure and would be easy to handle and transport, as they would have a total solids content of 90%. This granulation process comes at a significant capital cost of $40 to $45 million but provides a product that would contain the phosphorus from the manure and make it very easy to transport. The cost of the granulation is significant for this option given that it is pelletizing both the primarily separated solids and the DAF wet cake. This price can be reduced, as will be seen in the next option.

6.3 Recovered Fiber Bedding and Nutrient Granularization

The final option explored would take all the primarily separated solids off the screw presses, dry it with a drum dryer to be returned to the dairies as fiber bedding and pelletize the DAF wet cake as a soil amendment. This option assumes that all of the participating dairies will switch over to recovered manure fiber bedding but would keep the sand separation system at the raw manure reception to be sure to accommodate any future dairies while they transition over to fiber bedding. This would return all the fiber solids back to the dairies, along with their portion of the final concentrate off the DAF system or the UF-RO system, if it is selected. The composting barn space mentioned in the other two options would be utilized for the drying and storage of the recovered primary fiber (off the screw presses) and storage of the DAF wet cake pellets. The pellets would contain the majority of the phosphorus from the dairy manure received and would be easy to handle and transport. The soil amendment pellets can be given back to the dairies in quantities that meet their land nutrient plans, bagged and given to residents of Dane County, and sold in either bags or bulk to out of county parties. This option would produce around 70,000 tons of bedding fiber and 25,000 tons of soil amendment granules annually. There would be a nearly 50% savings in the cost of pelletizing only the DAF wet cake as opposed to both the primary separated fiber and wet cake.

7.0 ENVIRONMENTAL CONSIDERATIONS

7.1 Wastewater Requirements

The project proposes to discharge treated effluent to the surface waters of Wisconsin and will therefore require a Wisconsin Pollution Discharge Elimination System (WPDES) permit from the Wisconsin Department of Natural Resources (WDNR). This application process is required to quantify, prevent, and negate nutrient and suspended solids emissions into a watershed. The WDNR will evaluate:

- Do categorical or water quality based effluent limits apply?
- Are there biomonitoring concerns?
- Are any new or more stringent limits needed?
- What toxics monitoring should be considered or requested?
- Are there antidegradation concerns?
- Is an environmental review needed?

It is anticipated that the Facility will be designed in a watershed that has met the limit of its Total Maximum Daily Load (TMDL) of Total Phosphorous (TP) and Total Suspended Solids (TSS) and that no reserve capacity will be available for new discharge. To allow for novel effluent discharge into a system with no available TMDL, it is likely that the Project will necessitate a Water Quality Trading Plan (WQT) Review with the WDNR. The WQT will propose to generate TP and TSS credits via Adaptive Management (AM) and the implementation of conservation projects, offsetting the TP and TSS that the Project proposes to discharge. It is understood that Dane County is currently acting as a WQT and AM Broker and is currently generating credits within the watershed.

Should additional WQT or AM be required to offset the project discharge, the basic steps involved in a typical wastewater permit involve:

1. Submission of permit application.

2. Preparation of draft permit and supporting documents.

3. Public noticing the permit; and

4. Issuing the final permit following the public comment period.

The Facility is not allowed to discharge effluent into surface waters until the WQT and/or AM strategy, and subsequent Wastewater Permit, are approved by the WDNR. The approval process timeline from first submittal to credit general and discharge approval in a typical WQT approach may range from 4 months to 12 months. Given that Dane County is a Broker and currently generating credits via AM, this timeline may be compressed accordingly.

7.2 Surface Water Quality Analysis

To support the required Wastewater Permitting outlined in Section 6.1, a surface water quality analysis may be necessary for the Project. An initial evaluation of the TMDL within the watershed will be necessary to determine if there is available TMDL budget to allow for novel effluent discharge. A stream survey will also be conducted by the WDNR as part of the Wastewater Permitting process. It is recommended that an initial desktop review of surface waters in and around the Project Area be completed as part of an environmental review, to better inform the Wastewater Permitting Application.

7.3 Required Air Emissions and Permitting

An air permit will be required from the Wisconsin Department of Natural Resources (WDNR) prior to beginning construction on the project. WDNR offers several types of air permits including:

- **Registration Operation Permit Type A (ROP-A)**: The ROP-A is the easiest permit to obtain and is the most flexible. The key thresholds that must be met with the ROP-A are: total projected actual emissions must be less than 25 tpy for criteria pollutants, control devices must meet certain minimum control efficiencies, and stacks must be taller than all buildings and vent vertically unobstructed or else dispersion modeling is required. Important considerations for applying for a ROP-A for this project are: WDNR will likely require an assumption that raw biogas contains 6,000 ppm of total sulfur, meeting the dispersion modeling requirements can be difficult for 1-hr sulfur dioxide if the flare combusts raw biogas, hydrogen sulfide emissions from the sources must meet the requirements of Wisconsin Administrative Code Chapter NR 445. There is no fee to apply for an ROP-A and typically WDNR makes a decision to approve or deny the application within 15 days of receipt. The ROP-A does not expire and allows changes to be made at the facility without obtaining a permit amendment as long as the facility remains eligible for the ROP-A.

- **Registration Operation Permit Type B (ROP-B)**: The ROP-B is similar to the ROP-A except that allowable emissions are increased to 50 tpy for criteria pollutants. The ROP-B is more restrictive than the ROP-A.

- **Registration Operation Permit Type G (ROP-G)**: The ROP-G is available for facilities that have joined the green tier program. Total emissions must not exceed 80 tpy for criteria pollutants. More restrictions apply that are not detailed in this summary.

- **Construction Permit & Federally Enforceable State Operating Permit (FESOP)**: If a Registration Operation Permit is not an option, then a source-specific air construction permit and FESOP are required. These are two separate permits but are often issued at the same time. The construction permit allows the project to begin construction and the FESOP allows operation. WDNR guidelines suggest that construction permits are issued within 120 days of receiving a complete application but from experience, this timing can vary depending on WDNR workload. It can often take 6-9 months from receipt of an application to obtain a draft permit and then must go through public notice for 30 days. The initial permit application fee for a construction permit is $7,500 and can increase or decrease depending on site specific details. Construction may not begin until the construction permit is issued; however, there are options to request a waiver to allow construction to start before the permit is issued. There are options to expedite the permit issuance process for a fee.

- **Construction Permit & Title V Operating Permit or New Source Review Construction Permitting**: It is unlikely that a Title V operating permit or a New Source Review Construction permit would be required so they are not discussed in detail. These permits can take significantly longer to obtain.

Based on the information available, there is a chance that a ROP-A or ROP-B could be applicable (particularly if all the biogas is upgraded to RNG) but the construction permit and FESOP is a more realistic option.

The general steps to obtain an air permit are:

1. Define the process and estimate potential-to-emit.

2. Decide which air permit is applicable.

3. Initiate a pre-application meeting with WDNR if appropriate; this is not mandatory but is suggested particularly if a site-specific permit is required.

4. Complete a regulatory review, process description, process flow diagram, air permit application forms, emission calculations, and dispersion modeling (if applicable)

5. Submit the application.

6. Respond to requests for information from WDNR.

7. Review draft permit.

8. WDNR issues permit after public notice period (if applicable)

APPENDIX A : SITE GENERAL ARRANGEMENT

NOTES:
1. GENERAL ARRANGEMENT DOES NOT ACCOUNT FOR FUTURE EXPANSION.

PRELIMINARY - NOT FOR CONSTRUCTION

NO.	DATE ISSUED	BY	DESCRIPTION	DATE APPROVED	BY
A	11/06/24	WPF	ISSUED FOR CLIENT REVIEW		

REVISIONS

DRAWING NO.	TITLE

REFERENCE DRAWINGS

BURNS McDONNELL

COUNTY of DANE WISCONSIN 1839

DRAWN: W. FRANKE DATE: 11/06/24
CHECKED: DATE:
DESIGNED: DATE:
PROJECT ENGINEER:
PROJECT MANAGER:

PROJECT NUMBER: 169859
SCALE: 1" = 60'

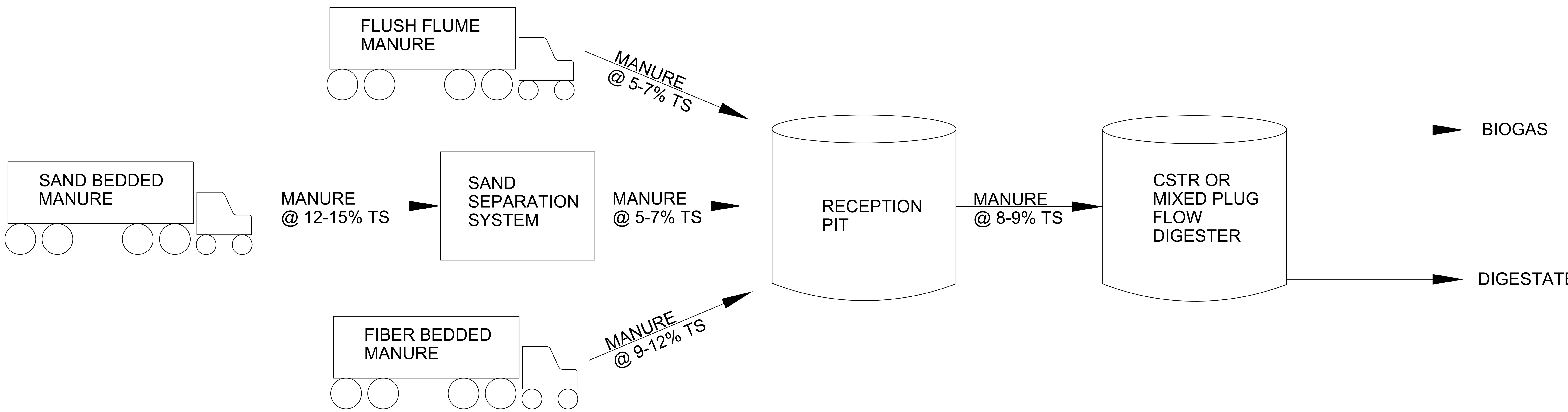
DANE COUNTY
COMMUNITY AD FEASIBILITY STUDY
MECHANICAL GENERAL ARRANGEMENT

DANE COUNTY WI

DRAWING NUMBER: 169859 - SITE GA
REVISION: A

Plotted by: WPFRANKE Date: 11/5/2024 2:29 PM Drawing: C:\Users\wpfranke\Burns & McDonnell\Dane County Community Digester -- Documents\General\Design\CADD\Process\Sheets\169859 -- Site GA.dwg

APPENDIX B : PROCESS FLOW DIAGRAM

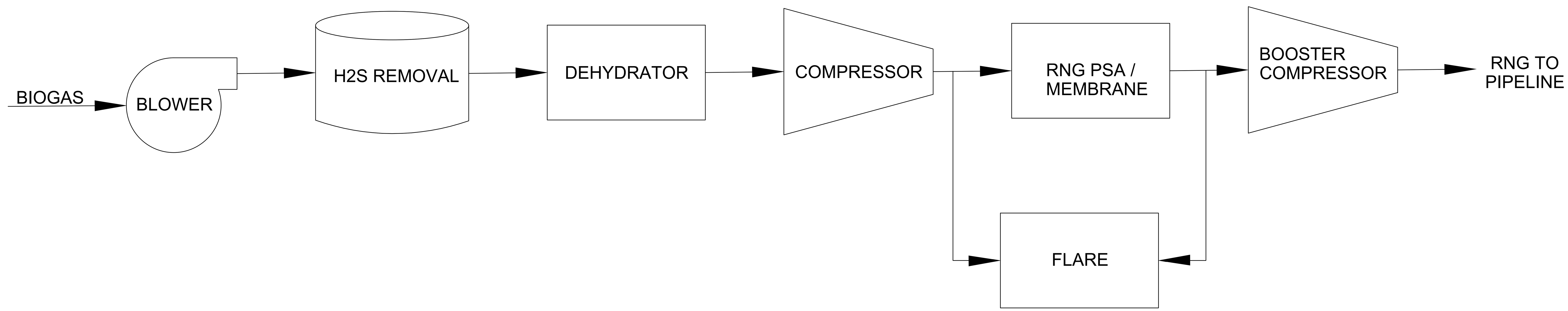


BURNS McDONNELL

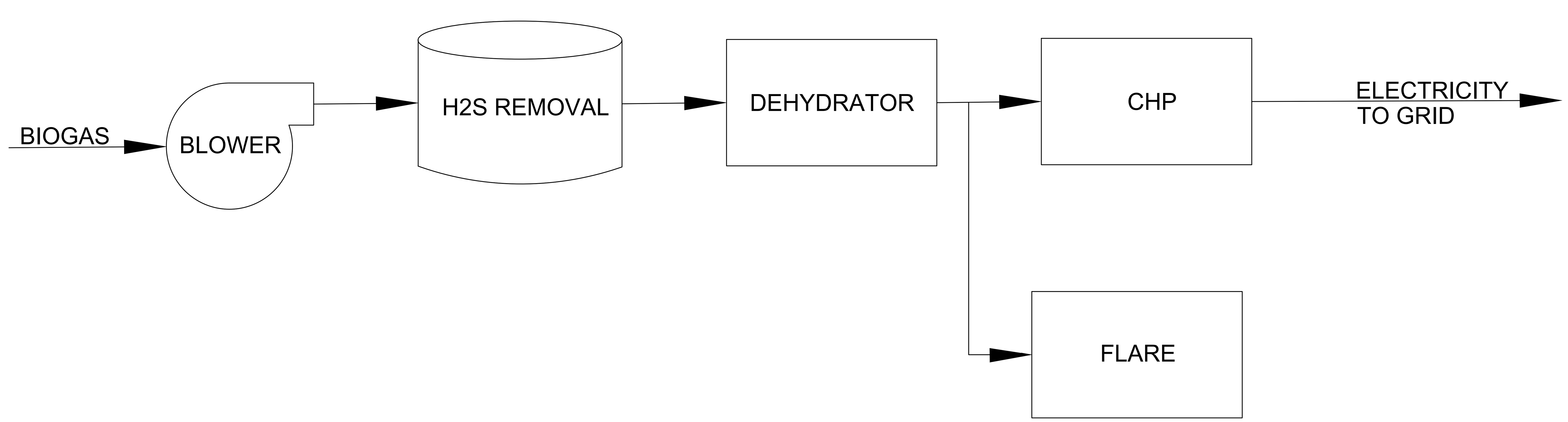
Figure 1

Manure Loading & AD PFD
Design Criteria
Dane County

BIOGAS TO DIRECT PIPELINE INJECTION



BIOGAS TO COMBINED HEAT AND POWER (CHP)



BURNS McDONNELL

Figure 2

Biogas Use PFD
Process Design Criteria
Dane County

Figure 3
Nutrient Removal PFD
Process Design Criteria
Dane County

APPENDIX C : COST ESTIMATE OF NUTRIENT RECOVERY

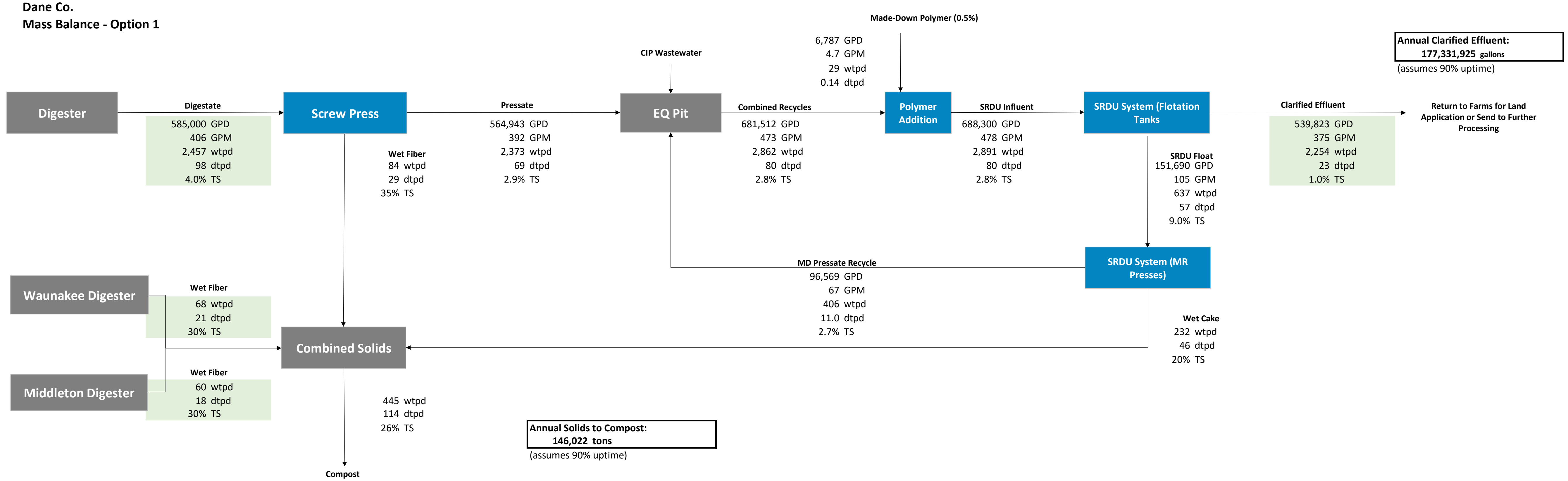
Dane Co. Option 1 - Compost all wet solids and fiber

Estimated Installed Price* for Equipment and Annual Operating Costs
***Capital cost assumes typical purchase price plus 30% for installation by EPC**

Unit Operation	Capital Cost ($MM)	Operating Cost ($MM/yr)
Screw Press	0.5 - 1	0.08 - 0.1
SRDU	3.5 - 4	0.5 - 0.8
Direct Filtration - UF	10 - 11	0.5 - 0.8
Direct Filtration - RO	2 - 3	0.3 - 0.5
Terraflow Process	25 - 30	2 - 2.5

Confidential & Trade Secret
11/8/2024

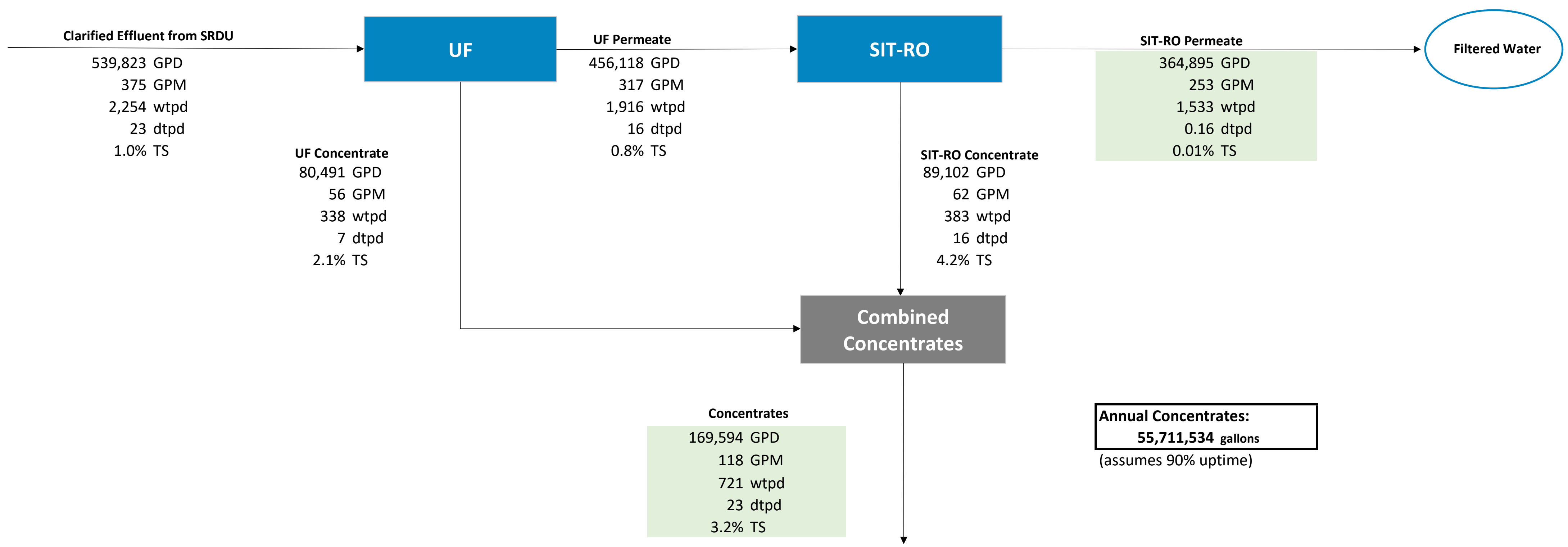
Dane Co.
Mass Balance - Option 1



Confidential & Trade Secret
11/8/2024

Dane Co.
Mass Balance - Optional Filtration

Annual Filtered Water:
119,867,937 gallons
(assumes 90% uptime)



Dane Co. Option 2 - Granulation of all wet solids and fiber

Estimated Installed Price* for Equipment and Annual Operating Costs
***Capital cost assumes typical purchase price plus 30% for installation by EPC**

Unit Operation	Capital Cost ($MM)	Operating Cost ($MM/yr)
Screw Press	0.5 - 1	0.08 - 0.1
SRDU	3.5 - 4	0.5 - 0.8
Granulation Process	40 - 45	5.4 - 5.8
Direct Filtration - UF	10 - 11	0.5 - 0.8
Direct Filtration - RO	2 - 3	0.3 - 0.5
Terraflow Process	25 - 30	2 - 2.5

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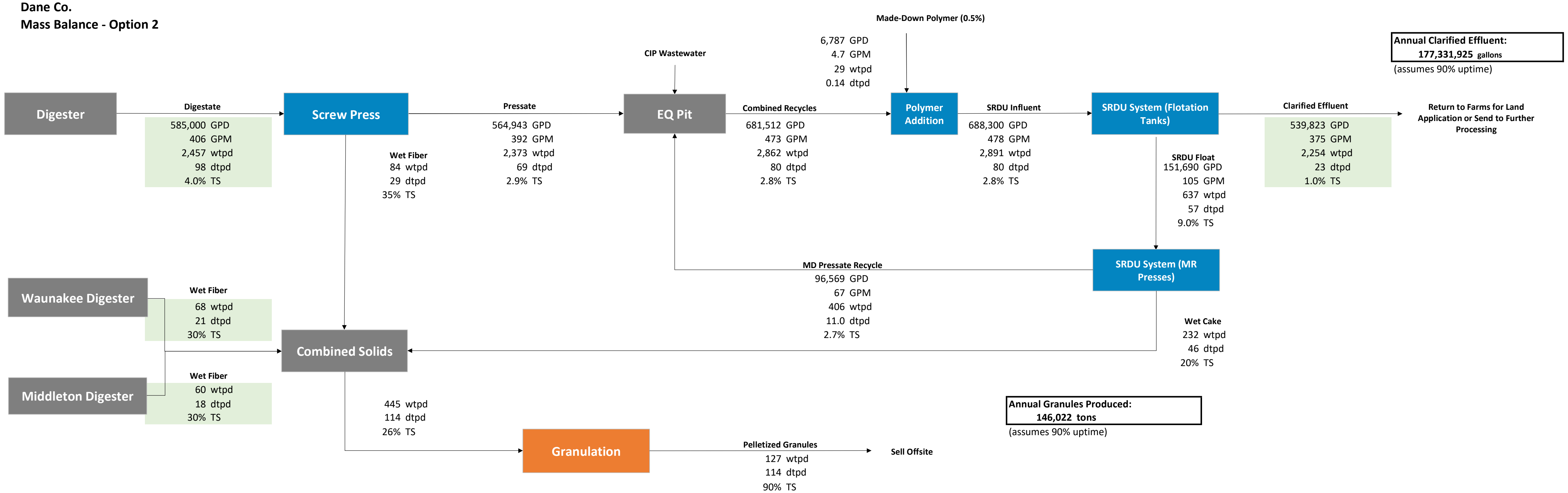
11/8/2024

Dane Co.
Mass Balance - Option 2



Dane Co. Option 3 - Granulation of wet solids, compost the fiber

Estimated Installed Price* for Equipment and Annual Operating Costs
***Capital cost assumes typical purchase price plus 30% for installation by EPC**

Unit Operation	Capital Cost ($MM)	Operating Cost ($MM/yr)
Screw Press	0.5 - 1	0.08 - 0.1
SRDU	3.5 - 4	0.5 - 0.8
Granulation Process	20 - 25	2.3 - 2.7
Direct Filtration - UF	10 - 11	0.5 - 0.8
Direct Filtration - RO	2 - 3	0.3 - 0.5
Terraflow Process	25 - 30	2 - 2.5

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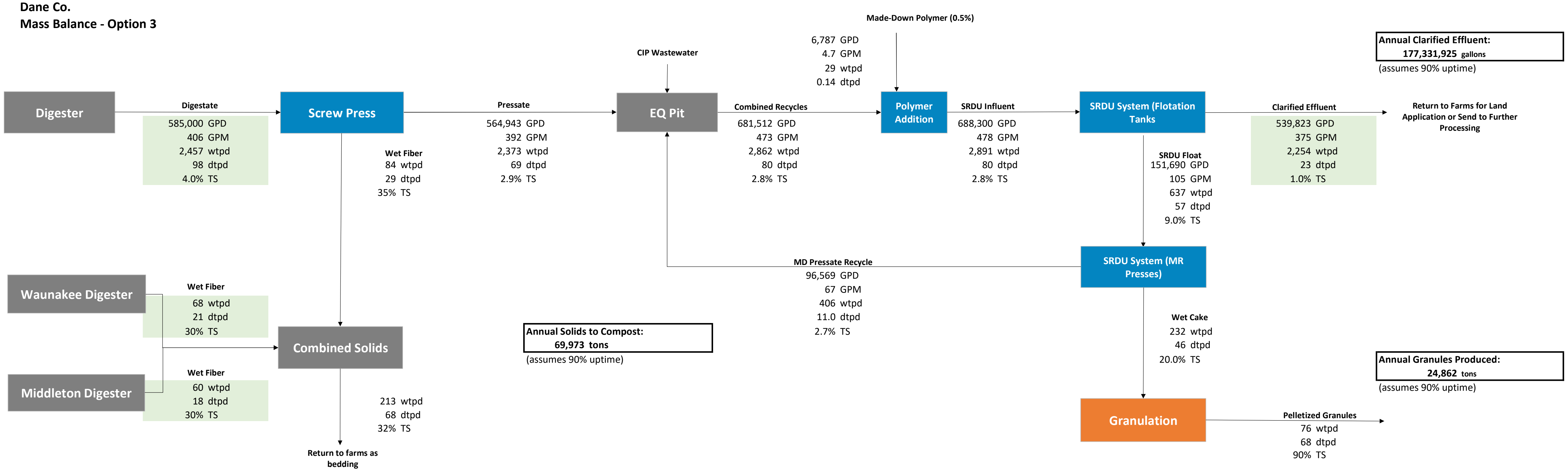
Dane Co.
Mass Balance - Option 3



APPENDIX D : CLASS V COST ESTIMATE

EXECUTIVE SUMMARY
DANE COUNTY COMMUNITY DIGESTER - CLASS V ESTIMATE

		COST ($)	CONTINGENCY (%)	CONTINGTENCY COST	COST WITH CONTINGENCY
DIRECT COSTS (RNG UPGRADING)	OPTION 1 MECHANICAL EQUIPMENT	$53,534,500	12%	$7,270,000	$60,804,000
	OPTION 2 MECHANICAL EQUIPMENT	$102,834,500	12%	$13,963,000	$116,797,000
	OPTION 3 MECHANICAL EQUIPMENT	$80,794,500	12%	$10,971,000	$91,765,000
	RNG UPGRADING	$34,263,588	12%	$4,653,000	$38,916,000
	ELECTRICITY GENERATION	$28,715,706	12%	$3,900,000	$32,615,000
	OTHER MECH EQUIPMENT, PIPING, FITTINGS, VALVES	$4,609,144	12%	$627,000	$5,236,000
	MAJOR ELECTRICAL EQUIPMENT & MATERIAL	$5,800,000	12%	$787,500	$6,588,000
	MAJOR IC EQUIPMENT & MATERIAL	$1,390,750	15%	$252,000	$1,643,000
	MECHANICAL, STRUCTURAL CONSTRUCTION COST	$33,738,600	15%	$5,829,000	$39,568,000
	ELECTRICAL, I&C CONSTRUCTION COST	$5,381,250	17%	$1,076,250	$6,458,000
	SUBCONTRACTORS (W/O INSPECTION)	$500,000	0%	$0	$500,000
	RNG UPGRADING				
	TOTAL DIRECT COST (OPTION 1)	$139,218,000	13%	$20,495,000	$159,713,000
	TOTAL DIRECT COST (OPTION 2)	$188,518,000	13%	$27,188,000	$215,706,000
	TOTAL DIRECT COST (OPTION 3)	$166,478,000	13%	$24,196,000	$190,674,000
	ELECTRICITY GENERATION				
	TOTAL DIRECT COST (OPTION 1)	$133,670,000	13%	$19,742,000	$153,412,000
	TOTAL DIRECT COST (OPTION 2)	$182,970,000	13%	$26,435,000	$209,405,000
	TOTAL DIRECT COST (OPTION 3)	$160,930,000	13%	$23,443,000	$184,373,000

INDIRECT COSTS	PROFESSIONAL SERVICES	$23,105,000	0%	$0	$23,105,000
	OWNERS COST	$0	0%	$0	$0
	ENVIRONMENTAL PERMITS AND SUPPORT	$0	0%	$0	$0
	ELECTRICAL INTERCONNECT AND POWER DELIVERY	$0	0%	$0	$0
	TOTAL INDIRECT COST	$23,105,000	0%	$0	$23,105,000

TOTAL INSTALLED COSTS

RNG UPGRADING	
OPTION 1	**COST**
PROJECT COST	$162,323,000
TOTAL CONTINGENCY	$20,495,000
OVERALL CONTINGENCY	13%
PROJECT COST WITH CONTINGENCY	**$182,818,000**
TOTAL INSTALLED COST WITH CONTINGENCY (+50%) Note 1	**$274,227,000**
TOTAL INSTALLED COST WITH CONTINGENCY (-30%) Note 2	**$127,973,000**
OPTION 2	**COST**
PROJECT COST	$211,623,000
TOTAL CONTINGENCY	$27,188,000
OVERALL CONTINGENCY	13%
PROJECT COST WITH CONTINGENCY	**$238,811,000**
TOTAL INSTALLED COST WITH CONTINGENCY (+50%) Note 1	**$358,217,000**
TOTAL INSTALLED COST WITH CONTINGENCY (-30%) Note 2	**$167,168,000**
OPTION 3	**COST**
PROJECT COST	$189,583,000
TOTAL CONTINGENCY	$24,196,000
OVERALL CONTINGENCY	13%
PROJECT COST WITH CONTINGENCY	**$213,779,000**
TOTAL INSTALLED COST WITH CONTINGENCY (+50%) Note 1	**$320,669,000**
TOTAL INSTALLED COST WITH CONTINGENCY (-30%) Note 2	**$149,646,000**

ELECTRICITY GENERATION	
OPTION 1	**COST**
PROJECT COST	$156,775,000
TOTAL CONTINGENCY	$19,742,000
OVERALL CONTINGENCY	13%
PROJECT COST WITH CONTINGENCY	**$176,517,000**
TOTAL INSTALLED COST WITH CONTINGENCY (+50%) Note 1	**$264,776,000**
TOTAL INSTALLED COST WITH CONTINGENCY (-30%) Note 2	**$123,562,000**
OPTION 2	**COST**
PROJECT COST	$206,075,000
TOTAL CONTINGENCY	$26,435,000
OVERALL CONTINGENCY	13%
PROJECT COST WITH CONTINGENCY	**$232,510,000**
TOTAL INSTALLED COST WITH CONTINGENCY (+50%) Note 1	**$348,765,000**
TOTAL INSTALLED COST WITH CONTINGENCY (-30%) Note 2	**$162,757,000**
OPTION 3	**COST**
PROJECT COST	$184,035,000
TOTAL CONTINGENCY	$23,443,000
OVERALL CONTINGENCY	13%
PROJECT COST WITH CONTINGENCY	**$207,478,000**
TOTAL INSTALLED COST WITH CONTINGENCY (+50%) Note 1	**$311,217,000**
TOTAL INSTALLED COST WITH CONTINGENCY (-30%) Note 2	**$145,235,000**

NOTES:

In preparing this report, BMcD relied, in whole or in part, on data and information provided by Dane County, which information has not been independently verified by BMcD and which BMcD has assumed to be accurate, complete, reliable, and current. Therefore, while BMcD has utilized reasonable efforts in preparing this report, BMcD does not warrant or guarantee the conclusions set forth in this Report which are dependent or based upon data, information or statements supplied by third parties or the client.

Use of this report or any information contained herein, if by any party other than Client, shall be at the sole risk of such party and shall constitute a release and agreement by such party to defend and indemnify BMcD and its affiliates, officers, employees and subcontractors from and against any liability for direct, indirect, incidental, consequential or special loss or damage or other liability of any nature arising from its use of the report or reliance upon any of its content. To the maximum extent permitted by law, such release from and indemnification against liability shall apply in contract, tort (including negligence), strict liability, or any other theory of liability.

1 - Upper Range Overall Project Cost +50%

2 - Lower Range Overall Project Cost -30%

3 - Material and Equipment include:

- Nutrient recovery equipment was based on high level quote received from Digested Organics
- Other material costs were based on previous projects (escalation has been included for current day pricing)

- 6% freight has been included on all equipment
- 5% sales tax has been added as a requirement of the State of Wisconsin. Sales tax is included on engineered equipment and materials only.

4 - Construction Subcontracts include:

- Mechanical, Structural Construction
- Electrical and Instrumentation Construction
- Assumes no deep foundations

All services above were based on high level estimate using data from similar size installations

5 - Subcontracts include:

- Engineering/Pre Construction Survey
- HAZOP/ LOPA
- Geotech
- Hydroexavation
- System Integration

All services above were based on high level estimate that needs to be refined in the next project phase.

6 - Professional Services include:

- BMcD Labor, Project Management, Procurement, Construction Management, Safety & Quality
- Construction Management & Construction Inspection Services
- Commissioning Planning & Site Management

All services above were based on high level estimate that needs to be refined in the next project phase.

Section C – Nutrient Recovery Report

BURNS McDONNELL

Nutrient Recovery Report

Dane County Land & Water Resources Department

Nutrient Recovery Report
Project No. 169859

Final Report
1/8/2025

TABLE OF CONTENTS

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DEFINITIONS

BOD - Biological Oxygen Demand

CHP - Combined Heat and Power

DAF - Dissolved Air Floatation

LCFS - Low Carbon Fuel Standard

MVR - Mechanical Vapor Recompression

PSA - Pressure Swing Absorption

PES - Polyethersulfone

PVDS - Polyvinylidene Difluoride

RFS - Renewable Fuel Standard

RIN - Renewable Identification Number

RNG - Renewable Natural Gas

RO - Reverse Osmosis

SAF - Sustainable Aviation Fuel

TS - Total Solids

VOC - Volatile Organic Compounds

WWTP - Waste Water Treatment Plant

LIST OF FIGURES

Page No.

EXECUTIVE SUMMARY

This report provides a discussion and background on the various nutrient recovery technologies currently available and provides a preliminary nutrient recovery process to be used for the Dane County community digester study. The focus of this report is on removing primarily phosphorus found in dairy cow manure and creating beneficial by-products.

Burns & McDonnell utilized project team members with previous experience with nutrient removal systems to fill information in this report. For new and emerging technologies, nutrient removal vendors were consulted to provide additional details and information. The information received was used to support preliminary recommendations of the technology selection and provide initial insight into potential nutrient recovery technology processes.

Members of the Dane County Agricultural Technical Work Group provided valuable insight into the local dairy community in a meeting with Burns & McDonnell and the Dane County Land & Water Resources Department held on August 21st, 2024. Several nutrient removal technologies were selected for the proposed Dane County community digester, further discussed in Section 3.0 of this report. Included in this report is a discussion on nutrient removal technologies with rationale as to why they are or are not strong candidates for this project. A technology decision matrix, see Appendix A, to compare the various nutrient removal technologies was assembled and reviewed with the Dane County agricultural stakeholder team. A nutrient recovery process flow diagram, see Appendix B, was also developed to help visualize the various technologies and how they would be used in tandem to capture the desired byproducts of the digestate based on incoming manure TS content ranges.

1.0 NUTRIENT RECOVERY TECHNOLOGY OVERVIEW

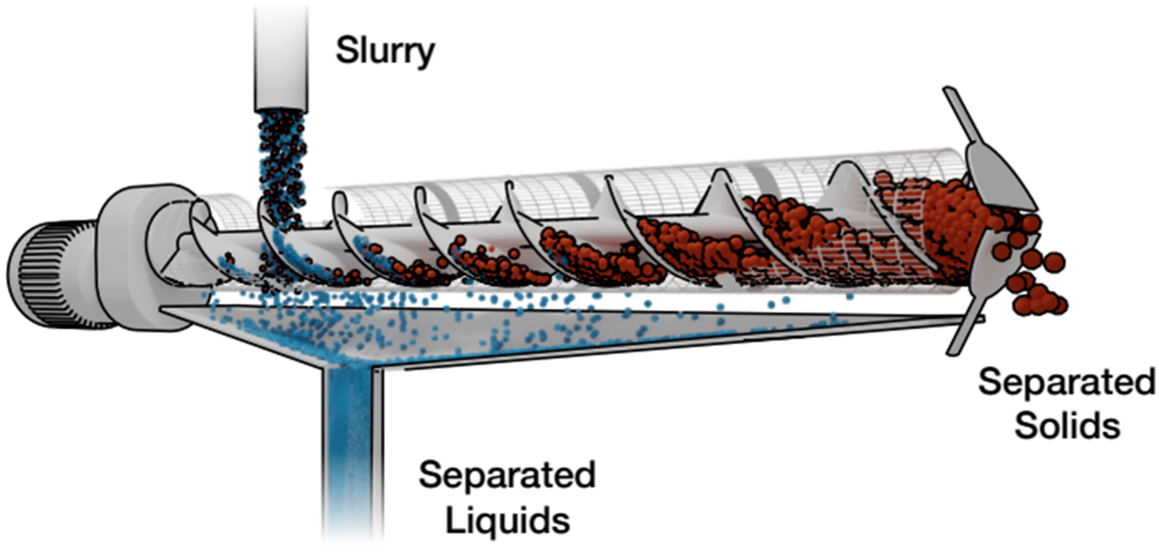
1.1 Physical Separation

The most common form of nutrient removal is physical separation. A variety of different technologies work to separate the liquid and solid portions of feedstocks. The separate portions can then be removed from the watershed or further processed to create a desirable by-product. Physical separation is key for removal of phosphorus but not nitrogen as shown in the nutrient recovery process flow diagram as provided in Appendix B.

1.1.1 Screw Press

A screw press is used to separate post-digestion manure, digestate, into two streams: a fiber-rich wet solid and a liquid portion (typically called liquid digestate, pressate, effluent, or thin fraction). Whole digestate enters the horizontal press from the top and is fed forward by an auger. The auger presses the digestate against a wedge wire screen (available in varying sizes with 500, 750, and 1,000 microns being the typically used sizes). Solids are retained inside the screen and exit the end of the auger after pressing through back-pressure plates (that form a plug) that can be adjusted to modify the dryness of the solids. The liquid passes through the screen and exits the bottom of the unit via gravity. Figure 1 provides a visual representation of the process. A screw press generally produces the driest material (usually 30-35% dry matter) without the use of chemicals compared to other nutrient removal technologies. Separated solids are typically used as bedding for cows, either directly or after additional processing (e.g., composting, drying, etc.) depending on environment and farmer bedding requirements. While a small amount of phosphorus is contained in the separated solids, most of the phosphorus remains in the smaller particles that remains in the liquid portion and requires either chemical flocculation or microfiltration to capture.

Figure 1: Screw Press Overview [5]



1.1.2 Side Hill Screen

A side hill screen (also called an inclined screen or slope hill screen) can be used to separate the solid and liquid portions of digested dairy manure. Digestate is pumped to the top of an angled wedge-wire screen (typically 500 to 1,000 microns) which retains large particles while the liquid portion can pass through. The solid portion accumulates on the screen and slowly falls towards the bottom of the screen, sometimes with the help of a scraper, air knife, vibratory motor, or water sprayers. Figure 2 shows the solids portion accumulating on a screen with water sprayers. These wet solids can be further dewatered with a screw-press or roller press to create drier solids. This has the advantage of reducing the number of screw-presses required, as most of the free liquid passes through the side hill screen. One of the major disadvantages of side hill screens is that they are open units, so there is volatilization of ammonia and odors from the digestate during this process. Also, side hill screens will struggle to separate digestate with a TS content of over 4%. To give an idea of what TS ranges would be expected, a typical scrape manure dairy would be seeing manure in the 8 to 9% TS range. After digestion, the digestate would still be in the 5 to 7% TS range. This might not rule out the side hill screen's use in the nutrient recovery part of this study, but it must be kept in mind when deciding how it might be used in a digestate handling system.

Figure 2: Side Hill Screen in Use

Photo provided by Digested Organics

1.2 Chemical-Assisted Physical Separation

When additional removal of suspended solids is desired beyond what can be achieved with screens or centrifugation alone, chemical treatment can be used. Chemical assisted physical separation can remove more phosphorus but is limited by additional reoccurring chemical costs. Two main classes of chemicals are commonly used: charged (negative/positive) flocculants (also called polymers) and coagulants (which are usually metal salts like alum or ferric chloride). At many facilities, only a flocculant is used, but coagulants can be added to enhance the efficacy of a flocculant, strengthen flocs, or reduce the amount of flocculant required to achieve good separation. Both types of chemicals can be provided as concentrated dry powders (which get mixed into water onsite) or as ready-to-use liquids. Figure 3 shows flocculated dairy digestate and wet cake, solid portion of digestate after separate.

Figure 3: Flocculated Dairy Digestate and Wet Cake

Flocculated solids (floating) and clarified liquid from dairy digestate

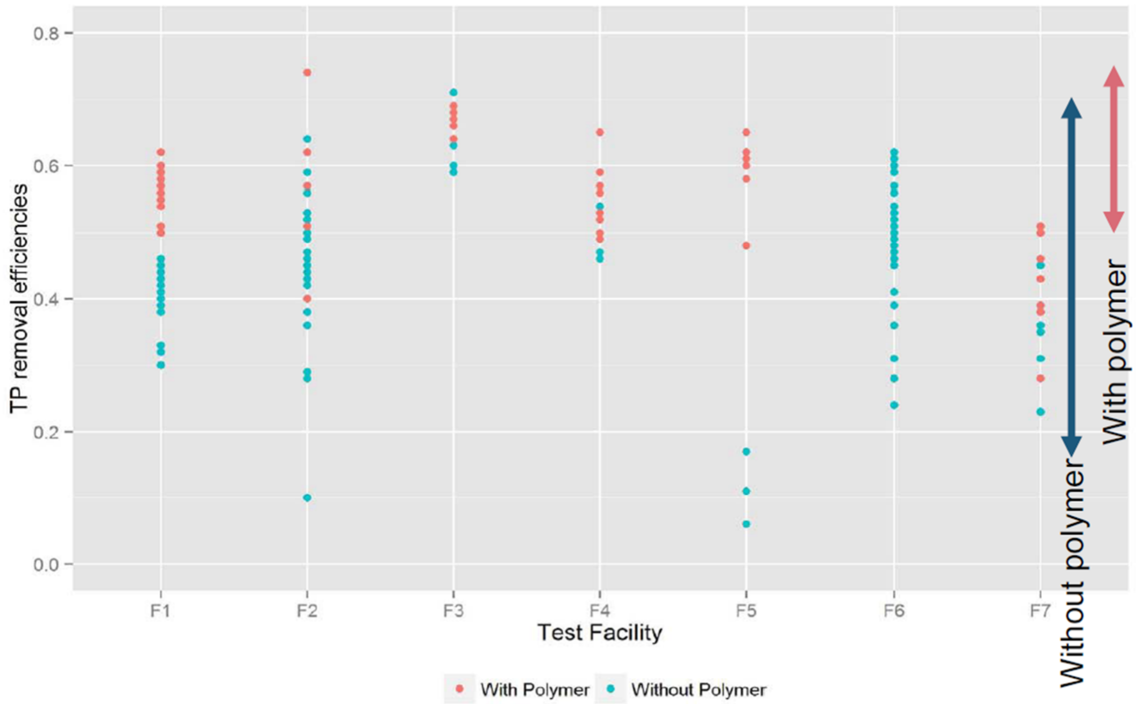
Wet cake (~20% TS)

Photo provided by Digested Organics

1.2.1 Horizontal Decanter

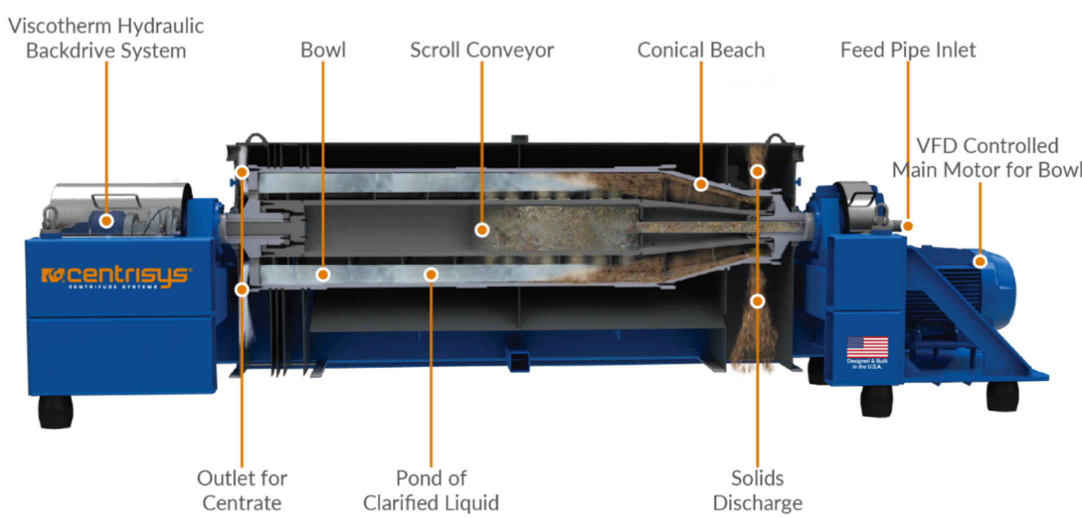
A horizontal decanter is a horizontally positioned centrifuge that removes particles heavier than water by applying many times the force of gravity to the digestate. Whole digestate enters the horizontal decanter where a bowl rotates. As the bowl spins, centrifugal and gravitational forces separate out the heavier solid material while the liquid portion moves through the length of the bowl until it is released from the far end of the bowl. Figure 5 provides an overview of a typical Centrisys horizontal decanter. The cleaner liquid is called centrate while the wet solids are typically referred to as a wet “cake”. The horizontal decanter takes considerably more energy to operate compared to a screw-press or side hill screen and incurs substantially higher maintenance costs as a result of abrasion of the rotating parts. While most facilities operate decanters after a screw-press, we are aware of some facilities that process whole digestate directly with decanters (to create the highest quality bedding, most operators prefer to capture larger fibers with a screw-press, compared to capturing both larger and smaller fibers in one step with a centrifuge). Some facilities also enhance centrifugation with the use of a flocculant, which is a chemical that helps clump solids together. Using flocculant adds a significant operational cost but can enhance phosphorus removal (see Figure 4 below).

Figure 4: Phosphorus removal with and without polymer at 7 different dairies (Facility 1-5 were all digested, Facilities 6-7 were raw manure)



Source: Removal of Phosphorus from Dairy Manure (Presentation by Josh Gable at World Ag Expo 2016)

Figure 5: Overview of Centrisys Horizontal Decanter

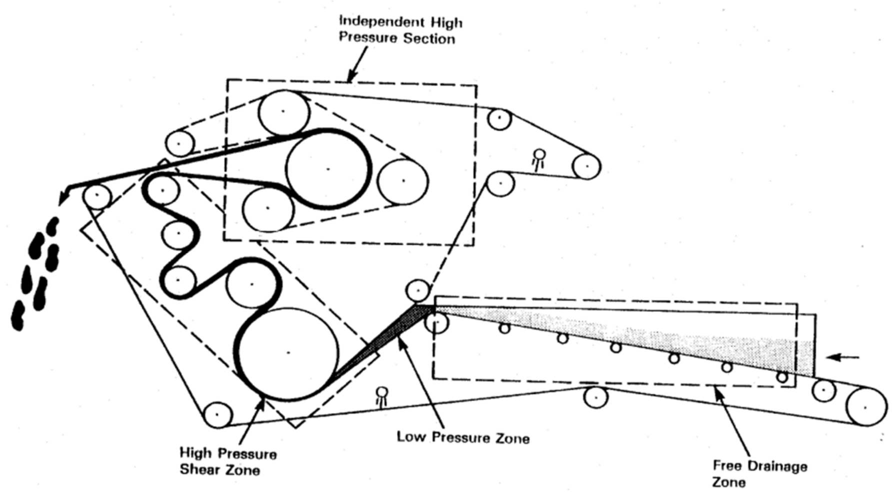


Source: https://www.centrisys-cnp.com/resource-hub/benefits-of-decanter-centrifuges-for-animal-waste-manure-management

1.2.2 Belt Filter Press

A belt filter press produces solid "cake" by pressing digestate between a filter belt and a series of rollers that press the liquid though the filter belt while the solids are scraped off of the belt after sufficient liquid recovery is completed. The digestate has coagulants and polymers mixed into it in a mixing chamber before it is distributed onto the belt over a large flat area, where it is then run through the press. As liquid is extracted it is drained off, and a solid digestate cake remains at the end of the process. This process almost always requires the addition of a polymer to the digestate to reach the desired thickness. Another disadvantage is that these systems are open and exposed, meaning they release more gases and odors from the digestate. There are also some safety concerns because of how many moving parts there are. On the other hand, operators report it's easy to see what's happening in the machine, which can make it easier to tune correctly.

Figure 6: Belt Filter Press Diagram [1]



1.2.3 DAF (Dissolved Air Floatation)

A DAF separates suspended solids in digestate by using small air bubbles to float the solids to the top of a tank, where they can be skimmed off and removed. Digestate that has been treated with polymers and/or coagulants is pumped into a basin where dissolved air is injected, causing the particles to float. A skimmer collects the solid particles, scraping them over a beach weir into a solids collection basin while the liquid portion of the digestate flows under the solids collection beach and exits the system. The skimmed solids are typically further dewatered with a press (a Multi-Ring press is commonly used in this application). Figure 7 shows a DAF unit with Multi-Ring presses in the foreground to dewater the float. This creates a wet cake product very similar to a centrifuge or belt filter press (~20-25% dry matter), but typically uses less energy. When tuned correctly, DAF and similar flotation technologies can remove a high proportion of phosphorus while using less polymer than a horizontal decanter and with lower operating costs (there are fewer moving parts and much less horsepower required to run a DAF compared to a horizontal decanter).

Figure 7: DAF Unit

Photo provided by Digested Organics

1.3 Advanced/Emerging Technology

There are several emerging technologies that are working to further advance the current nutrient recovery market. These technologies have the ability to enhance the removal of phosphorus, nitrogen, or other nutrients, but some technologies still have not been operated at an industrial scale yet.

1.3.1 Biological Nutrient Removal

Biological nutrient removal refers to a set of processes that rely on microorganisms to treat digestate, similar to how municipal wastewater treatment plants operate. One common example is the activated sludge process, where digestate (or effluent from one of the processes discussed above) is mixed with bacteria in an aerated tank. The bacteria consume the organic matter and convert the ammonia present into nitrate. In a second process, the nitrate can be converted to nitrogen gas (released to the atmosphere). The liquid from this process is usually separated from the bacterial sludge via a clarifier, but membrane filtration can also be used to create clean effluent (in which case a membrane-bioreactor may be used). Excess sludge must be removed and dewatered periodically and will contain most of the phosphorus. Because digestate is many folds more concentrated than typical municipal wastewater, facilities rarely use activated sludge type processes without substantial pre-treatment. Activated sludge processes would typically be more expansive for phosphorous removal compared to other solutions that can achieve phosphorus removal without biology but can be useful as part of a multi-step treatment train when clean water is discharged to a waterway. This technology is best applied with high flow rates and high water content, which does not make it an ideal candidate for a community digester.

1.3.2 Filtration Solutions

Since the majority of phosphorus in digested manure is in the smallest solid particles (between 0.1 and 5 microns), filtration can be a very effective way to remove phosphorus. The two main types of filtrations applicable are microfiltration and ultrafiltration. Usually, microfiltration removes particles larger than 0.5 microns whereas ultrafiltration removes particles larger than 0.05 microns. Both will typically remove >85% of the total phosphorus in digestate, along with >99% of the bacteria and suspended solids. Due to the high number of suspended solids in digestate, filtration is only performed after larger particles have been removed by a screw-press or one of the other technologies discussed above.

Tubular filtration technologies, where the liquid is pumped through membranes shaped like round pipes, is most commonly used for digestate as it is resistant to plugging. Pumps are used to circulate the material through the tubes; faster circulation velocities increase filtration rates but also use more energy, so a balance between membrane area and pump size must be considered during design. Membranes are typically made from plastic (such as PVDF and PES), metal (porous stainless steel), and ceramics. Special consideration must be given to the type of membrane used to ensure high filtration rates and longevity. Finally, while these filtration solutions can very effectively remove phosphorus, they produce a thick slurry containing the phosphorus (~8-12% dry matter) and not a stackable wet cake like some of the other solutions. This can be an advantage because the material remains in-pipe and is easy to pump but can be a disadvantage if the phosphorus needs to be transported far distances out of a watershed.

Once digestate has been micro- or ultrafiltered, the clean fluid (called permeate) can be further processed to remove dissolved solids (e.g. salts, color molecules, etc.). Nanofiltration and reverse osmosis (RO) are typically used here, and RO can generate clean, clear water for reuse or discharge. Because ammonia is a very small molecule (NH_3/NH_4), the RO permeate will often contain trace amounts of ammonia that requires further polishing prior to stream discharge. This can be done with a second RO, along with other technologies like ion exchange, biofiltration, etc.

While these filtration solutions have been commercially in use for decades throughout various industries, deploying filtration for digestate management is newer. Several large-scale commercial facilities utilizing both tubular PVDF membranes and titania-coated stainless-steel membranes have now been in operation for many years and can provide reliable data on long term cost of ownership.

Figure 8: Stainless Steel Ultrafiltration System for Digested Dairy Manure

Photo provided by Digested Organics

1.3.3 Mechanical Vapor Recompression

Mechanical Vapor Recompression (MVR) begins with a liquid slurry, in this application it would be digestate, being sprayed onto plates inside an enclosed, gas tight chamber. The liquid slurry is separated by thermal evaporation. The liquid portion evaporates while the solid portion is scraped from the heated plate, collected, and removed from the chamber. The vapor is then recompressed and captured as water vapor and ammonia (with a stripping tower). While ammonia is present in dairy manure and a vital part of fertilizers, it is not at very high concentrations and would require further equipment to make it into ammonium nitrate. This additional equipment and low concentration make it very cost prohibitive to remove and collect. While ammonia would be recovered by the MVR technology, this process is very energy intensive and requires constant maintenance and upkeep. This technology has not been proven to be effective in this application.

1.3.4 Algae

An alternative biological process to activated sludge involves growing microalgae, which are single cell organisms that can take up nitrogen and phosphorus from wastewater [3]. Algae require light, so are typically grown in outdoor raceways or enclosed bioreactors and are sensitive to temperature. While several universities and scientific institutions have proven algae can take up nutrients, it can be difficult and expensive to remove the algae from the treated water and effective scale-up of the technology has not been demonstrated. Plus, the cold temperatures and low light during Wisconsin’s winters would make year-round treatment using algae very challenging.

2.0 BY-PRODUCT MARKET

2.1 Sulfur

Sulfur can be recovered from biogas scrubbing systems that are designed to remove hydrogen sulfide (H_2S). Different technologies have been commercially available for many years. Some result in a sulfuric acid solution, while others generate elemental sulfur. The agriculture industry typically appreciates sulfur as a fertilizer nutrient, and sulfur by-products can be sold as-is or blended into other by-products to enhance their value. For example, elemental sulfur can be added to wet cake from a centrifuge or DAF unit prior to composting or granulation. Or sulfuric acid can be added to digestate during filtration to enhance the removal of ammonia during reverse osmosis (RO), ultimately generating a sulfur-enhanced liquid fertilizer (the RO concentrate).

The sulfur product produced via the methods discussed above can be land applied in either a liquid or solid state. It can be mixed (in liquid form) with compost or stored separately as a solid and land applied at agronomic rates. The key to land applying sulfur lies in having enough storage for it during times of the year when it cannot be land applied. It is important to note that there is not a viable market for sulfur, so a revenue stream should not be expected from sulfur generation.

2.2 Phosphorus

Phosphorus is necessary for all crop production and is the number one nutrient when looking at the impact on surface waters from agricultural applications. In the correct amount applied under the correct conditions it will ensure optimum crop production. When applied in excess, it can be carried off the fields by rain runoff and turn lakes and waterways green due to algae blooms. This fact is understood in great detail and is maybe the single most motivating issue for the development of this effort. The anaerobic digestion process can provide the breakdown of complex organics, liberating the phosphorus and making it more plant available. It also affects to the formation of calcium phosphate salts that may become plant available one to two years after application.

The recovery of the phosphorus from dairy manure is possible utilizing many of the technologies discussed previously. Overall, the type of phosphorus that can be made and the form it is in will be dependent on how the end users need to have the product. Making a thick slurry is relatively simple and lower in cost but generates a thick liquid and needs storage or tankage to be applied when the land is being tilled before planting. Making a granular or pellet solid is certainly preferred for storage, but it must be in a form that the local land application contractors can manage.

Finally, the value of the recovered phosphorus is greater when it is viewed as an organic fertilizer. This, however, requires that the process meets OMRI requirements. The digestion of dairy manure provides a significant raw material for the generation of phosphorus fertilizers. The final selection of a process and end product must be made in conjunction with the actual groups utilizing the nutrient.

2.2.1 Granulation and Pelletization

Granulation is one of the most common ways to convert phosphorus in a wet cake product into a sellable dry fertilizer. A wet cake with 20-25% dry matter is conveyed into a twin-shaft paddle mixer, where it combines with already dried material. This machine causes agglomeration of the material, forming a 2-5 mm granule. The agglomerated material then moves to a rotary drum dryer where it’s dried to about 10% moisture, followed by a cooler and then a screen. Granules that are too large or too small get ground up and recycled to the front, while granules that are on-size are conveyed into bulk bags or silos.

An alternative to granulation involves pelletization. While pellets are a well-known alternative to granules, our experience is that granules have a higher market value because they are perceived to be better incorporated into soil and more quickly available (since they have a higher surface area). Pelletization involves a high-pressure pellet mill that squeezes the dried material into the shape of a small pellet. There is a viable market for phosphorus in both granular and pellet form.

2.3 Nitrogen

In general, digestate is rich in ammonia as all organic nitrogen in the substrate is converted to ammonia. Depending on the type and incoming solids content of the substrate, this ammonia may be available in concentrations where it can be concentrated into a sellable liquid fertilizer rich in nitrogen. Dairy digestate obviously contains ammonia, and in high solids contents it can be recovered but in low concentrations that can be cost prohibitive to recover.

The ammonia that is present can be removed from the digestate through various forms of stripping and concentration, resulting in either aqueous ammonia (ammonia in water solutions) or ammonia salt solutions (like ammonium sulfate). Aqueous ammonia has a high pH and is volatile (meaning the ammonia will escape into the atmosphere), so it must be stored carefully and incorporated into the soil by the end user. Ammonium sulfate is not volatile but requires the use of sulfuric acid to produce it, which adds to operating costs. Besides ammonia stripping, nitrogen fertilizers can also be made by concentrating the digestate via filtration. By removing water, the concentration of nitrogen in the final product increases. Typically, these products are 4-10% nitrogen by weight. Depending on which process is used, nitrogen fertilizer can also be approved for use by organic farms. Several OMRI-listed products are now available, and these are worth significantly more than conventional nitrogen fertilizers (on a per pound of N basis). Since many farmers lose up to half of the ammonia nitrogen in manure or digestate while lagoon storing it, capturing the ammonia and creating a sellable by-product is very attractive. This reduces local air pollution of ammonia and nitrous oxides while generating new revenue streams for projects.

2.4 Compost

Composting is the aerobic decomposition of organic waste. The solid portion of digestate is an ideal candidate for compost due to its porosity and concentration of organic compounds and nutrients [2]. A porous structure is necessary to provide oxygen with a pathway through the material to promote aerobic decomposition. It is important to note that the solid portion of digestate will need to have a reduced water content of 60-75% to be suitable for composting. Raw digestate has a lower dry matter content and lacks the porous structure that a separated solid portion of digestate has. Liquid and solid separation can be accomplished by using one of the physical separator technologies mentioned in 1.1 Physical Separation or 1.2 Chemical-Assisted Physical Separation.

While composting with one substrate, such as dairy manure digestate, is possible, a minimum of two substrates is generally used [2]. Other substrates that are suitable for composting are grass clippings, leaves, mulch, food waste, straw, sawdust, and various other organic materials. A compost pile should have an initial ratio of carbon to nitrogen of 20-30:1.

Composting a material, manure digestate in this case, is made up of three steps; anaerobic, aerobic, and fungal. The digester provides the anaerobic portion, while stacking of the digestate solids/fiber into windrows handles the aerobic step. The fungal process works its way through the stacks as a white, “fungal line” that, upon completion, signifies a finished, stable composted product. This step’s completion can vary greatly on the climate at which the stacked material resides, as for example, winter conditions can stop the fungal step completely. These steps all come with their own timelines that add up to take anywhere from one month to one year to fully breakdown into a stable, potentially nutrient-rich soil amendment depending on a variety of factors such as the feedstocks, time of year, and weather conditions. With the proper conditions and management, compost can produce high quality organic fertilizer that can be appropriately marketed and sold.

A standard windrow compost pile will not reduce phosphorus that enters the watershed. For that reason, covered aerated static piles would be needed instead. Aerated static piles are more complex and therefore more expensive than standard windrow compost piles. That being said, if managed correctly with proper containment, compost could be created using the manure solids and returned to the participating dairies as a soil amendment. Given the time that composting can take to complete, the space requirements, its sensitivity to ambient conditions that can negatively affect its processing time, and its required containment to contain phosphorus, it could be difficult to name it as a financially viable option for this application.

2.5 Dairy Bedding

It is a very common dairy practice to use recovered manure solids for dairy cow bedding. Recovered manure solids are abundant, affordable, recyclable, and easy to transport, but require processing before they can be the best for bedding. If the manure was not processed completely within the anaerobic digester system or used raw (not processed in a digester before solids separation), it can harbor pathogens that can cause many issues for the cows. Also, unlike other popular bedding materials such as sand or mattresses that are inorganic, if the fiber gets wet within the bedding stalls, harmful bacteria can take hold within the fiber, requiring the fiber bedding to be changed out more frequently than the previously mentioned options. Some farmers have no problem with a higher maintenance bedding option given the savings but others who don’t have the time/attention to put towards their bedding solids will struggle.

Typically, if a diary is sending its manure through a digester, the manure is subjected to high temperatures and digestion times long enough to kill the majority of the pathogens within the manure. The digestate (digested manure) is then sent through a solids separation system, generally consisting of one or more screw presses in parallel, where the liquid (effluent) is squeezed from the digestate while the solids are recovered and piled up. The piled solids are then used for bedding the dairy cows on. During separation, the phosphorus will generally remain with the solids while the ammonia will go with the liquid fraction. It is important to note here that as the TS content of the digestate increases, the phosphorus recovery potential within the bedding solids also increases. So, if the digestate is of a lower TS percentage, the amount of the phosphorus recovered with the bedding solids will be lower than if the digestate has a higher percentage of TS. Depending on the dairy, the freshly separated solids can also be wind-rowed for further pathogen destruction via composting while waiting to be used.

This could be a very real solution for the solids portion of the manure received at the community digester, but it doesn't come without it's challenges. As mentioned above, a portion of the phosphorus (dependent on the TS of the digestate) will be going with the bedding solids, meaning that some of the phosphorus will continue back to the dairies within the watershed. Therefore, if the solids are being returned to the manure source dairies, it is not being captured and removed from said watershed. Now, as long as the recovered bedding fiber is being collected with the fresh manure at these dairies and is returned to the community digester, there shouldn't be any phosphorus issues but, if excess bedding is disposed of at a dairy, the phosphorus contained within will be released into the watershed. To avoid this, the community digester's excess solids bedding could be sent out of the watershed, to either other dairies or to a soil amendment manufacturer. This could come at either a net revenue or a cost, depending on the local need.

The other issue that arises is the quality of the bedding. If the digester isn't healthy for any given reason and the manure being processed by it isn't getting digested to completion (at the appropriate temperature, for the required time), the solids collected post solids separation will not have had sufficient pathogen kill. This will cause issues for any farmer that would use it to bed their cows on, hurting their cow health and decreasing milk production, on top of souring relationships between the community digester and the dairies, not to mention the liability issues for the community digester. To avoid this, a bedding drum (composting drum) or dryer system and/or windrowing practices can be installed/used at the community digester to assure good quality bedding fiber but this will increase capital and O&M costs.

Depending on the environment, a dryer may be necessary to produce a stable bedding fiber for the dairy cows. In more arid environments, a dryer is not necessary since the dry air will continue to remove moisture from the fiber but in a humid climate, a dryer will need to be implemented to make the fiber dry enough to be put into the dairy's free stalls. In wetter climates, the fiber will absorb moisture from the air, providing a bacteria-friendly environment within the bedding, causing issues for the dairy cows' health. This is why it is key for farmers to keep up on timely bedding change-outs and stall cleanings when using fiber bedding. The dryer is employed to both further kill bacteria within the bedding and to get it dry enough that it will last longer within the stalls before needing to be changed out. Due to the location and climate of this study, it is very likely that a dryer will be necessary when producing fiber bedding for the participating dairies. Some dairies have been able to utilize a BRU (bedding recovery unit), which are effectively large composting drums that utilize the heat produced during composting to dry the bedding, but these are greatly affected by the ambient air moisture and can be less effective.

2.6 RNG

When there is a natural gas pipeline interconnect nearby a biogas facility, RNG is usually the most feasible option for biogas. Biogas from an anerobic digester usually has concentrations of various compounds that are higher than what is allowed in natural gas pipelines. An RNG gas upgrading facility helps to remove those compounds, generally CO_2, N_2, H_2S, siloxanes, VOCs, to acceptable limits for injection into a pipeline. Typical equipment at a dairy manure to RNG facility includes, but is not limited to, the following:

- H_2S Bulk Removal and H_2S Polishing
- Condensate Removal
- VOC Removal
- CO_2 Removal
- Oxygen Removal (in instances where the pipeline specification is stringent)
- Compressors
- Gas Chromatographs
- Flow Meters
- Gas Sensors
- Flare

RNG can often be more financially appealing due to the availability of federal and state incentives, RFS RINs and California LCFS, to promote the RNG market. A full site analysis would be necessary to determine if RNG is the best path forward for any potential facility.

The three most common RNG upgrading technologies used within the RNG industry at this time are water wash, membrane, and PSA systems. A water wash system utilizes water scrubbing towers to scrub the methane from the biogas. Membrane systems use fiber strand filled cartridges that the biogas flows through under pressure, with the methane molecules being too large to exit the strands, they pass through the cartridge while the rest of the biogas constitutes are ejected from the fiber strands. A PSA (pressure swing adsorption) system uses special media with pores large enough to adsorb carbon dioxide molecules under pressure while the methane molecules can pass through the media beds. The beds are then depressurized, where the carbon dioxide is released from the media and vacuumed out of the media tanks. This will be discussed further in the design basis stage of this study.

2.6.1 Carbon Dioxide

CO_2 is a by-product of the RNG upgrading process, as the biogas produced by anaerobic digestion contains approximately 35% CO_2. RNG upgrading technology, specifically membrane and PSA systems, create highly concentrated exhaust streams of CO_2. This CO_2 can be refined to remove impurities, such as H_2S and N_2, to then create liquified CO_2 which has several applications. The CO_2 can also be converted into e-fuels, synthetic fuels produced from biogenic CO_2. For upgrading CO_2 to be financially viable, it is important to understand what markets for CO_2 exist in the area including food and beverage grade purposes.

2.6.1.1 Food Grade Production

CO_2 can be further refined to food grade quality, which is much more valuable than non-food grade CO_2. There are very few facilities that upgrade digester biogas CO_2 to food grade quality due to price of equipment, number of regulatory agencies involved, time required to get certified, and operations costs. It is most likely not feasible for Dane County to operate a food grade CO_2 production facility due to these costs and does not further the primary objective of removing nutrients of the watershed.

2.6.1.2 E-Fuel Production

Synthetic methane is created by binding H_2 and biogenic CO_2 in a high-pressure environment with a catalyst [4]. Furthermore biogas can be further processed and refined into e-gasoline, e-methane, e-kerosene, or SAF. There is growing interest in e-fuels from companies in industries that are difficult to de-carbonize, such as aviation. E-fuel production is still in its infancy, and it may take several years for the market for e-fuels to be fully realized.

2.7 Renewable Electricity

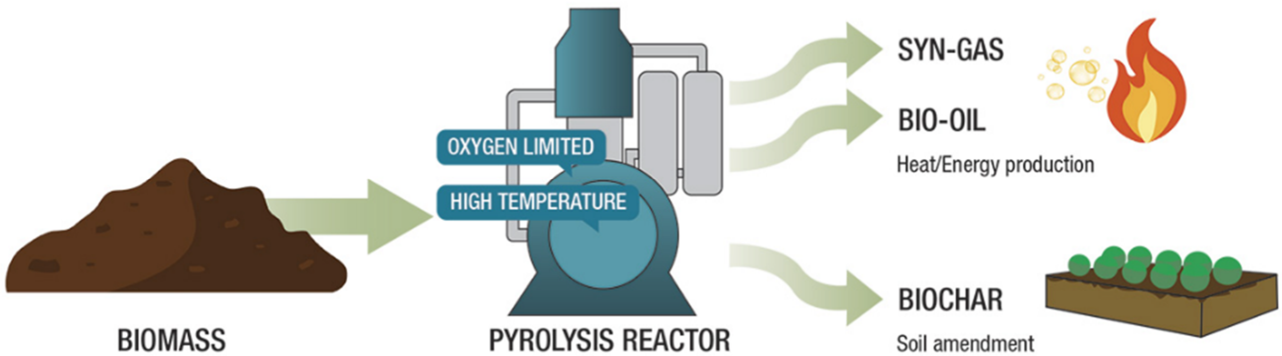
If an RNG connection is not feasible, generating renewable electricity is an alternative option. A CHP (combined heat and power) system includes electric generation and recovery of waste and exhaust heat that can be used for heating the facility or process heating needs, like heating the digester. If there are limits for utility gas at the proposed site, a CHP can serve as the gas for heating the building and necessary equipment. A CHP system maximizes the potential of the digester gas by utilizing the heat from the generator and the exhaust. The heat is cycled through a series of heat exchangers which can then cycle through a series of pipes that can bring heat to other locations of the facility. The generator and heat recovery system would be housed in a small building. If the CHP is used to heat the digester, a boiler will be necessary to heat it during commissioning or maintenance or general downtime of the CHP.

CHPs were very popular amongst digester sites for many years but have been utilized less and less over recent years. This is due to two major drawbacks of the CHP: high maintenance costs and low income from the electricity sold. CHP maintenance can be very cost-intensive due to the number of wear parts in a typical engine and the requirement of specially trained technicians to perform most of the CHP's required upkeep and repair. As for the revenue from the electricity created, most utility companies aren't signing high value PPAs (power purchase agreements) these days, sometimes offering only the bare minimum payment per kilowatt-hour. Due to this, the income received is not always enough to maintain the engine used. Despite these drawbacks, there are still some circumstances where CHPs make sense, but they are becoming less common as the industry evolves and as other technologies are developed.

2.8 Biochar

Biochar is produced during pyrolysis, a process where a feedstock is heated to temperatures between 660°F and 1,650°F in an oxygen deficient environment [6]. Pyrolysis produces three primary byproducts; Syn-Gas, bio-oil, and biochar. Syn-Gas and bio-oil can be used for heating or energy production, and biochar, which is a carbon-rich solid material. Pyrolysis results in a 40% to 80% reduction in mass of the feedstock but concentrates the phosphorus into the biochar. Biochar can either be applied as a soil amendment or removed from the county to reduce phosphorus runoff into watersheds of interest. Not only does a pyrolysis facility require significant capital investments and high operating costs, but digested dairy manure also lacks the carbon necessary to produce a dense, desirable biochar product. The digested dairy manure will have lost a good portion of its carbon to the digestion process; carbon necessary for biochar production. In summary, the biochar created by the dairy manure would be of low quality and given the high capital and operating costs of the system, does not necessarily make sense for this application.

Figure 9: Pyrolysis Overview [6]



3.0 TECHNOLOGY RECOMMENDATION

Given the conceptual nature of this report, the bedding and manure collection approaches at dairies within the selected townships have yet to be quantified. A number of potential scenarios for nutrient removal and byproduct recovery exist. Appendix B shows five possible manure TS content ranges with suitable nutrient removal technologies for each. Regardless of where the manure solids content lands for the dairies in the selected township(s), a technology exists for suitable nutrient removal.

Burns & McDonnell selected a midrange design condition as an example for the analysis discussed herein. The midrange design condition assumes a scenario with a manure TS content between 7% and 9% from a mix of sand bedded and flush dairies, based on typical manure collection methods known to be used by dairies in the area. As additional information about bedding, manure collection practices, or anticipated TS content at selected dairies within Dane County is received regarding a specific project application, the nutrient recovery technology selected may need to be modified.

3.1 Selected Technology

As noted prior, is assumed that the TS content of the manure into the digester will be between 7% and 9% TS. After digestion the digestate will have a TS content of around 5% TS. At that TS content, a screw press (Section 1.1.1) can be used to initially separate the majority of the solid (fiber) portion from the liquid portion of the digestate. After the solid portion is removed, it can be composted, as discussed in Section 2.4, or dried for reuse as dairy bedding, as discussed in Section 2.5. The solid portion will contain approximately 10% - 20% of the phosphorus in the digestate.

The liquid portion of the digestate will still contain approximately 80% - 90% of the phosphorus, and it will require further nutrient removal. There are several nutrient removal technologies that can continue to remove phosphorus. A horizontal decanter (Section 1.2.1), belt filter press (Section 1.2.2), or DAF (Section 1.2.3) can be used with chemical addition to remove suspended solids, and in the event of a thinner (lower TS) digestate, an ultrafiltration system (Section 1.3.2) can be used directly following the screw press. After passing through one of these technologies, nitrogen can be removed via a biological nutrient removal system (Section 1.3.1) or an additional ultrafiltration system with reverse osmosis and chemical addition (Section 1.3.2).

The permeate from the ultrafiltration and/or reverse osmosis process is essentially pure water that must be treated to return a buffer system (to reduce reactivity) before it can be utilized or released to the environment. That is, pure water is corrosive. The retentate from the process will contain the residual nutrients in the digestate after primary and secondary separation. This will be ammonia and phosphorus salts in addition to any other dissolved solids in the effluent. This residual can be thickened via evaporation or further separation processes. It is indeed a fertilizer and if this path forward is chosen reuse alternatives will need to be identified. Since it is a salt, storage must be planned if concentration is desired. In low concentrations, it can go to typical manure storage where the end result is land application at rates in compliance with the comprehensive nutrient management plan for the facility. Thickening can make the transport of the nutrients out of the watershed feasible. This can be affected by incorporating the UF/RO rejects into composts destined to leave the water shed.

3.2 Reliability

The selection of nutrient removal technologies need to consider number of moving parts, points of failure, and operator labor. By selecting the simplest equipment, the facility can have a high uptime while reducing O&M costs for multiple operators, repairs on broken equipment, and minimal need for replacement parts. As additional information about project criteria are identified, the nutrient recovery technologies can be selected to meet the defined project goals.

4.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

4.1 Summary

Burns & McDonnell has provided a high-level review of nutrient removal technologies and potential by-product markets available for a community digester. It is important to note that further investigation into specific project applications will help provide a more realistic outlook for the potential expenses and revenues that can be expected. This effort is part of a larger, high level study looking at the potential of a community digester system and its ability to help mitigate nutrients contained in dairy manure migrating into the county's surface waters.

4.2 Conclusions

There are a variety of nutrient removal technologies available to use in a future community digester for Dane County. Due to the high-level nature of this initial study, additional information about the local dairies will need to be known that could be served will be necessary to begin designing the community digester. This report should be used as a high-level guide to technology offerings and potential by-products that can be produced at a community digester.

4.3 Recommendations

From this point onward, there are several recommendations to further refine the scope of this project:

1.) The incoming manure from the anticipated participating dairies needs to be specifically quantified and more thoroughly understood. An estimated incoming manure load will help size and specify the potential nutrient removal technologies at the facility. Furthermore, by better understanding the anticipated total solids (TS) content of the manure, nutrient removal technologies can be further refined and selected;

2.) Further refinement of the desired phosphorus and nitrogen recovery goals and ultimate removal targets, currently and in the future. Additionally, the desired form that the nutrients should leave the watershed in, be it slurry, pellet, or as a solids cake; and,

3.) Financial analysis will help reveal the approximate cost of the facility based on size and nutrient removal technology selected. As discussed in Section 1.0, the desired nutrient removal and percentage removal is the primary driver in technology selection. Higher rates of removal for nutrients such as phosphorus and nitrogen from the waste stream will result in higher costs for additional equipment or chemical additions.

4.) Nutrient recovery recommendations and cost estimates will be developed in the Design Criteria that will be completed after this Nutrient Recovery Report.

5.0 REFERENCES

1. Biosolids Technology Fact Sheet Belt Filter Press. (September 2000). *EPA 832-F-00-057*.
2. Czejaka, W., et. al. (2023). Sustainable management and recycling of anaerobic digestate solid fraction by composting: A review. *Bioresource Technology*, Volume 375, 128813, ISSN 0960-8524. https://doi.org/10.1016/j.biortech.2023.128813
3. Delfanian, C. (March 22, 2021). Algae pull nutrients from swine facility manure, air. *South Dakota State University*. https://www.sdstate.edu/news/2021/03/algae-pull-nutrients-swine-facility-manure-air
4. EBA Working Group on Biogenic CO_2. (n.d.). Biogenic CO_2 from the Biogas Industry. *European Biogas Association.*
5. Larson, R., et. al. (2021). Screw Press Separation of Manure. *University of Wisconsin-Madison*.
6. Sanford, J. (March 25, 2023). Biochar as a potential tool for manure management. *Progressive Dairy.* https://www.agproud.com/articles/57209-biochar-as-a-potential-tool-for-manure-management#:~:text=Converting%20manure%20solids%20to%20biochar,phosphorus%20is%20achieved%20through%20pyrolysis

APPENDIX A – NUTRIENT RECOVERY DECISION MATRIX

DECISION MATRIX - PATH FORWARD FOR NUTRIENT REMOVAL TECHNOLOGY, RANGE = 10 (BEST) TO 1 (WORST)

PURPOSE - DETERMINE THE BEST NUTRIENT REMOVAL TECHNOLOGY

	OPTION	Safety	Capital Expenses	Operating Expenses	Major Consumables	Mechanical Reliability	Phosphorus Removal	By-Product Generation	Ease of Operation	WEIGHTED TOTAL
	Description	The dangers that equipment poses to an operator or person in the vicinity of the equipment	Typical capital expenses required for installation/startup	Typical operational expenses required to run the equipment	Chemicals or equipment that must be replaced consistently	How many points of failure are there on this piece of equipment	Phosphorus is the main nutrient of concern, and some equipment remove more than others	Value by-products produced by the technology	Some equipment needs numerous operators while others can be automated	
	WEIGHT FACTOR = 1.0	0.15	0.1	0.1	0.1	0.1	0.25	0.1	0.1	1
1	**Technology 1:** Screw Press	7	7	8	9	9	4	7	8	6.85
	Notes: A very basic piece of technology, the recovery can be significantly impacted by the incoming solids content, output solids content, and screen sizes; the higher the TS the more phosphorus recovery. **Fiber dry matter content and fine solids recovery are mutually exclusive.** These do have the ability to be put in series to get bedding and a fine solids nearing the limit of mechanical separation.	Pinch points, moving parts	Pipe work, screw press, and feed pump	Hands-off operation, can be fully automated	Occasional screen replacement	Simple design with few moving parts	Dependent on solids content in digester, but generally the fiber post-digestion is not holding phosphorus	Excellent for producing bedding or compostable material	Hands-off operation, can be fully automated	
2	**Technology 2:** Side Hill Screen	10	9	9	10	10	1	7	6	6.85
	Notes: The thin influent to the screen limits the amount of phosphorus that can be recovered; see screw press notes. These are best for bulk removal and do not provide the precision that (a) screw press(es) can provide.	Moving parts dependent on specific vendor design	Pipe work, side hill screen, and feed pump	Hands-off operation, passive, only requires daily check-in /washing; Water useage	No consumables	Simple passive design, moving parts dependent on specific vendor	**Only applicable if post-digestion content is consistently less than 3% TS; poor phosphorus removal**	Produces excellent compost and bedding with secondary pressing (paired with a screw press)	Hands-off operation, passive operation (does need to be cleaned daily)	
3	**Technology 3:** Horizontal Decanter	5	3	3	5	7	8	5	7	5.75
	Notes: These systems can be excellent for removal of the phosphorus when augmented with a polymer feed. Without this, the recovery can many times be matched closely by nested screw presses. The most important issue with horizontal decanters is consistent feeding and consistent TS concentrations. Sand can be a big wear issue. A high TS influent concentration is needed.	High speed spinning equipment, pinch points, potential noise hazard, chemical addition (potentially corrosive)	Horizontal decanter, pipe work, conveyor for solids, feed pump, potential chemical addition dosing system	Potential chemical addition, high energy costs	Chemical consumption, occasional drive belt replacement	Design and implementation is key	With chemical addition, phosphorus removal can be very high. Without chemical addition, phosphorus removal matches that of the screw press.	Produces compost material, but not ideal bedding	PLC run after initial startup; requires daily operator attention	
4	**Technology 4:** Belt Filter Press	8	6	4	5	6	9	5	5	6.55
	Notes: Much like the horizontal decanter with polymer, the recovery can be highly effective, although neither system affects any dissolved removal. These are lower energy systems, and at certain flow rates, ideal for solids removal. These are not usable without a coagulant and polymer body feed. These are really only applicable on higher TS influent concentrations.	Several moving parts, pinch points, spinning components, chemical addition (potentially corrosive)	Belt filter press, pipe work, chemical addition dosing system, feed pump, additional processing equipment (upstream solids removal)	Chemical consumption, moderate electrical use	Chemical consumption	Multiple moving parts that require regular maintenance	Great for phosphorus removal	Produces compost material, but not ideal bedding	Relatively simple design, after initial startup runs automatically, requires daily operator attention	
5	**Technology 5:** DAF (Dissolved Air Floatation)	8	6	4	5	8	9	6	8	7.15
	Notes: Excellent for lower solids content influent. Needs coagulants and polymers to affect recovery of suspended solids. An excellent application is a DAF managing high flows with variable TS up to 5% with the solids (float) fed to a smaller horizontal decanter or belt press. This reduces the size of the secondary systems and ensures these systems feed at consistent rates. **Requires pretreatment of solids (i.e. screw press).**	Pinch points, open aeration water basin (drowning hazard), chemical addition (potentially corrosive)	DAF, pipe work, feed pump, chemical addition dosing system, additional processing equipment (upstream solids removal)	Chemical consumption, moderate electrical use	Chemical consumption, white water pump maintenance	Few moving parts that require regular maintenance	Great for phosphorus removal	Produces good material for compost or land application with secondary pressing of recovered solids (float)	Simple design, requires daily operator attention	

6	**<u>Technology 6:</u>** Biological Nutrient Removal	6	4	4	4	8	8	6	5	**6.00**
	<u>Notes:</u> High flows and low concentrations are best for this treatment technology. This is a destruction technology; the nitrogen is made into nitrogen gas and released to the atmosphere. This requires a full recovery of suspended solids before the process but can be very dependable in generating a dischargeable effluent. The suspended solids will be where most of the phosphorus is recovered. Wastewater treatment plants primarily use this technology.	Open aeration water basin (drowning hazard), chemical addition (potentially corrosive)	Tanks, pumps, blowers, control system	Chemical addition, higher energy costs due to blowers and pumps	High electricity usage due to pumps, aerators, mixers, blowers	Very few points of failure, biological points of failure due to temperature or environmental conditions	Good phosphorus removal in the SS form required up-front. Very good nitrogen removal for dischargeable water.	Main by-product is a sludge which can be pressed with secondary equipment and composted or land applied	Full time operator required to run system	
7	**<u>Technology 7:</u>** Ultra Filtration	10	2	6	6	8	8	4	8	**6.90**
	<u>Notes:</u> No impact to dissolved solids. Generally must be followed by a RO (#8) and acid addition for nitrogen removal. Generally requires high pressures which, in turn mean higher energy costs to operate. Will require processing of the material upstream of the UF to avoid filter plugging. **Requires pretreatment of solids (i.e. screw press and DAF)**.	No considerable safety hazards	Very expensive	Moderate energy costs	Electricity, filter replacement	Few points of failure	Good phosphorus removal (a precursor for nitrogen removal in RO) with primary solids separation equipment	Main by-product is a concentrated liquid which can be dried, added to dry fiber to compost, or land applied	Easy to operate: automated, but requires operator supervision	
8	**<u>Technology 8:</u>** Reverse Osmosis	8	2	4	4	8	2	4	8	**4.70**
	<u>Notes:</u> Affects a clean permeate H2O as without a buffering system and needs lime addition to stabilize the water. The retainate is concentrated dissolved solids that can be high in salinity. It can be used in fertilizer applications when mixed with the UF retainate and dewatered. With acid addition it is highly effective for ammonia removal. Will require processing of the material upstream of the RO (i.e. screw press and DAF) to avoid filter plugging. Reverse osmosis must have a UF upstream.	Moving parts, potential chemical addition (potentially corrosive), potential noise hazard	Very expensive	Higher energy costs, chemical addition	Electricity, filter replacement, chemical addition	Few points of failure	Majority of phosphorus will be removed before a RO is used by primary separation equipment. Nitrogen removal possible with chemical addition	Main by-product is a concentrated liquid which can be dried, composted, or land applied	Easy to operate: automated, but requires operator supervision	
9	**<u>Technology 9:</u>** MVR (Mechanical Vapor Recompression)	2	1	1	2	1	10	5	2	**4.00**
	<u>Notes:</u> This is a developing technology. As the demand for the nutrients increase, the high operating costs may become more economically viable. Essentially makes pure water (steam) by boiling of the pre-separated effluent and collecting volatile fraction during condensation.	Noise hazard, moving parts, pinch points, hazardous vapors	Large building required, complicated process with many steps requires lots of piping, pumps, etc., additional processing equipment (upstream solids removal),	Operator intensive, energy intensive	Scrapping blades and solids removal chain are both considerable time and capital investments	Many parts of potential failure due to the complication of the process	100% phosphorus removal	Makes a dry product, not compostable on its own and does not make bedding	Multiple moving parts, operator intensive, requires fully staffed operations and maintenance, entire process shutdown weekly for scraper change outs.	
10	**<u>Technology 10:</u>** Algae	8	6	7	10	4	1	2	2	**4.55**
	<u>Notes:</u> There are projects currently in operation using digestate to grow algae and then compost the resultant algae for land application. This is currently a developing technology and is certainly applicable in low solids digestate. Significant pretreatment is necessary to affect an influent to the algae process that is not too high in nutrients or BOD. Footprint is at about an acre with most recent technological advances in algae.	Potential drowning hazard (if are ponds used)	Requires significant pre-treatment equipment and large ponds or greenhouse for operations	Mixers, paddles, pumps, belts for media that algae grows on.	No consumables	Runs in the warm weather outside, but not the cold weather unless in covered greenhouses.	Equipment upstream removes majority of phosphorus, algae is final "polishing" and removes ammonia	Algae is the by-product	Impossible to operate in cold weather (below 47 F) unless in greenhouses, minimum 1 FTE operator required for daily maintenance. Does not require 24-7 support.	

APPENDIX B – PROCESS FLOW DIAGRAM

BURNS McDONNELL

Figure 1

Process Flow Diagram
Nutrient Removal Technology
Dane County

Section D – Business Structure Analysis Report

Dane County Community Digester Business Structure Analysis

Dane County Land & Water Resources Department

Business Structure Analysis
Project No. 169859

Final Report
4/14/2025

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Executive Summary

The Dane County Land & Water Resources Department has tasked Burns & McDonnell with performing a feasibility study for a community manure digester facility (Facility) within Dane County, Wisconsin to reduce nutrient runoff to waterways, specifically Lake Mendota and Lake Monona. Local dairy farmers will provide the manure for the community digesters located at the Facility Site. Via anaerobic digestion, the manure will produce biogas that will be either upgraded to renewable natural gas (RNG) for injection into a pipeline or burned in engines to generate electricity and heat in a combined heat and power (CHP) biogas engine.

As part of the feasibility study, 1898 & Co. has provided possible ownership arrangements for the community manure digester facility. The possible ownership arrangements considered are as follows:

1. Public Ownership – prioritizes public benefit (reducing nutrient runoff) over profit but may suffer from inefficiency and funding constraints. Public acceptance and efficient cost management are crucial.

2. Private Ownership - Driven by profit and market forces, potentially conflicting with the primary goal of nutrient reduction. Uncertainty in commodity prices and the potential for cost-cutting measures pose risks.

3. Cooperative Agreement - Combines member control and community focus with profit sharing, potentially mitigating some drawbacks of public ownership. However, capital raising and decision-making processes may be slower.

4. Public-Private Partnership (PPP or P3) - Aims to leverage the strengths of both public and private sectors, sharing risks and accessing private capital. However, complex negotiations and potential conflicts of interest require careful planning and clear agreements.

For each of the business structures, we have detailed the pros and cons of each structure as well as discussed how each scenario would impact Dane County.

Dairy manure-to-biogas projects offer farmers a way to reduce waste management costs and diversify income through biogas sales. Successful implementation hinges on carefully negotiated contracts between farmers and renewable natural gas (RNG) developers. These contracts typically cover revenue sharing, contract duration (often 20 years), capital investment responsibilities, and operational duties for the digester equipment. Farmers may be involved in manure handling, but operational responsibilities within the digester facility itself can vary widely depending on the project's design and the contract terms. Thorough contract review is crucial for farmers to understand maintenance obligations, revenue distribution, and risk mitigation strategies. The use of digestate as fertilizer is also a key benefit, often accommodated within existing nutrient management plans. Examples from various locations illustrate the successful implementation of such projects, highlighting both economic and environmental benefits.

The cost of transitioning dairy farms to a community manure management approach will vary greatly depending on existing manure handling and bedding practices. The table below summarizes the various dairy manure management and bedding extremes by type.

Category	Generalized Dairy Management Types	Description
Type 1	**Vacuum Collection**	Any size dairy vacuuming manure and placing in any type of conveyance for current processing or storage on site.
Type 2	**Scrape/Flush in a Lagoon**	Any size dairy scraping or fluming directly into a large pit or lagoon for storage.
Type 3	**Sand Bedded with Closed Loop Sand Recovery System**	Any dairy size bedding on sand and closed loop separating.
Type 4	**Flush/Flush Flume without Sand Bedding**	Any size dairy utilizing flush or flush flume recovery and bedding on anything other than sand.
Type 5	**Flush Flume with Sand Bedding**	Any size dairy utilizing flush manure collection and bedding on sand.

Dairies currently using vacuum collection systems (Type 1) will experience minimal cost increases, primarily related to trucking. Dairies using scraping or fluming into pits or lagoons (Type 2) will face higher costs for new collection and loading systems, with smaller dairies experiencing the largest impact. Dairies with closed-loop sand separation (Type 3) will likely see cost savings due to centralized separation, unless they choose to continue on-site operations. Dairies using flush or flush-flume systems with non-sand bedding (Type 4) will incur significant hauling cost increases due to diluted manure volume. Finally, sand-bedded flush systems (Type 5) will experience the highest costs due to the need for extensive dilution to separate the sand, resulting in a substantial increase in hauling volume. The finer the sand, the greater the dilution and hauling costs. Overall, smaller, simpler systems will see the most significant cost increases compared to larger dairies already handling high manure volumes. Standardizing sand size is recommended for optimal community system operation.

1.0 Public Ownership

A public owner and public operator business structure is where the government or a public entity owns and operates a business or service. This model is often used for utilities, transportation, and healthcare services. Below are some of the pros and cons of this structure:

Pros		Cons	
Public Interest Priority	Primary goal is to serve the public rather than to make a profit	**Inefficiency**	Can be less efficient due to bureaucratic red tape and lack of competitive pressure
Accountability	Higher level of transparency and accountability to the public	**Funding Constraints**	May rely on government budgets which are subject to allocation constraints
Quality Focus	Prioritize quality and safety over profit or cost-cutting	**Limited Innovation**	Without the drive for profit, there may be less incentive for innovation & improvement
Long-Term Vision	Plan for long-term rather than focus on pressure of short-term financial returns	**Cost to Taxpayers**	The cost of running the service may be covered by taxpayers which could be a burden if not managed properly

1.1 Impacts for Dane County

A public ownership structure is appealing for Dane County as the economics of the project may be stressed due to low commodity prices. If the primary goal of the community digester is to reduce nutrient runoff to waterways, specifically Lake Mendota and Lake Monona, a public ownership and public operation may be the preferred business structure. This would allow Dane County to focus on the public benefits of reducing nutrient runoff to waterways rather than driving to generate a profit. Given the uncertainty in future commodity prices, if Dane County wanted to act quickly to reduce the nutrient runoff to waterways, their best option may be to explore a public ownership and public operator business structure. However, the county needs to weigh the general public acceptance and be willing to take accountably for some of the cons outlined above.

2.0 Private Ownership

A private owner and private operator business structure, where a private entity owns and operates a business or service, is common in many sectors. This business structure is the most common structure in the dairy manure to RNG industry as government support such as Low Carbon Fuels Standards and RINs make projects commercially attractive. However, the environmental and economic benefits of RNG are linked and can create a complex economic picture. For example, the Henry Hub Natural Gas spot price averaged $2.21/MMBTU in 2024. RNG sells at a premium to Henry Hub because of its climate offsetting benefits and incentive programs at the state and federal level. Additionally, some purchasers will pay a premium price for RNG because of its status as renewable natural gas.

Since the economic value of many of these RNG projects hinges on credits related to the environmental attributes of the projects, private ownership offers the capability to navigate complex inner workings. Private companies have access to capital markets to fund the capital expenses associated with an RNG project. Here are some of the pros and cons:

Pros		Cons	
Efficiency	Private companies are often driven by earning profits which leads to higher efficiency and reduced costs	**Profit Motive**	Primary focus on profit can sometimes lead to cost-cutting measures that may negatively impact employees or environment
Innovation	Competitive nature of the private sector often drives innovation and improvement	**Short-term Focus**	Pressure to deliver short-term financial results can overshadow long-term planning and stability
Flexibility	Can quickly adapt to market changes and customer needs without the constraints of bureaucracy	**Accountability**	May not be as transparent with the public
Investment	Access to capital markets allows for investment opportunities		

2.1 Impacts for Dane County

Private ownership and private operator structure may be challenging for the proposed Community Digester Facility in Dane County. The private sector model is driven by profit and associated market forces. This may interfere with the ultimate goal of Dane County to reduce nutrient run off to waterways as the business structure favors generating a profit rather than public benefit. Additionally, given the uncertainty of commodity prices, the project may be subject to cost-cutting measures which may affect the nutrient run off to the waterways. For example, if the facility is struggling to generate a profit, the operator may choose cost-cutting measures that benefit the bottom line rather than managing the nutrient run off to the waterways. Additionally, market forces may present a challenge of when the project would be constructed. Finally, profits are not likely to be reinvested into the local community and will be decided by the private owner.

3.0 Cooperative

Cooperative (co-op) businesses are unique structures where members, who are also the owners, work together for their mutual benefit. This model is often used in agriculture, retail, housing, and finance. Here are some pros and cons of a co-op business structure:

Pros		Cons	
Member Control	Members have a say in the decision-making process, ensuring that the business operates in their best interest	**Limited Capital**	Raising capital can be challenging as co-ops rely on member contributions
Governance	Typically, each member has a vote, regardless of their investment size, promoting fair representation	**Slow-Decision Making**	Democratic processes can sometimes slow down decision making
Community Focus	Often prioritize community needs and local development, contributing to social & economic of the area	**Conflict Potential**	Differences in member opinions and interests can lead to conflicts or impact decision making
Profit Sharing	Profits are distributed among members, fostering a sense of ownership and investment in the co-op's success	**Regulatory Challenges**	Navigating different regulations and compliance requirements can be complex
Long-Term Focus	Tend to focus on sustainable growth and long-term stability rather than short-term profits		

3.1 Impacts for Dane County

The Cooperative structure is similar to a public ownership as many of the owners could be customers, employees, or community members. Each member has a theoretical equal vote in the facility and the members can strive for a common goal. Profit sharing is also a more direct impact back into the community because the Cooperative members are likely to share the same vision or measure of success for the facility and reinvest the profits back into the project or community. The Cooperative structure can alleviate some of the taxpayer burden and inefficiencies experienced by a public ownership structure.

4.0 Public-private partnership (PPP) or P3

A Public-Private Partnership (PPP) is a collaborative arrangement between a government agency and a private-sector company to finance, build, and operate projects such as public transportation systems, parks, and infrastructure. Here are the pros and cons of such a partnership:

Pros		Cons	
Risk Sharing	PPPs allow for the sharing of risk between public and private sectors. Financial and operational risks can be distributed	**Complex Negotiations**	Agreements can be complex and time consuming to negotiate requiring detailed legal and financial expertise
Access to Private Capital	Access to private capital can reduce the need for public borrowing and ease strain on government budgets	**Limited Public Control**	Public sector may have limited control over certain aspects of the project, potentially leading to decisions that prioritize profit over public interest
Improved Efficiency	Compared to a public ownership, the involvement of the private sector can lead to improved efficiency	**Accountability**	Accountability can become blurred and become challenging to determine responsibilities
		Risk of Failure	If the private partner fails to deliver, the public sector may have to step in leading to additional costs

4.1 Impacts for Dane County

Public-Private Partnerships can offer significant benefits over other single ownership structures such as public ownership or private ownership. Public-Private Partnerships attempt to blend the best of both private and public ownership structures. While this looks great on paper, the agreements can be complex and require careful planning and clear agreements. Accessing private capital can alleviate the taxpayer burden but also limits the public interest of the project. This may be a preferred option for Dane County to explore if the capital cost burden is too cumbersome for the county, but they still want oversight with the facility.

5.0 Farmer Economic Evaluation

The farmer is often considered the primary stakeholder in a dairy manure-to-biogas project. With a well-established dairy business, the farmer's decisions regarding bedding and manure management are made to support their dairy operations. Therefore, the integration of digester equipment into a dairy farm must prioritize the farmer's existing dairy activities. For dairy farmers, it is crucial that digester equipment does not disrupt daily operations. The farmer has a financial incentive to install a digester, as it can reduce waste management costs by utilizing digestate as fertilizer. Furthermore, if the farmer chooses to become an owner, the increased revenue from biogas sales can help diversify their income sources beyond milk sales.

The contract negotiation and agreement between a farmer and the RNG developer is crucial to successful digester implementation. Typically, farmers and the RNG developer enter into RNG contracts to agree on the following:

- **Revenue Sharing** – The contract often stipulates how the proceeds from the RNG sales will be allocated between the farm and the developer.
- **Duration** – Generally, this extends for a 20-year period or the expected life of the digester facility.
- **Capital Investment** – This will determine who will contribute certain amounts for the initial costs of the facility. This can drastically influence the financial viability of the project and also revenue sharing arrangements.
- **Operational Responsibilities** – An important agreement between the RNG facility and the farmer details out who is responsible for operating and maintaining each piece of equipment at the RNG facility. For example, the farmer may choose to be responsible for operating certain major equipment. For the Dane County project, it was originally assumed that the dairymen would handle getting the manure to the facility and taking back the nutrients/bedding fiber/final effluent. It is even possible that a contract hauler would be brought in to do all the hauling, in which event the farmers would do no operations within the RNG facility. Since the Dane County project is an offsite facility, the farmers would not be responsible for operating any equipment.

It is crucial for a farmer to understand the importance of contract scrutiny, focusing on maintenance duties, revenue distribution, and risk management.

As discussed in the Community Manure Treatment Feasibility Study Report, the dairies will have allowance in their nutrient management plans to take the bulk of the composted solids back after processing to be used as a soil amendment.

5.1 Farmer Economic Costs Impact

The actual costs incurred by each individual dairy operation will largely depend on the specific manure management practices currently in place at each facility. Additionally, the type of bedding used at each facility will also influence overall costs. Given the typical manure management practices and bedding types, the following table describes five types of dairies for consideration:

Category	Generalized Dairy Management Types	Description
Type 1	**Vacuum Collection**	Any size dairy vacuuming manure and placing in any type of conveyance for current processing or storage on site.
Type 2	**Scrape/Flush in a Lagoon**	Any size dairy scraping or fluming directly into a large pit or lagoon for storage.
Type 3	**Sand Bedded with Closed Loop Sand Recovery System**	Any dairy size bedding on sand and closed loop separating.
Type 4	**Flush/Flush Flume without Sand Bedding**	Any size dairy utilizing flush or flush flume recovery and bedding on anything other than sand.
Type 5	**Flush Flume with Sand Bedding**	Any size dairy utilizing flush manure collection and bedding on sand.

Dairy Type 1, which currently utilizes vacuum collection, will experience the least disruption in transitioning to the community-based approach regardless of facility size. Since these dairies are already actively collecting and handling manure, existing practices will largely remain in place. The vacuum tankers will simply bring the collected manure to a central location for loading and trucking to the regional facility. The return trip from the dairy will bring back the manure in the digested form for storage until it is land applied or repurposed. Accounting for nutrients will need to be exercised to ensure the farm gets what is part of their Nutrient Management Plan (NMP) or crop plan to avoid overapplication. For this farm, the cost impact will be minimized from the viewpoint of trucking.

The variation for sites currently scraping or fluming (Dairy Type 2) to a central collection or lagoon will need to provide a new option for collection and loading. After this step, the back haul and discharge to the holding lagoons will be nearly identical to the current operation. The smaller dairy sites, utilizing small onsite storage and having minimum contact with the manure, except for land application, will feel the cost impact greatest in this scenario.

Dairy Type 3 facilities, which currently separate sand in a closed-loop system and utilize vacuum collection, are likely to experience a more favorable cost impact. The centralized sand separation system will remove this operating cost from the dairy and then the hauling to a return of sand and digestate will replace onsite costs. If a facility chooses to maintain on-site operations, it will incur increased hauling costs associated with transporting thinned manure containing between 4% and 6% total solids (TS). This cost impact will be consistent across all herd sizes.

Dairy Type 4, flushing or flush fluming bedding on fiber, will see the greatest impact on hauling the thinned manure. Flush fluming will dilute the manure to 6% to 7% TS, effectively doubling the volume of manure and therefore doubling hauling costs. The flush dairy on fiber will benefit in that they must only get the volumes to the point that the flush can clean the lanes but not the point that the bedding need be removed. They can send this to the digester and benefit with digested fiber returned to the site.

The sand bedded flush manure systems (Dairy Type 5) will have the greatest impact, with herd count commensurate to the costs. In this scenario, the system must not only scour the lanes to provide a clean lane but also move all the sand and then be thin enough to allow the sand to settle out in the onsite sand lane. This may mean diluting the manure from 12%, as excreted, to 1.5%, resulting in a 12-fold increase in manure volume that needs to be hauled. The energy held in the manure is in the soluble form and therefore the whole, fully diluted manure volume must be digested.

Overall, the finer the sand being utilized implies more water needed to dilute the emulsion holding the sand in suspension and therefore the thinner the manure becomes. A standardization of sand size must be considered for the community system to best operate.

The biggest impact to individual cost from size will be on the sophistication of the dairy for its size. That is, generally, small systems can be very simple, moving manure only once, scraping to a pit or lagoon, etc. These sites will see the impact of double hauling and loading and unloading, etc. In addition to the use of collection points on the farms. The larger dairies will already be dealing with this double handling just due to the size of the operation.

As part of the Feasibility study, an economic assessment was prepared for various manure management scenarios and bedding types versus herd size. All farms will have some perturbations that will limit all blanket statements on how they will each be impacted by the proposed central manure digestion and nutrient management systems. Therefore, quantification of the entire universe of opportunities potentially encountered is not feasible. The economic analysis that was developed utilized several herd sizes and variations using sand, recovered fiber and other organic bedding. The analysis made standard decisions about how the diary is managing manure based on experience across the dairy industry. The costs were developed for manure volumes expected given a specific management procedure and bedding type and if the bedding separation or processing was to be provided at the central hub or at the dairy. That is, a dairy currently operating a flush system with sand is currently separating sand on-site. Whereas a scrape management dairy on recovered fiber will need the bedding returned from the solid separation system after the digester. The universe assessment is provided within the Farmer Economic Costs breakdown that can be found in Appendix A.

The following assumptions were used during the assembly of the table discussed above.

- All analysis is based on a Wet Cow Equivalent (WCE) of a full-grown milking Holsteins producing 21 gallons of manure per cow, per day.
- For sand bedding dairies using scrape recovery, the dairy will pay for return of the sand per ton and will haul back the volume of liquid they hauled to the community digester.
- The manure volume that sand bedding dairies haul to the community digester will be diluted to 5% total solids on average using flush manure or recycle at the location; that is, the flush manure will go back to the flush dairy, not the sand bedder.
- Each WCE requires 40 lbs. of bedding sand.
- Storage size is the size of a tank necessary to hold the manure on-site before being pumped to the tanker for hauling to the site. This does not in all cases imply a day's volume of manure generated.
- Manure Handling is the loading, offloading, and hauling of manure. Its cost is doubled to cover the return trip with an equal volume of digestate.
- The management costs for any given farm is held as constant as the diaries will get the volume of manure sent raw as digestate. Whatever processes were being utilized on site will be the same for the same volume.
- For small dairies, the Cap-EX includes a holding tank as it is assumed the current process is some type of direct push to an onsite pit or lagoon. This would not be feasible for a situation where pumping and hauling are expected.
- The cost of a new manure hauling tanker is estimated at $250,000.00, with a hauling capacity of 8,000 gallons.
- Hauling assumptions
    - A 5 mile round trip will cost $0.015 per gallon.
    - A 17 mile round trip will cost $0.0175 per gallon.
        - These rates assume that diesel is under $4.00/gal.

APPENDIX A - FARMER ECONOMIC COST EVALUATION

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Manure Feasibility Study: Farmer Economic Cost Evaluation					Dane County, Wisconsin
Burns & McDonnell	Assembled by:	BBS / BPS	on	6/6/2025	

Green	Simple Implementation - Candidate for hauling from/to Central Digester/Nutrient Management Facility
Yellow	Definition - Marginal for hauling due to bedding and volume. Candidate for local Hub Digester and Nutrient Management Facility
Red	Definition - Management Limits participation via hauling, strongest candidate for Hub Digester and Nutrient Management.

Dane County Manure Digester Study: Farmer Economic Costs

Bedding Material: Sand

Dairy Size in Holstein WCEs	Manure Mgt Type: / Cost/Volume Categories	Scrape – Current	Scrape – With Facility	Scrape w/ Flush Flume – Current	Scrape w/ Flush Flume – With Facility	Flush/Sand Lane – Current	Flush/Sand Lane – With Facility
300	Cap-X (reception):		$25,000	Generally too small for anything but scraping		Generally too small for anything but scraping	
	Daily Expected Manure (gal/day):	7,739	7,739				
	Manure Handling ($/day):		$271				
	Pump to/from storage ($/day):		$50				
	Storage Size (gal):		10,000				
	Loading of Land App Equip($/day):		N/C**				
	Transport to Field ($/day):		N/C				
	Land Application ($/day):		N/C				
	Return Sand/fiber/Equip + Staff ($/day):		$8,796				
500	Cap-X (reception):		$35,000	Generally too small for anything but scraping		Generally too small for anything but scraping	
	Daily Expected Manure (gal/day):	12,898	12,898				
	Manure Handling ($/day):		$451				
	Pump to/from storage ($/day):		$75				
	Storage Size (gal):		15,000				
	Loading of Land App Equip($/day):		N/C				
	Transport to Field ($/day):		N/C				
	Land Application ($/day):		N/C				
	Return Sand/fiber/Equip + Staff ($/day):		$9,674				
1,000	Cap-X (reception):		$50,000		$75,000		$75,000
	Daily Expected Manure (gal/day):	25,796	25,796	95,814	95,814	168,000	168,000
	Manure Handling ($/day):		$903		$3,354		$5,880
	Pump to/from storage ($/day):		$100		$150		$200
	Storage Size (gal):		27,500		50,000		50,000
	Loading of Land App Equip($/day):		N/C		N/C		N/C
	Transport to Field ($/day):		N/C		N/C		N/C
	Land Application ($/day):		N/C		N/C		N/C
	Return Sand/fiber/Equip + Staff ($/day):		$50,150		$200,150		$400,150
2,000	Cap-X (reception):						
	Daily Expected Manure (gal/day):	51,592	51,592	191,629	191,629	336,000	336,000
	Manure Handling ($/day):		$1,806		$6,707		$11,760
	Pump to/from storage ($/day):		$250		$300		$400
	Daily holding Storage Size (gal):		50,000		50,000		50,000
	Loading of Land App Equip($/day):		N/C		N/C		N/C
	Transport to Field ($/day):		N/C		N/C		N/C
	Land Application ($/day):		N/C		N/C		N/C
	Return Sand/fiber/Equip + Staff ($/day):		$50,800		$250,000		$450,000
4,000	Cap-X (reception):						
	Daily Expected Manure (gal/day):	103,185	103,185	383,257	383,257		672,000
	Manure Handling ($/day):		$3,611		$13,414		$23,520
	Pump to/from storage ($/day):		$400		$400		$400
	Storage Size (gal):		50,000		50,000		50,000
	Loading of Land App Equip($/day):		N/C		N/C		N/C
	Transport to Field ($/day):		N/C		N/C		N/C
	Land Application ($/day):		N/C		N/C		N/C
	Return Sand/fiber/Equip + Staff ($/day):		$100,800		$400,800		$600,000

Bedding Material: Recovered Fiber

Dairy Size in Holstein WCEs	Manure Mgt Type: / Cost/Volume Categories	Scrape – Current	Scrape – With Facility	Scrape w/ Flush Flume – Current	Scrape w/ Flush Flume – With Facility	Flush w/ Possible Grit Recovery Lane – Current	Flush w/ Possible Grit Recovery Lane – With Facility
300	Cap-X (reception):	N/A	$20,000	Generally too small for anything but scraping		Generally too small for anything but scraping	
	Daily Expected Manure (gal/day):	6,300	6,300				
	Manure Handling ($/day):		$221				
	Pump to/from storage ($/day):		$50				
	Storage Size (gal):		7,500				
	Loading of Land App Equip($/day):		N/C				
	Transport to Field ($/day):		N/C				
	Land Application ($/day):		N/C				
	Return Sand/fiber/Equip + Staff ($/day):		$8,796				
500	Cap-X (reception):	N/A	$20,000		$25,000		$30,000
	Daily Expected Manure (gal/day):	10,500	10,500	18,000	18,000	84,000	84,000
	Manure Handling ($/day):		$368		$630		$2,940
	Pump to/from storage ($/day):		$100		$150		$200
	Storage Size (gal):		10,000		20,000		20,000
	Loading of Land App Equip($/day):		N/C		N/C		N/C
	Transport to Field ($/day):		N/C		N/C		N/C
	Land Application ($/day):		N/C		N/C		N/C
	Return Sand/fiber/Equip + Staff ($/day):		$16,742		$20,075		$66,742
1,000	Cap-X (reception):		$50,000		$50,000		$50,000
	Daily Expected Manure (gal/day):	21,000	21,000	36,000	36,000	168,000	168,000
	Manure Handling ($/day):		$735		$1,260		$5,880
	Pump to/from storage ($/day):		$100		$150		$200
	Storage Size (gal):		20,000		20,000		20,000
	Loading of Land App Equip($/day):		N/C		N/C		N/C
	Transport to Field ($/day):		N/C		N/C		N/C
	Land Application ($/day):		N/C		N/C		N/C
	Return Sand/fiber/Equip + Staff ($/day):		$25,150		$50,150		$200,150
2,000	Cap-X (reception):		N/C		N/C		N/C
	Daily Expected Manure (gal/day):	42,000	42,000	72,000	72,000		336,000
	Manure Handling ($/day):		$1,470		$2,520		$11,760
	Pump to/from storage ($/day):		$150		$200		$250
	Daily holding Storage Size (gal):		25,000		25,000		25,000
	Loading of Land App Equip($/day):		N/C		N/C		N/C
	Transport to Field ($/day):		N/C		N/C		N/C
	Land Application ($/day):		N/C		N/C		N/C
	Return Sand/fiber/Equip + Staff ($/day):		$50,300		$100,300		$600,300
4,000	Cap-X (reception):		N/C		N/C		
	Daily Expected Manure (gal/day):	84,000	84,000	144,000	144,000		672,000
	Manure Handling ($/day):		$2,940		$5,040		$23,520
	Pump to/from storage ($/day):		$150		$200		$250
	Storage Size (gal):		25,000		25,000		25,000
	Loading of Land App Equip($/day):		N/C		N/C		N/C
	Transport to Field ($/day):		N/C		N/C		N/C
	Land Application ($/day):		N/C		N/C		N/C
	Return Sand/fiber/Equip + Staff ($/day):		$200,300		$400,300		$600,300

Bedding Material: Other Organic Bedding Material (straw, rice hulls, wood chips, etc.)

Dairy Size in Holstein WCEs	Manure Mgt Type: / Cost/Volume Categories	Scrape – Current	Scrape – With Facility	Scrape w/ Flush Flume – Current	Scrape w/ Flush Flume – With Facility	Flush/Sand Lane – Current	Flush/Sand Lane – With Facility	Notes
300	Cap-X (reception):	N/A	$20,000	Generally too small for anything but scraping		Generally too small for anything but scraping		Smaller dairies scrape their manure since it is the most cost effective for their size as a flush flume system would be very costly for so little manure; Its possible but highly unlikely to have a flush flume at this herd size.
	Daily Expected Manure (gal/day):	6,300	6,300					
	Manure Handling ($/day):		$221					
	Pump to/from storage ($/day):		$50					
	Storage Size (gal):		7,500					
	Loading of Land App Equip($/day):		N/C					
	Transport to Field ($/day):		N/C					
	Land Application ($/day):		N/C					
	Return Sand/fiber/Equip + Staff ($/day):		$8,796					
500	Cap-X (reception):	N/A	$20,000		$25,000		$30,000	Smaller dairies scrape their manure since it is the most cost effective for their size as a flush flume system would be very costly for so little manure; Its possible but highly unlikely to have a flush flume at this herd size.
	Daily Expected Manure (gal/day):	10,500	10,500	18,000	18,000	84,000	84,000	
	Manure Handling ($/day):		$368		$630		$2,940	
	Pump to/from storage ($/day):		$100		$150		$200	
	Storage Size (gal):		10,000		20,000		20,000	
	Loading of Land App Equip($/day):		N/C		N/C		N/C	
	Transport to Field ($/day):		N/C		N/C		N/C	
	Land Application ($/day):		N/C		N/C		N/C	
	Return Sand/fiber/Equip + Staff ($/day):		$16,742		$20,075		$66,742	
1,000	Cap-X (reception):		$50,000		$50,000		$50,000	
	Daily Expected Manure (gal/day):	21,000	21,000	36,000	36,000	168,000	168,000	
	Manure Handling ($/day):		$735		$1,260		$5,880	
	Pump to/from storage ($/day):		$100		$150		$200	
	Storage Size (gal):		20,000		20,000		20,000	
	Loading of Land App Equip($/day):		N/C		N/C		N/C	
	Transport to Field ($/day):		N/C		N/C		N/C	
	Land Application ($/day):		N/C		N/C		N/C	
	Return Sand/fiber/Equip + Staff ($/day):		$25,150		$50,150		$200,150	
2,000	Cap-X (reception):		N/C		N/C		N/C	
	Daily Expected Manure (gal/day):	42,000	42,000	72,000	72,000		336,000	
	Manure Handling ($/day):		$1,470		$2,520		$11,760	
	Pump to/from storage ($/day):		$150		$200		$250	
	Daily holding Storage Size (gal):		25,000		25,000		25,000	
	Loading of Land App Equip($/day):		N/C		N/C		N/C	
	Transport to Field ($/day):		N/C		N/C		N/C	
	Land Application ($/day):		N/C		N/C		N/C	
	Return Sand/fiber/Equip + Staff ($/day):		$50,300		$100,300		$600,300	
4,000	Cap-X (reception):		N/C		N/C			
	Daily Expected Manure (gal/day):	84,000	84,000	144,000	144,000		672,000	
	Manure Handling ($/day):		$2,940		$5,040		$23,520	
	Pump to/from storage ($/day):		$150		$200		$250	
	Storage Size (gal):		25,000		25,000		25,000	
	Loading of Land App Equip($/day):		N/C		N/C		N/C	
	Transport to Field ($/day):		N/C		N/C		N/C	
	Land Application ($/day):		N/C		N/C		N/C	
	Return Sand/fiber/Equip + Staff ($/day):		$200,300		$400,300		$600,300	

** N/C denotes no change to current operational costs.

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Section E – Economic Evaluation Report

Dane County Community Digester Economic Evaluation

Dane County Land & Water Resources Department

Economic Evaluation
Project No. 169859

Final Report
4/14/2025

Disclaimer

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List of Abbreviations

Abbreviation	Term
RNG	Renewable Natural Gas
LCFS	Low Carbon Fuel Standard
RIN	Renewable Fuel Identification
NPV	Net Present Value
IRR	Internal Rate of Return
LTSA	Long Term Service Agreement
MWh	Mega Watt hour
RICE	Reciprocating Internal Combustion Engine
BOP	Balance of Plant
WCE	Wet Cow Equivalents
MMBtu	Million British Thermal Units
DAF	Dissolved Air Filtration

Executive Summary

An economic assessment of the Dane County Community Digester renewable natural gas ("RNG") project was conducted utilizing the capital cost projections formulated by the engineering team at Burns & McDonnell, along with revenue projections and operations and maintenance assumptions. For each of the capital cost projections, we evaluated a Low, Med, and High price index for each of the associated revenue streams. Depending on the configuration, most of the options sell either RNG or electricity, Nitrogen, and Granules (pelletized). Typical of RNG projects, the economics depend heavily on the LCFS (Low Carbon Fuel Standard) and RIN (Renewable Identification Numbers) credits. Approximately 84% of the revenue generated by the project derives from LCFS and RIN credits. Results of the economic evaluation are detailed in Table 1-1.

Figure 1 1: Economic Evaluation Results

Option	Project Cost ($MM)	High Case NPV ($MM)	High Case ROI (%)	Med Case NPV ($MM)	Med Case ROI (%)	Low Case NPV ($MM)	Low Case ROI (%)
RNG - Option 1	$163	$135	13%	$12	6%	($99)	-3%
RNG - Option 2	$212	$201	14%	$54	8%	($81)	1%
RNG - Option 3	$190	$178	14%	$41	8%	($85)	0%
Power - Option 1	$157	($86)	-2%	($158)	-	($231)	-
Power - Option 2	$207	($23)	4%	($120)	-2%	($216)	-
Power - Option 3	$185	($44)	3%	($131)	-5%	($218)	-

Key observations and discussion of the pro forma model are as follows:

- The project generates positive economic results as an RNG Upgrading facility at both Med and High commodity prices.
- Electricity generation results in poor economics. This is largely the result of not receiving LCFS or RIN credits and the LTSA (major maintenance) cost provided by the OEM to service the equipment outweighing the revenue generated. The model assumes High, Med, and Low electricity sales prices of $300/MWh, $180/MWh, and $60/MWh. However, none of the prices produce sufficient revenue to offset the capital cost and associated operations and maintenance costs.
- Option 1, for both RNG Upgrading and Electricity, has lower Capex but results in lower NPVs across the board. This is a result of Option 1 not generating any revenue from granules sales. Option 1 assumes compost being sold rather than granules.
- At the time, contingencies have not been included in the capital cost estimates.

1.0 Community RNG Pro Forma

1898 & Co. utilized the capital cost estimates generated by the Burns & McDonnell engineering team along with anticipated expenditures and potential revenue streams to develop a pro forma financial estimate ("pro forma"). Facility capital expenditures ("CAPEX"), operating expenditures ("OPEX"), major maintenance, and revenue streams for different configurations and scenarios were considered for the pro forma. The pro forma is intended to project the Facility's potential financial performance based on various conditions and assumptions detailed in this section. Based on these conditions and assumptions, the anticipated net present value ("NPV") and internal rate of return ("IRR") for each configuration and scenario are calculated.

1.1 Capital Expenditure

Six cost estimates, representing various configurations of the Facility, were developed by the Burns & McDonnell engineering team. These cost estimates are detailed in Table 1-1.

Table 1-1: Cost Estimate Summary ($MM)

Description	RNG Only			RNG & Power		
	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Total Direct Costs	**$162.79**	**$212.30**	**$190.17**	**$157.22**	**$206.73**	**$184.60**

In Table 1-1 the RNG Only options represent the Facility configurations that are designed to output and sell RNG, Nitrogen, and pelletized granules as the final product. The RNG & Power options represent the Facility configurations that are designed to generate RNG, then consume the RNG in reciprocating internal combustion engine ("RICE") power generation units to generate sell electricity as the final product. More detailed descriptions of the design specs, major equipment, and Facility configurations are detailed in the "Community Manure Treatment Feasibility Study Report."

It is important to note that the CAPEX estimates shown above in Table 1-1: Cost Estimate Summary ($MM) do not include contingency. The contingency was excluded as the CAPEX estimates generated are considered a Class 5 estimate by AACE Standards and would carry contingencies of -20% to +100% which could skew the economic evaluation.

1.2 Operating Expenditures

In addition to CAPEX, ongoing expenditures incurred for staffing, consumables, electricity, etc. were evaluated. While these costs will vary depending on the size of the Facility selected, specific location, source of power, and owner preferences, estimated values have been included to support the full evaluation of the project.

OPEX was considered for the pretreatment, RNG production, and power generation equipment, as applicable for each option. Based on similar facilities and general industry practice, a percentage of the CAPEX cost of each configuration of Facilities was used to calculate the total annual OPEX. 1898 & Co. used a database of approximately 20 similar RNG projects to benchmark the forecasted annual OPEX. Using inflation at 1.50%, the annual OPEX was projected over the anticipated useful life of the Facility (20 years). Using the discount rate of 6%, the equivalent annual OPEX amount for each scenario is detailed in Table 1-2.

Table 1-2: OPEX Summary

Option	Levelized Annual OPEX
RNG – Option 1	$7,775,175
RNG – Option 2	$10,139,938
RNG – Option 3	$9,082,739
Power – Option 1	$8,392,466
Power – Option 2	$11,035,436
Power – Option 3	$9,853,861

1.3 Major Maintenance

In addition to OPEX, major maintenance items were included in the evaluation for the pretreatment, RNG production, and power generation equipment.

RNG production major maintenance items include clean-outs and roof rebuilds every eight years for each digester. Regular clean-outs help the digester operate efficiently, preventing blockages and maintaining the quantity of the biogas produced. Roof rebuilds for the digester buildings are critical to prevent leaks, air intrusion, and structural failures.

Power generation major maintenance items include the costs for a long-term service agreement ("LTSA") with the RICE engine manufacturer as well as a yearly allowance for additional major maintenance items for balance of plant ("BOP") equipment. An LTSA is put in place to cover major maintenance items associated with the main systems of the RICE units, additional maintenance will be required on the uncovered and BOP equipment.

Using the discount rate of 6%, the equivalent annual major maintenance amount for each scenario is detailed in Table 1-3.

Table 1-3: Major Maintenance Summary

Option	Levelized Annual Major Maintenance
RNG – Option 1	$838,757
RNG – Option 2	$838,757
RNG – Option 3	$838,757
RNG & Power – Option 1	$2,344,680
RNG & Power – Option 2	$2,344,680
RNG & Power – Option 3	$2,344,680

1.4 Pro Forma Inputs

Multiple inputs, or independent variables, were included in the pro forma to be used in the financial statement. The major inputs are detailed in Table 1-4.

Table 1-4: Pro Forma Inputs Summary

Category	Input	Options / Input
Site Details	Scenario	Option 1/2/3 – RNG Option 1/2/3 - RNG & Power
	Number of Cows	20,000
	RNG Production (MMBtu/yr)	380,000
	Plant Useful Life (years)	20
Financial Inputs	Discount Rate (%)	6%
	Inflation	1.50%
	Capital Spend Start	2026
	Construction Period (yrs)	3
	Year 1 (Engineering) Capital Split	5%
	Year 2 (Construction) Capital Split	70%
	Year 3 (Commissioning/Startup) Capital Split	25%
Revenue Parameters	RNG Sales?	TRUE / FALSE
	Electricity Sales?	TRUE / FALSE
	Nitrogen Sales?	TRUE / FALSE
	Pelletized Granules Sales?	TRUE / FALSE
	Natural Gas Price Case	Low / Med / High
	RIN Price Case	Low / Med / High
	LCFS Price Case	Low / Med / High
	Electricity Price Case	Low / Med / High
	Nitrogen Sales Price Case	Low / Med / High
	Pelletized Granules Price Case	Low / Med / High
Operating Parameters	Operating Days (days per year)	341
	Availability (%)	93.5%
Power Generation Parameters	Heat Rate (Btu/kWh)	8,475
	Capacity (kW)	5,628

1.5 Revenue Streams

1898 & Co. anticipated the revenue streams of the Facility based on each configuration.

1.5.1 RNG Production

The anticipated quantity of RNG produced by the Facility is 380,000 MMBtu/year, which equates to approximately 19 MMBtu/WCE. The entire assumed herd size of 20,000 cows are assumed to be wet cow equivalents (WCE), Holstein basis. The RNG is assumed to operate and generate pipeline quality

RNG approximately 341 days a year, resulting in an availability of 93.5%. Further definition of the gas production volumes is discussed in the "Community Manure Treatment Feasibility Study Report."

1.5.2 Electricity Production

For the options that include electricity production, four RICE units will be installed at the facility for power generation. Each engine has a rated capacity of 1,407 kW for a combined total capacity of 5,628 kW. The engines' heat rate is 8,475 Btu/kWh. For options with electricity production, the sweetened biogas produced by the digestor is consumed by the RICE units, which in turn produce approximately 42,923 MWh per year, achieving a capacity factor of almost 85%.

1.5.3 Nitrogen Production

All options presented in the pro forma for both RNG Upgrading and Electricity generation assume a nitrogen production rate of approximately 578,782 gallons/year. This is based on the wastewater stream leaving the UF/RO having a concentration of 1% nitrogen. There is approximately 169,594 gallons of wastewater leaving the UF/RO per day with a nitrogen concentration of approximately 1% or 1,696 gallons per day.

The concentrated Nitrogen has a market to be sold as fertilizer. However, most nitrogen fertilizer sales require a concentration of around 6% to receive demand. Therefore, the 1% concentrated Nitrogen generated by this Facility would require additional equipment and processing to achieve the 6% concentration threshold. To account for this additional equipment cost, we have assumed a discounted sales price for the 1% nitrogen concentration of $2.50/gallon. We used this price as our base case or Med price assumption within the pro forma.

Nitrogen production accounts for approximately 6-10% of the total revenue generated by the Facility.

1.5.4 Granules Production

Option 2 and Option 3 assume that all recovered manure fiber (except the fiber required by the dairies bedding on recovered manure fiber) and DAF (Dissolved Air Floatation) wet cake will be pelletized as granules and returned to the dairies as allowed by their land nutrient plans, to Dane County residents, and sold/moved out of the county.

Option 2 assumes a pelletized granules production rate of approximately 127 tons per day. Option 3 assumes a pelletized granules production rate of approximately 76 tons per day. Option 3 has less pelletized granule production due to all of the recovered fiber returning to the participating dairies as bedding.

1.5.5 Commodity Price Projections

The sale of RNG has the potential for multiple revenue streams. A projection of each potential revenue stream was developed, including a "High", "Medium", and "Low" forecast to allow for a sensitivity analysis. The anticipated 2025 values of each of the potential revenue streams of RNG sales are detailed in Table 1-5.

Table 1-5: Revenue Stream Parameters

Revenue Stream	Scenario	2025 Price	Sales Unit
LCFS	High	$37.10	$/MMBtu

Revenue Stream	Scenario	2025 Price	Sales Unit
	Med	$24.73	
	Low	$12.37	
RIN	High	$36.28	$/MMBtu
	Med	$24.76	
	Low	$15.55	
Natural Gas	High	$3.30	$/MMBtu
	Med	$2.75	
	Low	$2.20	
Nitrogen	High	$3.00	$/gallon of 1% N concentration
	Med	$2.50	
	Low	$2.00	
Pelletized Granules	High	$240.00	$/ton
	Med	$200.00	
	Low	$160.00	
Electricity	High	$300.00	$/MWh
	Med	$180.00	
	Low	$60.00	

For facility configurations that include the construction of power generation facilities, 1898 & Co. projected three different scenarios to calculate the potential revenue streams due to selling electricity via a virtual purchase power agreement ("VPPA"). These scenarios represent on the low end, a scenario where Dane County will enter a VPPA at a comparable price to wind and solar. On the high end, the electricity sales would be compared to the value of carbon offsets assuming a value of $2.25 eRIN.

Due to the rapidly changing energy markets, these costs were projected using a standard rate of inflation of 1.50% year over year. This is not intended to be indicative or speculative of future markets, rather to provide a steady increase to be used to calculate net present value ("NPV") and internal rate of return ("IRR") of each configuration.

1.6 Pro Forma Conclusions

The anticipated NPV and IRR of each option are detailed in Table 1-6. The NPV and IRR for the results shown in Table 1-6 represent the *Med*-price scenario for all revenue options, as detailed in Table 1-4 and Table 1-5.

Table 1-6: Pro Forma Results

Option	NPV ($MM)	IRR (%)
RNG – Option 1	$12.14	6.27%
RNG – Option 2	$54.09	8.02%
RNG – Option 3	$40.73	7.64%

Option	NPV ($MM)	IRR (%)
Power – Option 1	($158.24)	-
Power – Option 2	($119.48)	-2.43%
Power – Option 3	($131.41)	-5.41%

1898 & Co. also conducted a sensitivity analysis to determine the Best- and Worst-case scenarios for each option. These scenarios correspond to the *High*- and *Low*-price scenarios for all revenue options, as detailed in Table 1-4 and Table 1-5. The sensitivity analysis results are detailed in Table 1-7.

Table 1-7: Sensitivity Analysis

Option	Best-Case NPV ($MM)	Best-Case IRR (%)	Worts-Case NPV ($MM)	Worst-Case IRR (%)
RNG – Option 1	$134.88	12.85%	($99.36)	-3.01%
RNG – Option 2	$200.55	13.72%	($81.13)	0.84%
RNG – Option 3	$177.66	13.64%	($84.96)	-0.13%
Power – Option 1	($85.46)	-1.84%%	($231.03)	-
Power – Option 2	($22.97)	4.27%	($215.98)	-
Power – Option 3	($44.43)	2.71%	($218.39)	-

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