Organic Waste Systems

ANAEROBIC DIGESTER FEASIBILITY STUDY
-Executive Summary-

To: City of Madison, WI, Mr. G. Dreckmann and Ms. B. Bemis

EXECUTIVE SUMMARY

INTRODUCTION

The study was conducted between May and September 2012. The purpose of this feasibility study was to assess the potential implementation of an Anaerobic Biodigester Facility in the City of Madison, Wisconsin. The proposed facility is meant to recover energy and compost from the anaerobic digestion of municipal source separated organics (SSO) from households, restaurants, and grocery stores. The tonnage of the facility is estimated to be initially 25,000 to 30,000 tons annually, and to be increased to 50,000 tons within 5 years. Madison, Wisconsin is a uniquely progressive community located in Dane County in south-central Wisconsin. With a population of 233,000, Madison makes up slightly less than 50 percent of Dane County's population. Madison is home to the University of Wisconsin and is Wisconsin's state capital. The City is also a recognized leader in recycling and composting, currently diverting 66 percent of its waste stream from landfill disposal. The City continues to seek ways to further its goals of increased landfill diversion and renewable energy production.

The diversion of organics is the single largest opportunity for the City to achieve these goals and get closer to "zero waste", while providing a reduction in greenhouse gas emissions. It is also anticipated that the anaerobic biodigestion facility could serve as an ongoing economic development tool, attracting complementary business activities and anaerobic digester industry companies to the City. Given these benefits, the key objective of the feasibility study was to determine whether the City could own and operate a commercially proven anaerobic biodigester facility at a tipping fee that was comparable to current landfill costs, using revenues from renewable energy production and compost to offset the remaining debt service and operating costs.

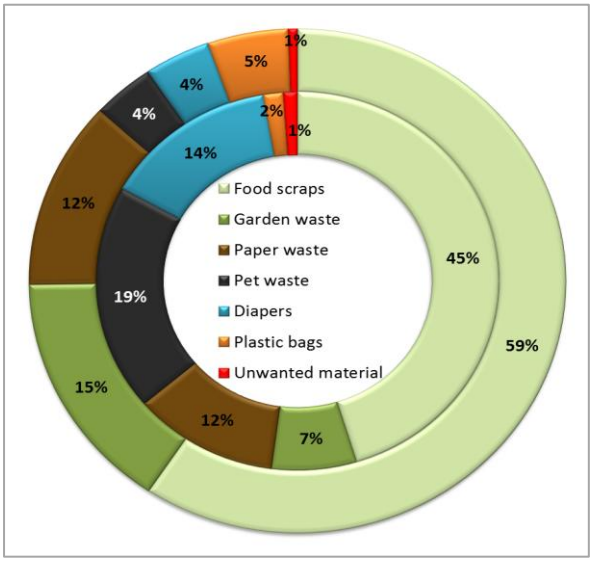
The study focused on exploring options that could be implemented adjacent to the Rodefeld Landfill operated by Dane County in order to take advantage of any synergies or efficiencies that might result from a combination of landfill gas with the biogas from the new anaerobic biodigester facility. The City currently owns parcels contiguous with the landfill which could be suitable. In addition, as part of the recently approved expansion to the Rodefeld Landfill, Dane County and the City are exploring options that would exchange these parcels for land to be purchased on the east side of County Road A/B which could then be used for the anaerobic biodigestion facility.

The Feasibility Study has been conducted in three tasks. In Task 1, samples of City SSO were collected and waste characterization and laboratory testing was conducted. In Task 2, the feasibility study incorporated the feedstock characterization information and then analyzed relevant biodigester technologies, along with the pretreatment and posttreatment technologies that each would require. A wide variety of relevant technologies and variables were evaluated for their feasibility to effectively process the City SSO. In Task 3, the study provides design details for a subset of biodigestion plant designs and energy utilization options, and then assesses the economic feasibility of each. The subset was chosen by the City and was based on the relative merits of each option.

The Feasibility Study found that multiple options appear feasible for the City to implement an anaerobic biodigester facility that meets its sustainability and economic objectives. The study recommended that a formal RFP be conducted to provide vendor quotations, and that the City explore one or more opportunities for financial incentives available to municipalities.

TASK 1: FEEDSTOCK BENCH TOP ANALYSIS

The results from Task 1 indicated that the City SSO is a fairly clean and easy feedstock with a rather high yield of biogas per ton.



(L) Waste pile from which 1st sample was taken on June 26, 2012 at transfer station
(R) Distribution of waste type, inner circle 1st sample, outer circle 2nd sample

The food scraps account for half of the input weight and half of the biogas production. The soiled (mostly non-recyclable) paper waste is the second largest contributor to the biogas production (almost 25%). Because of the high biogas potential of this fraction and its positive effect on the carbon to nitrogen ratio, encouraging households and businesses to include non-recyclable soiled paper will have positive effects on the digestion parameters and the economic feasibility of the system. The last quarter of the biogas production is originating from the pet waste (± 10%), and to a lesser extent the garden waste, diapers and compostable bags.

To achieve the 30,000 tons per year, the City will have to expand from its pilot residential SSO collection program. To achieve the beneficial economy of scale associated with a larger facility, say 60,000 tons per year, the City could include green yard waste and encourage the use of the anaerobic digestion facility by private waste haulers and surrounding communities. Collecting the SSO in biodegradable bags is shown to increase participation and reduce contamination, but the use of biodegradable bags does not significantly impact the operation of the anaerobic biodigester facility.
The resulting input mixture had a dry matter content of 36% (64% moisture) with a volatile solids content of 73% (27% ash on the total solids). The SSO feedstock is very well suited for anaerobic fermentation with a high biogas production potential of about 4500 scft/ton and a favorable C/N-ratio. The biogas contained 57% of methane and is suitable for use in engines or for upgrading to pipeline quality.

A good quality, marketable compost ccould be produced from the SSO. However, as long as the incoming waste includes diapers and pet waste, the compost would not be eligible for certification as Wisconsin Class A limits for compost even if the compost composition otherwise met all technical specifications for Class A compost. The City will have to assess the extent to which inclusion of diapers and pet waste in the City SSO are necessary or desirable for maximizing consumer and business participation and compliance.

TASK 2: EVALUATION OF RELEVANT BIODIGESTER TECHNOLOGIES

As stated earlier, the City SSO is a fairly clean and easy feedstock with a rather high yield of biogas, with no abnormal characteristics compared to many other communities. This type of waste can be processed in a variety of commercially available biodigester systems with proven track records over as much as 10-20 years. Most of these systems operate in Europe and Asia due to the implementation of mandatory organics diversion legislation in the 1990s. These factors reduce project risk and provide a highly competitive environment for design, engineering and construction.

Wet anaerobic digestion facility (L) and dry anaerobic digestion facility (R) with pre- and posttreatment and energy production

The City SSO as sampled under Task 1 is neither a typically ‘dry’ or a ‘wet’ feedstock so that either wet (6 to 8% solids in the digester) and dry biodigester systems (20 to 35% solids in the digester) could be applied. The addition of a larger fraction of non-recyclable paper, biodegradable bags, FOGs (Fats, Oils and Greases) and yard waste will tend to make dry digestion the more preferred option, while the addition of wetter commercial waste feedstocks in the future would favor wet digestion. Both wet and dry continuous digestion technologies can operate under either mesophilic (95-100°F) or thermophilic (115-125°F) temperature conditions, with a general preference for mesophilic for wet operation and thermophilic for dry continuous operation.

Even the best, well-established SSO collection programs will have some level of contamination that, if not removed, may:

- interfere with the reliable mechanical operation of the biodigester;
- take up valuable capacity in the digester
- lead to excess contamination in the compost

The level and type of feedstock pretreatmentis generally greater for wet digestion systems, since heavy contaminants will sink, causing sedimentation and lighter contaminants will float, interfering with agitation and biogas production. The most common SSO pretreatment approach for wet digestion is to dilute the waste prior to digestion to remove heavy and light contaminants to the maximum extent possible.

The study found that the level and type of pretreatment for dry digestion systems also varies, with dry continuous digestion systems incorporating higher levels of contaminant removal prior to digestion than dry batch tunnel digestion. In dry batch tunnel digestion, remaining contaminants must be removed during the compost refining step.

The study found that it would be feasible and beneficial to inject any remaining excess liquid from the anaerobic biodigester facility into the leachate recovery system at Rodefeld Landfill. This makes pre- and post-treatment options that result in the production of excess wastewater more feasible because high transportation and wastewater treatment costs are avoided. The high concentrations of pet waste (high degree of inerts) and diapers (high amount of plastics) need to be taken into consideration during the design phase or the inclusion of these wastes should be evaluated prior to issuing a request for proposals, as these fractions influence the design of the plants and the compost quality significantly.

Aspects like weather and climate restraints are also very dependent on the type of technology selected, but both mesophilic and thermophilic operation are considered to be feasible in the Southern Wisconsin climate provided the necessary precautions are taken. Tunnel digestion systems may be more challenging to heat adequately in the winter as they require larger volumes of digester capacity and usually produce less biogas and correspondingly less waste heat for heating the digesters.

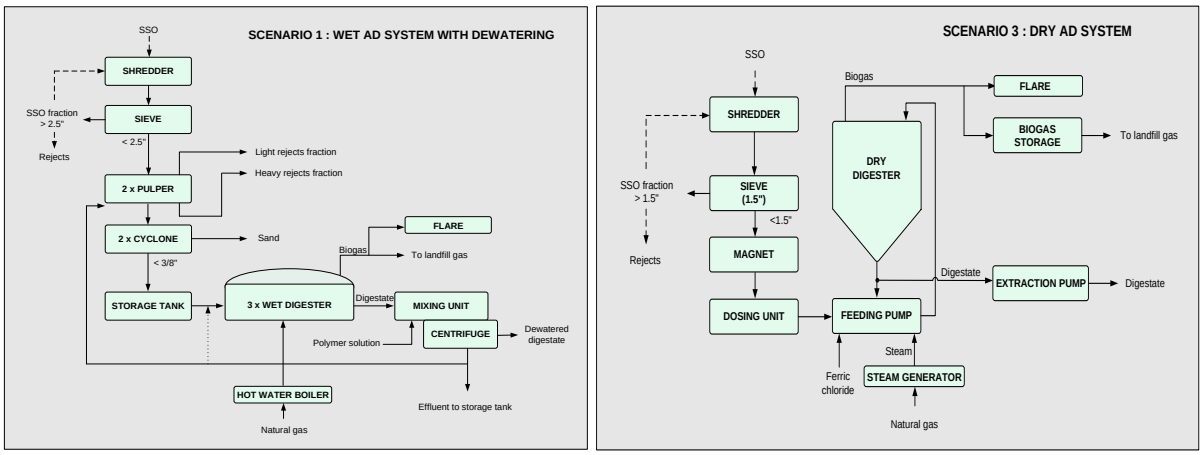
The proposed location for the anaerobic biodigestion facility adjacent to the landfill provides sufficient space for multiple physical plant configurations and scope of processing. The surface area requirements range from 1.8 to 3.75 acres for the range of systems assessed.

There are a wide variety of possible uses of the biogas. The use of the biogas in the existing gas engines for the remaining 1.5 MW of installed capacity at the Rodefeld Landfill and for the duration of the contract between MG&E till 2020 seems the most straightforward and economical solution. However, depending on the changes in landfill gas production associated with leachate recirculation and the limited duration of the power purchase agreement, the option of the conversion of the biogas into RCNG for vehicle use should be concurrently pursued. The proximity to the Rodefeld Landfill provides an excellent opportunity for the City to implement a hybrid or transitional business plan: initially pipe 100% of the biogas to the landfill, while sizing and sourcing a RCNG system for optimal economics and proportionate to its fuel usage in converted vehicles. The RCNG station could be installed as funds become available and, once operational, the facility could continue to pipe any excess biogas to the landfill for electrical production.

None of the scenarios or energy utilization options require the use of experimental, pre-commercial or un-proven technology or equipment. In each aspect of the facility, technology and equipment providers are continuously implementing incremental improvements that improve the reliability and productivity of the systems.

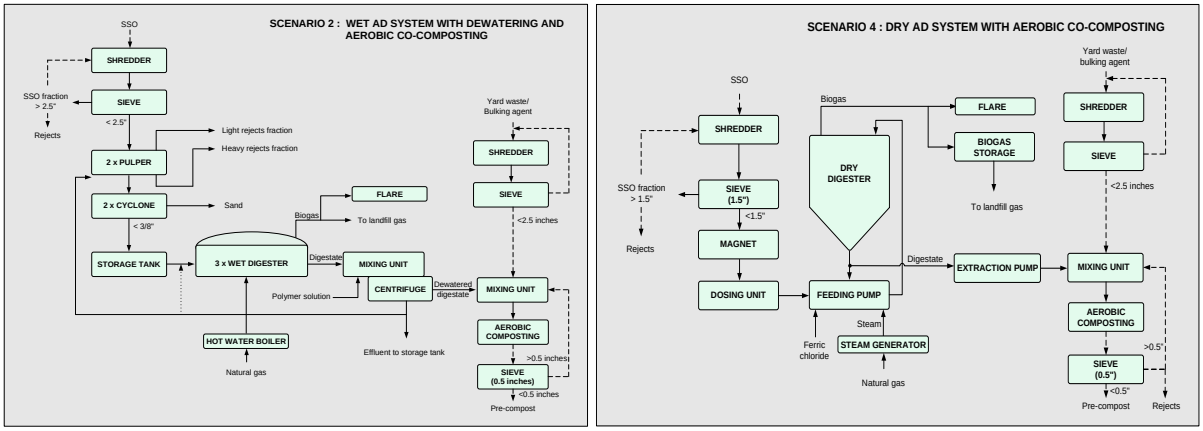
TASK 3: ECONOMIC ANALYSIS OF GENERIC WET AND DRY BIODGIESTER SYSTEMS

The Task 3 report divides the economic assessment into the two major decision areas - biodigestion approaches and biogas utilization options. The selection of a preferred biodigestion system and a preferred biogas utilization scheme is nearly totally independent. Five scenarios were evaluated for implementation based on a generic wet and a generic dry biodigester for a capacity of 30,000 ton per year of SSO with the composition as produced in the current City SSO collection pilot program.



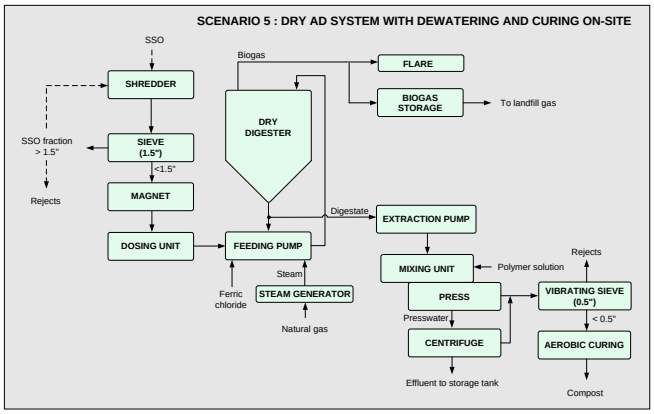
(L) Scenario 1 - Wet AD System with Dewatering, and (R) Scenario 3 - Dry AD System

The first two scenarios shown above, Scenarios 1(wet) and 3(dry), were basic approaches in which the pretreatment and wet or dry digestion were included. The posttreatment (co-composting, curing or any other treatment) is assumed to be done either at the existing yard waste composting site or in cooperation with partners that provide the posttreatment. The additional investment and operating costs would depend on the level of integration with the city yard waste composting facility or on the partners providing composting capacity, either in existing facilities or adjacent to the digestion facility to be constructed. The investment costs for Scenarios 1 and 3 are the lowest, respectively $15.1 and $14.3 million. Notably, the dry digestion option provides an attractive breakeven tipping fee of $51.54 per ton. However these options do not provide a marketable compost as a final product. The study assumed that the digestate could be transferred at no cost and no revenue to either a local compost company and combined with their existing operations (similar to the procedure at University of Wisconsin - Oshkosh), or to an agricultural services company for further processing as a crop fertilizer or for subsequent direct land application (similar to the procedure at the Dane County wet digester at Waunakee).



(L) Scenario 2 - Wet AD System with Dewatering and Aerobic Co-Composting with yard waste, and (R) Scenario 4 - Dry AD System and Aerobic Co-Composting with yard waste

Two other scenarios were developed for both wet and dry digestion, Scenarios 2 and 4 shown above, where co-composting of the digestate with the yard waste was applied in order to convert the digestate into a finished compost. These plants require an additional pretreatment of the yard waste and a facility for the co-composting operation in order to produce a stabilized compost. Investment costs were $18.5 and $20.2 million with a breakeven tipping fee of $82.71 for a wet digestion system and $61.90 for a dry digestion system.



Because the extra process water can be injected into the leachate collection system, the alternative of dewatering the digestate from the dry AD plant was evaluated, followed by curing. This is Scenario 5, shown on the left. This decreased the investment cost to $18.5 million but increases the breakeven tipping fee to $73.59 per ton due to higher operational costs.

Scenario 5 - Dry AD System with Deatering and Curing On-Site

The same plant layout as in Scenario 5was also evaluated for 60,000 tons per year (50,000 tons per year of SSO and 10,000 tons per year of leaves/yard waste) instead of 30,000 tons per year. This Scenario 6 requires an investment of $22.1 million, showing that doubling the capacity only increases the investment by 20%. However the concomitant breakeven tipping fee is reduced by 45%, down to a fee of $41.70 per ton, well within the expected tip fee at the county landfill by the time an anaerobic biodigestion facility could be operational, around 2015.

The six scenarios discussed above are based on using the current gas engines at the Rodefeld landfill and selling electricity under the power purchase agreement with MG&E at a rate that is roughly equivalent to retail rates. If the City were to install a "greenfield" site and

negotiate a separate power purchase agreement, the purchase price would be less than one third of the rate. The difference is due to the fact that local electric utilities have already met their Renewable Portfolio Standard obligations and will now only sign contracts which provide an avoided cost for energy only.

Other options for improving the monetization of the biogas were also explored. Purchasing new high performance biogas engines would increase electrical production compared to the older, existing landfill generators and decrease the breakeven tipping fee by about $5, ***for as long as the power could be sold under the power purchase agreement currently in place between Dane County and MG&E***. However after the expiration of that agreement, the breakeven tipping fee would have to be increased by $15 per ton in order to service the additional debt.

Table: Financial overview for Scenarios 1 to 6 using existing generators

SCENARIOS		1	2	3	4	5	6
		Wet AD + dewatering	Wet AD + dewatering + Co-composting	Dry AD	Dry AD + co-composting	Dry AD + dewatering + curing	Dry AD + dewatering + curing (60,000tpy)
Investment cost	**k$**	**$15,075**	**$18,575**	**$14,325**	**$20,225**	**$18,475**	**$22,075**
Debt service	**k$/y**	$1,017	$1,255	$967	$1,366	$1,246	$1,488
Operating costs	**k$/y**	$1,823	$2,210	$1,308	$1,851	$1,911	$2,907
Revenues	**k$/y**	$627	$983	$729	$1,360	$949	$1,893
Net operating cost	**k$/y**	**$2,213**	**$2,481**	**$1,546**	**$1,857**	**$2,208**	**$2,502**
Breakeven tip fee	**$/ton**	**$73.78 +?**	**$82.71**	**$51.54 +?**	**$61.90**	**$73.59**	**$41.70**

The biogas can also be upgraded to renewable compressed natural gas (RCNG) and utilized for transportation to replace diesel fuel in trucks or gasoline in cars. Assuming that the RCNG could be valued at $3.75 per gallon of diesel fuel equivalent, the potential reduction in breakeven tipping fee is about $18 per ton for each of the first 5 scenarios, resulting in both Scenario 3 and 4 having breakeven tipping fees that meet the City's economic objective of being equal to or less than landfill costs. In general, the 30,000 tpa scenario variations utilizing dry digestion have lower breakeven tipping fees, ranging from a low of $32.98 to a high of $74.95 per ton, compared to the scenario variations utilizing wet digestion which have breakeven tipping fees ranging from $57.39 to $83.63. Breakeven tipping fees required for the additional capital and operational costs associated with further processing of the digestate to a marketable compost are only within current landfill disposal fees of $44 per ton when combined with **either** RCNG production **or** expansion of the plant to 60,000 tpa.

The capital cost estimates in this feasibility study were based on several inputs, including published data for similar facilities, budgetary quotations from vendors, and experience of the study provider. Within the range of budgetary capital costs shown in Table 14, each one million dollar change in estimated capital cost results in a debt service change of ~$2 per ton.

The estimates for civil works were the most difficult to provide given the number of variables (timing, scope, construction standards, site selection and geotechnical considerations, proximity to Rodefeld Landfill) and actual costs may be less depending on construction market dynamics during the RFP and contracting phases. Since the debt service is a large contributor to the breakeven tipping fee, it will be important for the City of Madison to conduct an RFP that clearly outlines the relevant assumptions that each bidding entity must use so that quotations include the appropriate construction scope and standards.

The study identified a limited number of grants and incentives available to municipalities for this type of project. Since the timing for the City of Madison to move forward with the project, the availability of these programs is uncertain and no benefit from these programs were included in the financial analysis.

RECOMMENDATIONS

The recommendations that can be extrapolated from this feasibility study are that the City of Madison should:

- further define the types of waste to be included in the SSO collection
- try to increase the tonnage of SSO and other similar waste streams to 50,000 tpy and potentially higher (this is the most important factor in obtaining an attractive breakeven tip fee for the anaerobic digester facility)
- utilize the existing gas engines at the Rodefeld Landfill and produce power under the current Dane County – MG&E agreement, at least under an interim basis
- plan to convert the biogas to Renewable Compressed Natural Gas and convert its fleet to run on this source of fuel, prior to the expiry of the current power agreement
- apply for grants, incentives and funding in order to further reduce debt service costs on the investment of the anaerobic digestion system.

CONCLUSION

The SSO collected currently by the City of Madison is well suited for the recovery of Energy by means of anaerobic digestion and the production of a marketable compost. The diversion of organics is the single largest opportunity for the City to achieve greater landfill diversion and get closer to "zero waste", while providing a reduction in greenhouse gas emissions. It is anticipated that the anaerobic biodigestion facility could also serve as an ongoing economic development tool, attracting complementary business activities and anaerobic digester industry companies to the City. The feasibility study determined that the City could own and operate a commercially proven anaerobic biodigester facility for 30,000 tons per year at a tipping fee that is comparable to landfill costs, assuming the renewable compressed natural gas produced at the facility is used to replace conventional diesel fuel and valued at conventional fuel market pricing.

If the capacity of the plant is built and operated at 50,000 ton per year or more within 5 years, the breakeven tip fee for the facility producing and selling electricity would be below the landfill tipping fee estimated at $45 per ton at the time this project could be implemented. This fee could further be reduced in case the City is successful in adapting its truck fleet to

use Renewable Compressed Natural Gas as a replacement for diesel fuel so that even a plant which includes comprehensive pre- and posttreatment would become economically attractive. A number of grants and incentives, as well as funding mechanisms may be available to the City which may reduce the needed tip fee even more.