Report

Source Separated Organic Materials Anaerobic Digestion Feasibility Study

Project I.D.: 09R007

Ramsey Washington Counties Resource Recovery Project Board and

St. Paul Port Authority

June 2009

Ramsey/Washington County
Resource Recovery Project

SAINT PAUL PORT AUTHORITY

June 11, 2009

Mr. Zachary Hansen
Ms. Judy Hunter
Ramsey/Washington Counties Resource Recovery Project Board
2785 White Bear Avenue, Suite 350
Maplewood, MN 55109-1320

Mr. Pete Klein
St. Paul Port Authority
345 St. Peter Street, Suite 1900
St. Paul, MN 55102

Dear Mr. Hansen & Mr. Klein:

RE: Final Report – Source Separated Organic Materials Anaerobic Digestion Feasibility Study

This letter transmits the final report on Source Separated Organic Materials Anaerobic Digestion Feasibility Study (Study).

The study examines the feasibility of an anaerobic digestion facility to convert source separated organic materials (SSOM) into biogas. The biogas can then be converted to energy for beneficial use.

If sufficient quantities of SSOM, or other organics suitable for anaerobic digestion are collected, the proposed facility could produce 400,000 to 525,000 MMBtu's annually. Tipping fees for an AD facility of the magnitude studied were projected to range from $55 to $60 per ton depending on capital financing for the project and actual energy related revenues.

Thank you for the opportunity to provide this study. We look forward to working with you on the next steps to advance this exciting technology.

Please feel free to contact us if you have any questions.

Sincerely,

Foth Infrastructure & Environment, LLC

Warren A Shuros
Senior Project Manager

Curtis L. Hartog, P.E.
Senior Technology Manager

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Source Separated Organic Materials Anaerobic Digestion Feasibility Study

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Project ID: 09R007

Prepared for

Ramsey/Washington Counties Resource Recovery Project Board

and the St. Paul Port Authority

St. Paul, Minnesota

Prepared by

Foth Infrastructure & Environment, LLC

June 2009

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Executive Summary

The following study examines the feasibility of an anaerobic digestion (AD) facility for source separated organic materials (SSOM) in the eight county Minneapolis/St. Paul Metropolitan area. The study examines current anaerobic digestion technologies, availability of source separated organic materials and utilizing AD technology to convert the organic material to methane for thermal or electric power generation.

The scope of work was developed with input form the Ramsey/Washington Counties Resource Recovery Project Board and the Saint Paul Port Authority. In general the scope of work includes:

- Overview of AD processes
- Current AD development
- Examples of large scale AD plants
- Option for biogas generation and use
- Energy market status
- Availability and composition of SSOM in the 8 County Area
- AD Facility Design Considerations
- Permitting and Environmental Considerations
- Economic Analysis

AD in the broadest sense is a process to degrade organic material in the absence of oxygen. AD occurs naturally in low-oxygen environments including marshes, wetlands, sediments, landfills, and within the digestive tracts of some animals and insects. Degradable organic material refers to carbohydrate, protein, and fat molecules. The degradation that occurs during AD is the result of microorganisms transforming these molecules into water, carbon dioxide and methane. These by-products are formed as a result of the respiration and digestion activities of the microorganisms.

When discussed in terms of SSOM, AD is a waste pre-treatment process, as opposed to a waste disposal option. The typical organic fraction of municipal solid waste (OFMSW) is comprised of textiles (cloth and paper products), yard waste (grass, leaves, and brush), food waste (commercial, residential) and other organic waste. On average, OFMSW comprises approximately 50% of MSW by volume, and only approximately 50% of the OFMSW is readily degradable in most AD facilities. However, SSOM may be more organically rich than OFMSW, but SSOM also comprises a smaller portion of the total waste stream, about 25%.

During the AD process the degradable portion is broken down into what is referred to as biogas and can be used for thermal or electrical energy. The non-degradable portion is referred to as

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digestate and is typically used for composting, as a soil amendment, or as landfill alternative daily cover. The study analyzed the various AD processes and vendors to provide a frame of reference on the state of AD technology. Most AD processes used on MSW feedstocks are located in Europe. Of the over 70 AD suppliers, four vendors were highlighted that have the proven capability of developing an AD system to process 100,000 TPY of SSOM. The size of the AD process was determined from the anticipated availability of SSOM in the eight county metro area.

The primary output from AD processes is the production of biogas. The amount of biogas produced from AD processes ranges from about 2 cubic feet per pound of input to 5 cubic feet per pound of input.

Utilizing the biogas typically requires some treatment of the biogas. The type of treatment (and cost) will depend on the ultimate use of the biogas. Potential biogas options include direct use, electric generation, fuel cells and pipeline quality. Each option has advantages and disadvantages, with the direct use option being the most economical as long as the user is in close proximity to the AD facility and is willing to use the biogas with minimal clean up.

A challenge to developing an SSOM plant in the metro area is sourcing a supply of SSOM large enough to support an AD facility. A wide variety of studies have been completed that have information on the quantities and qualities of SSOM collected from residents and commercial establishments. Several pilot and city wide collection programs have been initiated in the eight county area.

In addition, several national studies have been conducted on SSOM collection. The studies provide a background for estimating the potential volume of SSOM that may be collected in the eight county metro area and used at an AD facility.

Based on the data reviewed and provided for this study, potential SSOM supply for an AD facility ranges from 38,900tons per year (TPY) to 97,300 TPY. If SSOM is also combined with yard waste and smaller wood waste, the anticipated volumes increase to 44,900 TPY to 112,300 TPY.

However, collection of SSOM in the eight countymetro area has complexities that would need to be addressed, including:

- SSOM collection systems economics and financing
- Potential legal and political constraints due to legal definitions
- Policy considerations from counties and cities responsible for collection.

These considerations are further explored in the report and are included to spur dialogue on these issues.

An AD facility design capable of processing 100,000 TPY was developed using known components and process flow requirements for typical AD facilities. The facility includes a receiving area, processing area, digesters and a potential biogas conversion facility. The total facility area requiredis 7 to 8 acres including support facilities.

With a general facility design, capital costs were developed using two methods. Method 1 used published sources of AD facility capital cost information. Method 2 used a cost estimating method based on the capital and installation costs for the components that make up an AD facility.

For a 100,000 TPY facility a capital cost of $30 to $45 million is likely based on published sources.

From using the plant buildup method to estimate capital costs, an estimated capital cost for a 100,000 TPY facility was $39 million to $44 million depending on the biogas use option selected.

Operation and maintenance (O&M) costs were estimated using a similar approach as capital costs estimates; published sources and a plant build up approach.

Published sources for O&M costs ranged from $10/ton to $100/ton depending on the complexity of the AD facility, siting, and potential biogas revenues that were used to reduce O&M costs.

The plant build up estimate for O&M resulted in an estimated cost per ton ranging from $53 to $60 per ton.

An estimate of debt service was developed by the St. Paul Port Authority that provided an estimate of $30 per ton. With energy revenue estimates ranging from $24 to $42 per ton, the net cost per ton was projected to be in the range of $55 to $60 per ton for a 100,000 TPY facility.

To build such a facility an estimated schedule to permit, design and build would be 24 to 48 months. The time frame is dependent on the permitting process. For example, if an Environmental Impact Statement is required for the facility, that process could add 6 to 12 months to the project schedule. However, if plant siting and permitting is not contested an AD facility could be operational by 2012.

List of Abbreviations, Acronyms, and Symbols

AD	Anaerobic digestion/digester
ADC	Alternative daily cover
BACT	Best Available Control Technology
BAKG	Biotechnische Abfallverwertung GmbH & Co. KG
BOD	Biochemical oxygen demand
BOD-5	5-day biochemical oxygen demand
BMP	Biomethane potential
BTU	British thermal unit (a standard unit measure of energy)
C&D	Construction and demolition waste
cfm	Cubic feet per minute
C/N	Carbon to nitrogen ratio
CEMS	Continuous Emissions Monitoring System
CH_4	Methane
CHP	Combined Heat and Power
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent emissions
COD	Chemical oxygen demand
CSTR	Continuously stirred tank reactor
d	Day
EAW	Environmental Assessment Worksheet
EC	European Community
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
Ft^3/lb	Cubic feet per pound
EPR	Extended producer responsibility
g	Gram
GDP	Gross domestic product
GHG	Greenhouse gas
GWh	Gigawatt hours (1 million megawatt hours)
HERC	Hennepin Energy Recovery Center
H_2S	Hydrogen sulfide
HSAD	High Solids Anaerobic Digestion
hr	Hour
HRT	Hydraulic retention time
ISO	International standards organization
kg	Kilogram
kW	Kilowatt
kWe	Kilowatts of electricity
kWh	Kilowatt hour
L	Liter
lbs	Pounds
LCA	Life cycle assessment
m	Meter
m^3	Cubic meter

MMBTU	Million British Thermal Units
MBT	Mechanical-biological treatment
MC	Moisture content
Mgal	Million gallons
MPCA	Minnesota Pollution Control Agency
MRF	Material recovery facility
MS-OFMSW	Mechanically sorted organic fraction of municipal solid waste
MSW	Municipal solid waste
MT	Metric ton
MW	Megawatt
MWe	Megawatts of electricity
MWh	Megawatt hour
NAAQS	National Ambient Air Quality Standards
Nm^3	Natural cubic meters (at standard pressure and temperature)
NO_x	Nitrogen Oxide
N:P:K	Nitrogen to phosphorus to potassium ratio
NREL	National Renewable Energy Laboratory
OFMSW	Organic fraction of municipal solid waste
OIW	Organic Industrial Waste
OLR	Organic loading rate
OWS	Organic Waste Systems, Inc.
ppm	parts per million
Port Authority	St. Paul Port Authority
POTW	Publicly owned treatment works (e.g. wastewater treatment system)
PM	Particulate Matter
PPP	Purchasing power parity
psi	Pounds per Square Inch
RDF	Refuse Derived Fuel
RFW	Residential Food Waste
rpm	Revolutions per minute
scf	Standard cubic feet
SCORE	Minnesota's Select Committee on Recycling and the Environment solid waste and recycling programs administered by the MPCA
SO_2	Sulfur Dioxide
SRT	Solids retention time
SS-OFMSW	Source separated organic fraction of municipal solid waste
SSOM	Source Separate Organic Material
SWANA	Solid Waste Association of North America
SWMCB	Solid Waste Management Coordinating Board
TKN	Total Kjeldahl nitrogen
tons	Short ton (2,000 pounds)
TPY (or t/y)	Tonsp er year
TS	Total solids
UMP	Ultimate methane potential
UASB	Upflow anaerobic sludge blanket
VS	Volatile solids
WAS	Waste activated sludge

WRS	Waste Recovery Systems, Inc.
WWT	Waste Water Treatment
yr	Year
YW	Yard waste

Source Separated Organic Materials Anaerobic Digestion Feasibility Study

Definitions

Alternative daily cover	Material other than soil used to cover the surface of active landfills at the end of each day to control diseases, fires, odors, etc.
Anaerobic digester	A dedicated unit process for controlling the anaerobic decomposition of organic material. Typically consists of one or more enclosed, temperature controlled tanks with material handling equipment designed to prevent the introduction of oxygen from the atmosphere.
Biogas	The methane, carbon dioxide and trace gases that are produced as a result of anaerobic digestion or degradation. The gas can be used for producing heat and electricity, or successfully compressed for use as an alternative transport fuel.
Biomass	Any organic matter that is available on a renewable or recurring basis (excluding old-growth timber), including dedicated energy crops and trees, agricultural food and feed crop residues, wood and wood wastes and residues, aquatic plants, grasses, residues, fibers, and animal wastes, municipal wastes, and other waste materials.
Biomixer	A rotating drum often with a trommel screen used for size reduction and pretreatment of the organic fraction in mixed MSW for sorting. Can be aerated to encourage biological breakdown. Can be operated at retention times from several hours to several days.
Bioreactor-landfill	A landfill operated as a bioreactor using leachate recycling (or other management schemes) to increase the rate of organic decomposition and biogas production. Not to be confused with an anaerobic digester.
Biosolids	A generic term generally used for sludges (e.g. from WWT plants, etc.)
Biowaste	A generic term generally used for sludges (e.g. from WWT plants, etc.) and may include the putrescible organic fraction of MSW.
Biochemical oxygen demand	The amount of oxygen required for complete (aerobic) biological decomposition of a material. The standard laboratory method BOD-5 tests the amount of dissolved oxygen consumed in a closed aqueous system over a five-day period. It is a fairly direct but time-consuming measure of biodegradability of liquid streams.
Co-Collected	Two or more material streams collected side-by-side in separate compartments on the collection vehicle. For example, "co-collected" yard waste and SSOM means that each material is loaded in separate compartments and tipped into separate piles upon unloading.
Commercial waste	Waste from any combination of institutional, industrial and commercial (businesses)
Compost	Stabilized and screened organic material ready for horticultural or agricultural use. If anaerobically digested material is used as compost, it must be biologically stabilized, typically through aeration and maturation.
Continuously stirred tank reactor	A digester configuration in which the entire digester contents are mixed to create an homogeneous slurry.

Digestate	A slurry containing undigested solids, cell-mass, soluble nutrients, other inert materials and water. High quality digestate (i.e., from centralized separation) is commonly used as a soil conditioner. Lesser quality digestate is commonly used for landfill cover or land remediation projects.
Food waste	Food scraps and other organics from food preparation discards that is readily decomposable.
Grey waste	The residue that remains after source separating the organic fraction from MSW. Generally, grey waste has a lower biogas potential because the easily digestible fraction has been removed.
High-solids Anaerobic Digesterion (HSAD)	Commonly referred to as a "dry" AD system, in which total solids (TS) concentration is greater than 20%.
Hydraulic retention time (HRT)	The average length of time liquids and soluble compounds remain in a digester. Increasing the HRT allows more contact time between substrate and bacteria but requires slower feeding and larger reactor volume.
Materials recovery facility	A facility where mixed MSW is sorted in order to recover material for reuse or recycling.
Mechanical-biological treatment	A waste processing system that combines a sorting facility for materials recovery (the mechanical portion) with biological treatment, either aerobic or anaerobic, for stabilizing the organic fraction before landfilling or beneficial use.
Mechanically separated OFMSW	Organic material separated from the mixed waste stream by mechanical means (i.e., trommels, screens, shredders magnets, density dependent mechanisms). Isolating the OFMSW from mixed waste is less effective using mechanical separation as compared with source separation.
Mesophilic digestion	The digester is heated to 95 ºF to 100 ºF and the feedstock remains in the digester typically for 15 to 30 days. Mesophilic digestion tends to be more robust and tolerant than the thermophilic process, but gas production is generally less and larger digestion tanks are required.
Mixed Municipal solid waste	Means garbage, refuse, and other solid waste from residential, commercial, industrial, and community activities that the generator of the waste aggregates for collection. It does not include auto hulks, street sweeping, ash, construction debris, mining waste, sludges, tree and agricultural waste, tires, lead acid batteries, motor and vehicle fluids and filters, and other materials collected, processed and disposed of as separate waste to streams. (Minn. Statute 115A.03
Non recyclable paper	Low grade paper that is deemed as a contaminant to the higher grades of recyclable paper such that there is no market demand from the local recycling infrastructure. Examples usually include: poly or wax coated cardboard (e.g., packaging for cold food storage;tissue paper (e.g., napkins, paper towels, coffee filters, tea bags, etc.); paper contaminated with moisture, other liquids, food, paint; and other paper reused in a manner that renders it a contaminant to local recycling processes.

Organic fraction of municipal solid waste (OFMSW)	The biogenic fraction of MSW. OFMSW can be removed from the waste stream at the source (source-separation), or downstream by mechanical separation, picking lines or a combination of the two. The wood and paper fraction is more recalcitrant to biological degradation and is therefore not desired for biochemical conversion feedstocks.
Organic industrial waste (OIW)	Organic waste residues from larger food processing and other manufacturing processes.
Other organic material	Any organic material not classified by another organics category including cotton balls, feminine hygiene products, hair, and other small organic fragments not readily identified.
Plug flow digester	A digester in which materials enter at one end and push older materials toward the opposite end. Plug flow digesters do not usually have internal mixers, and the breakdown of organic matter naturally segregates itself along the length of the digester.
Pre-treatment	In reference to municipal solid waste, pre-treatment can refer to any process used to treat the raw MSW stream before disposal. This includes separation, drying, comminuting, hydrolysis, biological treatment, heating, pyrolysis, and others.
Septage	Liquid seepage from private wastewater treatment systems, including individual sewage treatment systems (ISTS) and community or cluster systems.
Solids retention time (SRT)	The average length of time solid material remains in a reactor. SRT and HRT are equal for complete mix and plug flow reactors. Some two-stage reactor concepts decouple HRT from the SRT allowing the solids to have longer contact time with microbes while maintaining smaller reactor volume and higher throughput.
Source-separated Organic Material (SSOM)	Organic solid waste separated at the source (i.e., not mixed in with the other solid wastes). Often comes from municipal curbside recycling programs in which items such as, kitchen food scraps, nonrecyclable paper and other organic materials are collected separately from the rest of the MSW stream. The precise composition of SSOM can change significantly depending on the collection scheme used. SSOM as used in this report excludes yard waste and wood waste.
Thermophilic digestion	The digester is heated to 120 ºF to 130 ºF and the residence time is 12 to 14 days typically. Thermophilic digestion systems typically offer higher methane production, faster throughput, and better pathogen control, but require more capital intensive technology, greater energy input and a higher degree of operation and monitoring.
Total Kjeldahl nitrogen (TKN)	The sum of organic nitrogen and ammonia in a water body. Measured in milligrams per liter (mg/L). High measurements of TKN typically results from sewage and manure discharges to water bodies.
Total solids (TS)	The amount of solid material (or dry matter) remaining after removing moisture from a sample. Usually expressed as a percentage of the as-received or wet weights. Moisture content plus TS (both expressed as percentage of wet weight) equals 100 percent.

Ultimate methane potential	This is a standard laboratory technique used to measure the anaerobic biodegradability and associated methane yields from a given substrate. The test is run until no further gas production is detected and can last up to 100 days. The result can be influenced by the substrate concentration and particle size, the inoculum source, the food to microorganism ratio and the presence or build-up of inhibitory compounds among others. (Also known as ultimate biomethane potential, BMP, and B_o.)
Volatile solids (VS)	The amount of combustible material in a sample (the remainder is ash). The value is usually reported as a percentage of the TS, but may occasionally be given as a fraction of the wet weight. VS are used as an indicator or proxy for the biodegradability of a material, though recalcitrant biomass (i.e., lignin) which is part of the VS is less digestible. Because of the simplicity of the measurement procedure, it is commonly reported in the literature on anaerobic digestion.
Wet AD System	AD system in which total solids (TS) concentration is generally less than 20%.
Wood waste	Tree waste and dimensional lumber fromconstruction and demolition operations (including both treated and untreated wood scrap).
Yard waste	Grass, leaves, small brush and garden trimmings normally accepted by municipal recovery programs (curbside or drop-off facilities). Generally does not include larger wood waste items (e.g., tree limbs, stumps, lumber, etc.)

1 Introduction

1.1 Purpose

The following study examines the feasibility of an anaerobic digestion (AD) facility for source separated organic materials (SSOM) in the eight county Minneapolis/St. Paul Metropolitan area. The study examines current anaerobic digestion technologies, availability of source separated organic materials and the challenges and opportunities of collecting SSOM and utilizing AD technology to convert the organic material to methane for thermal or electric power generation.

1.2 Scope of Work

The scope of work was developed with input from the Ramsey/Washington Counties Resource Recovery Boards and the St. Paul Port Authority. In general the scope of work includes:

- Overview of AD processes
- Current AD Development
- Examples of large scale AD plants
- Option for biogas generation and use
- Energy market status
- Availability and composition of SSOM in – the 8 County Area
- AD Facility Design Considerations
- Permitting and Environmental Considerations
- Economic Analysis

The following report addresses the general scope of work items addressed above and provides specific details and sources of information for this feasibility study.

2 Anaerobic Digestion

Many systems have been developed for digestion of the organic fraction of municipal solid waste (OFMSW), SSOM, manure, or co-digestion of a combination of organic feedstocks. Each has its own particular benefits and constraints. A general overview of the various systems is discussed in the following section, as well as additional detail pertaining to the systems that satisfy the project objectives (i.e. a system capable of handling at a minimum 100,000 tons/year of SSOM).

2.1 Definition and Overview

AD in the broadest sense is a process to degrade organic material in the absence of oxygen. AD occurs naturally in low-oxygen environments including marshes, wetlands, sediments, landfills, and within the digestive tracts of some animals and insects. Degradable organic material refers to carbohydrate, protein, and fat molecules. The degradation that occurs during AD is the result of microorganisms transforming these molecules into water, carbon dioxide and methane. These by-products are formed as a result of the respiration and digestion activities of the microorganisms.

When discussed in terms municipal of solid waste or SSOM, AD is a waste pre-treatment process, as opposed to a waste disposal option. The typical OFMSW is comprised of textiles (cloth and paper products), yard waste (grass, leaves, and brush), food waste (commercial, residential) and other organic waste. On average, OFMSW comprises approximately 50% of MSW by volume, and only approximately 50% of the OFMSW is readily degradable in most AD facilities. However, SSOM may be more organically rich than OFMSW, but SSOM comprises a smaller portion of the total waste stream; about 25%.

During the AD process the degradable portion is broken-down into what is referred to as biogas and can be used for thermal or electrical energy. Although highly dependent on feedstock composition and AD technology employed, one standard cubic foot (scf) of biogas can produce on the scale of 600 British Thermal Units (BTUs) of thermal energy or 20 Kilowatt hours (kWh) of electrical energy.[1] The non-degradable portion is referred to as digestate and is typically used for composting, as a soil amendment, or as landfill alternative daily cover.

2.2 Process Types

There are currently several AD processing systems. They include single-stage, multi-stage, batch and sequenced batch systems. Each of these systems can either be wet (total solids <20%), dry (total solids >20%), or can operate in both modes. The primary challenges associated with wet systems include:

- Homogenizing large solids to slurry during pretreatment
- Chemical stability during digestion
- Wastewater management resulting from dewatering

To overcome some of these challenges, a new process called a wet perculation system has been developed. This system uses liquids to percolate through the waste in an anaerobic environment.

The liquid is then digested to make biogas. This process helps address the homogenization challenges with wet systems, but chemical stability and wastewater management tend to continue to be problematic.

Dry AD systems can be dry continuous, dry sequencing batch, and dry multi-stage. “Dry” AD processes are not dry as is commonly understood. Dry AD processes are where solids (in this case SSOM or OFMSW) are placed in liquid so that the solid portion is greater than 20% of the mixture. That means the liquid fraction is between 60% and 80%. This is hardly “dry” as is commonly understood. However, in terms of AD processes, this is considered dry versus a wet system where the solids make up less than 20% of the total mixture.

The dry continuous system is where waste is received and sized. The waste enters a mixing tank where liquid is added and a slurry is created. This slurry is pumped to tanks where the anaerobic digestion occurs. Typical residence time in the tank is 20 to 28 days. The residuals are removed from the tank, dewatered, and further composted.

In the dry sequence batch system, the waste is processed and mixed as described above, but the waste is digested using three tanks instead of a single tank in the continuous system. The advantage of using three tanks is to allow different microorganisms to digest the waste in each tank. As the waste moves from one tank to the next, the waste is inoculated with liquid to allow new microorganisms to form in each tank. This process speeds the AD process since microorganisms are not competing as in the single stage process.

The dry multi-stage AD process adds an additional step to the dry sequence batch system. In this step, called the hydrolysis reactor, materials are broken down into sugars, peptides and amino acids. This initial step allows for further breakdown of the organic materials in the subsequent tanks and offers greater biogas yields.

The primary challenges associated with dry systems include:

- Mechanical items associated with handling, mixing and pumping large solids
- Dewatering solids during pretreatment
- Inoculation after pretreatment to accelerate digestion of new waste
- Feed rate
- Contact time required for adequate digestion

In addition to the systems previously described, AD plants are also operated at either mesophilic temperatures (approximately 95°F-100°F) or thermophilic temperatures (approximately 120°F-130°F). The temperature of the process impacts digestion rates, biogas production, and the quality of the residual materials after digestion. Thermophilic digestion appears to be a more commonly used technology. Roughly half of the biowaste digesters today are operated at thermophilic temperatures. The advantages of higher temperature are faster degradation, greater biogas yields, and increased pathogen destruction. More detail about each process is provided in the following sections.[2,3,4]

2.2.1 Wet, Single-Stage Process

A wet, single-stage AD process involves the addition of large proportions of liquid to the organic matter to produce a slurry. The slurry is approximately 10%-15% total solids (TS) and is fed to a mix tank digester, often called a continuously stirred tank reactor (CSTR). The process liquid from the process is recycled for feedstock preparation to avoid generating an excessive volume of diluted digestate for disposal. However, there is a limit to the recycling of the dilution liquid. The liquid contains nondegradable organic and inorganic substances which can accumulate in the recycled make-up water. To minimize the accumulation, a liquid polishing step is used or external fresh water is added.

Wet, single-stage AD systems are not well suited for digesting the OFMSW alone due to several reasons including:

- Accumulation of sand and stone sediments in the reactor
- Formation of plastic films (fibrous material has a tendency to form strings that wind around the CSTR's stirrer)

The wet stage step AD systems tend to be better suited for co-digesting the OFMSW with more dilute feedstocks such as animal manures or sewage sludge. Of the operational wet single-stage systems in Europe, approximately 50% co-digest the OFMSW with manure and most are located in Germany, Sweden and Denmark. Most of the Danish Centralized AD (CAD) systems and Swedish digesters are operated as co-digestion plants with manure as the main substrate .[5,6,7]

2.2.2 Wet, Multi-Stage Process

A few multi-stage wet digestion processes are used that form a slurry by combining OFMSW with water or recycled liquid. The slurry is sent to a hydrolysis reactor to convert the material to sugars, pepticles and amino acids. The material is pumped to the AD vessel where the material is further digested and makes biogas.

One particular multi-step, wet digestion process is the BTA process, which uses a patented "hydro-pulper" to mix the feedstock into an organic slurry,and to s eparate the plastics and inerts. The wet separation system removes metals, plastics, glass, etc. prior to the AD process which results in a high quality organic material which is suitable for digestion.

2.2.3 Dry Continuous Feed Process

The dry continuous feed process involves continuously feeding the digestion vessel using a feedstock composed of approximately 25%-40% total solids. The process can be either a completely-mixed or a plug-flow system. A plug flow system sends a small amount of material into the digester at a set time interval. The systems are configured as either vertical or horizontal. Vertical systems externally recycle a large proportion of the outgoing liquid to prepare the incoming raw feedstock. The waste within the digester is recycled rapidly, which provides a mixing system and minimizes wastewater production. Horizontal systems use equipment with a slow, intermittently rotating stirrer and therefore recycle only a small proportion of the liquid. The dry process still requires minimal water addition, which makes the process favorable for operating at thermophilic digestion temperatures. The dry technologies are probably among the best adapted systems and most commonly used technologies for OFMSW and SSOM digestion.[8,9]

2.2.4 Dry Sequencing Batch Process

In the dry sequencing batch process, the digester vessels are batch-loaded with raw feedstock. The feedstock is treated with liquid recycled from the previous batch. After the vessels are batch-loaded they are sealed and left to digest naturally. Typically, there are three vessels into which the material is loaded. Vessel 1 contains new material; vessel 2 contains mature material, and vessel 3 contains old material. During natural digestion, liquid from older batches is added to new batches to facilitate start up. The preheated leachate helps to maintain a relatively uniform moisture content as well as uniform temperature in the digester and allows for redistribution of bacteria. Upon completion of natural digestion, the reactor is unloaded. The material is moved to the next batch process. Operation of the dry sequencing batch process is labor intensive.[10]

2.2.5 Dry Multi-Stage Process

In a dry multi-stage process, the material first passes through a hydrolysis reactor and is subsequently fed through several additional AD reactors in a continuous manner. As the material moves from one reactor to the next it is treated in a specific state of degradation. The organic acid forming stage of anaerobic digestion (acetogenesis) is separated from the methane forming stage (methanogenesis) through the use of multiple reactors. Separating the stages of digestion results in increased efficiency as the two microorganisms are separate in terms of nutrient needs and growth capacity. Some of the dry multi-stage systems use an aerobic (with oxygen) reactor as the first reactor to raise the temperature and increase degradation of the organic material. Some other processes separate the system such that there is a low temperature (mesophilic) and a high temperature stage (thermophilic).[11]

2.3 Summary of Advantages and Disadvantages

Table 2-1summarizes the advantages and disadvantages of the AD processes discussed previously. The list of advantages and disadvantages is not intended to be exclusive in nature, rather to provide a general sense of each process in a comparative fashion.

Table 2-1 Summary of Digester Technology Advantages and Disadvantages[A]

Wet Single Stage Process	
Advantages ♦ Based on mature waste water treatment technology for material handling and mixing. ♦ Less expensive material handling equipment ♦ Wet multi-stage process permits higher loading rates ♦ Higher process volumes since each stage works efficiently to break down materials	**Disadvantages** ♦ For SSOM, the process mixing is challenging due to sinkers and floaters in SSOM. ♦ Requires large tanks due to high liquid requirement ♦ Complex designs and material handling ♦ True separation of biological processes hard to achieve which can cause reduced digestion of the material
Dry Continuous Process	
Advantages ♦ No moving parts in reactor ♦ Simple design and operations	**Disadvantages** ♦ Typically not all material is digested ♦ Material handling equipment expensive due to high total solids content of material
Dry sequencing batch process	
Advantages ♦ More complete digestion of materials due to the batch process ♦ Simplified material handling and limited pretreatment	**Disadvantages** ♦ Lower degradation of materials ♦ Low biogas yield; labor intensive process
Dry Multi-stage Process	
Advantages ♦ Higher throughput capacity ♦ Better tolerates feedstock fluctuations	**Disadvantages** ♦ Costly material handling equipment ♦ Difficult to separate processes in each stage

[A] Current Anaerobic Digestion Technologies Used for Treatment of Municipal Organic Solid Waste for the California Integrated Waste Management Board, March 2008.

2.4 Current AD Development

It should be noted that the number of full scale AD applications that use a portion of MSW as part of the materials entering the AD process are mainly limited to Europe and Asia. Subsequently, the discussions that follow and literature that is available are primarily based on AD experience in these countries. Since the waste management policies of these countries are vastly different than the policies in the U.S., the economic feasibilities may not be directly comparable. In other words, an AD system that could be demonstrated to be economically feasible in Europe may not be economically feasible in the U.S. due to the lack of adequate waste management policies, regulation, incentives and private market conditions (e.g. energy prices, landfill tipping fees, demonstrated demand for waste derived compost and other by-products.) The following discussion is based largely on the research in the March 2008 report developed for the California Integrated Waste Management Board[12] , recent studies regarding the economic feasibility of AD of MSW in the U.S. and vendor-specific web searches.

The following sections will provide an overview of:

- Processes and process plant suppliers,
- Existing full scale OFMSW AD facilities, and
- Results of initial vendor screening.

2.4.1 Processes and Process Plant Suppliers

The list of AD processes and plant suppliers is changing as a result of acquisition, mergers, sell-offs or disbandment, and technological advances. This is not uncommon considering the particular use for the technology (AD of SSOM) is still developing. The majority of the existing processes and process suppliers were developed and are located in Europe. The total number of AD vendors is also a highly variable number, however, there are approximately 15 vendors of significance in the global market and of those seven vendors provide about 70% of the AD capacity in Europe.[13] The main suppliers, process name, and range of capacity at currently operating facilities are summarized in Table 2-2.

Table 2-2 Main AD Technology Suppliers[A]

Supplier Name	Process Name	Range of Capacity at Operating Facilities (tons/year)[A]
Arrow Ecology	ArrowBio	90,000-180,000
BTA International GmbH	BTA	1,000-150,000
Citec	Waasa	3,000-230,000
Ros Roca International	Biostab	10,000-150,000
Organic Waste Systems	DRANCO	3,000-120,000
Haase	Mechanical-Biological Waste Treatment (MBT)	50,000-200,000
Farmatic Biotech Energy AG	Schwarting-Uhde	18,000-200,000
Valorga International	Valorga	10,000-497,600
Kompogas	Kompogas	5,000-100,000
Strabag (formerly Linde)	Linde-KCA/BRV	6,000-150,000
Entec	Entec	40,000-150,000
Wehlre-Werk AG	Biopercolat	100,000
Global Renewables Ltd.	ISKA	88,000-165,000

[A.] Adopted from IEA Bioenergy, Task 37. http://www.iea-biogas.net

A full list of suppliers and operating facilities with various capacities as reported by the International Energy Agency (IEA) is included in Appendix A. The IEA reported suppliers that use AD technology for MSW, as well as various other feedstocks (i.e. biowaste, manure, sludge, etc.).

2.4.2 Specific Suppliers

The suppliers and the AD processes that are employed will be discussed in the following sections based on the proven capacity of each system (i.e. plant suppliers with a proven capacity greater than 100,000 tons/year and those with a capacity less than 100,000 tons/year).

2.4.2.1 Plant Suppliers <100,000 TPY(General Overview)

Table 2-3 shows the process/plant suppliers, number of operational facilities, system type (wet or dry), feedstock, and range of capacity at operational facilities.

Table 2-3 AD Plants Less Than 100,000 TPY of SSOM

Process or Supplier Name	Number of operating facilities	Wet or Dry System	Feedstock	Range of Capacity at operating Facilities (tons/year)
Ing. Bauer GmbH	1	Wet	Biowaste, manure	7,000
Doda U.S.A Inc.	1	Wet	Biowaste, manure,	1,000
Visiam, LLC	1	Wet	MSW	30,000
BST	6	Wet	Biowaste, catering waste	2,000-15,000
Eigenbau	1	Wet	Catering waste, EC	20,000
Nahtec	1	Wet	Catering waste, EC	12,000
Führer,Schweitzer	3	Wet	Vegetables, catering waste, slaughterhouse waste, manure, EC	4,000-6,600
Komptech	2	Wet	Biowaste, catering waste, OIW	15,000-16,000
AAT, Wolf	6	Wet	Biowaste, catering waste, slaughterhouse waste, whey, manure, OIW, EC	3,600-55,000
Bioenergetica	1	Wet	Biowaste, manure, EC	5,000
Waltenberger	1	Wet	Catering waste	10,000
C.G.Jenson	1	Wet	Biowaste, manure, OIW	125,000
NIRAS	5	Wet	Manure, biowaste, OIW	17,500-55,000
Kruger/Bioscan	15	Wet	Manure, biowaste, sludge, OIW	12,000-190,000
Hering Municipal	2	Wet	Biowaste, manure, OIW	52,700-130,000
WWW Engineering	1	Wet	Biowaste, manure, OIW	30,000
BioEnergy Biogas	1	Dry	Biowaste, NawaRo	18,200
AN	1	Wet	Biowaste	3,000
DSD	2	Wet	Biowaste, manure, OIW	20,000-42,000
BWSC	6	Wet	Manure, OIW	5,400-160,000
Biovakka Oy/Watrec Oy	1	Wet	Manure, OIW	120,000
Hese-Umwelt	1	Wet	Grey waste	110,000
IMK	1	Wet	Biowaste	18,000
T.B.W.	2	Wet	Biowaste, manure	10,000-13,000

BEKON	1	Dry	Biowaste	8,000
Eggersmann	2	Wet	Biowaste	20,000
Bioplan	1	Wet	Manure, OIW	100,000
D.U.T	1	Wet	Biowaste	10,000
Horstmann	2	Wet	Grey waste, biowaste	25,000-80,000
RPA	1	Wet	Manure, OIW	300,000
Ionics Italbia	1	Wet	MSW	4,000
SPI	1	Wet	Manure	300,000
Enbasis	1	Wet	MSW, food industry waste	120,000
KIKIos	1	Wet	Manure, OIW	60,000
Biocel	1	Dry	Biowaste	35,000
Roediger	1	Wet	MSW, OIW	20,000
VMT/Lackeby	5	Wet	Biowaste, manure, OIW	15,000-40,000
NSR	1	Wet	Manure, OIW	80,000
Purac	1	Wet	Manure, OIW	105,000
Greenfinch	1	Wet	Foodwaste	5,000
Duke Engineering	1	Wet	Yardwaste	30,000
Enviro-Control	1	Wet	Biowaste, manure, sewage	3,000
Preseco Oy (ADA)	2			2,000-30,000
Envirotech Engineering Ltd (DBA-Wabio Process)	4	Wet	Biowaste, manure, sewage	6,000-60,000

[A]Adopted from IEA Energy IEA Bioenergy, "Biogas and More: Systems and Markets Overview of Anaerobic Digestion". July 2001. Company website and C.E. Nichols, "Overview of Anaerobic Digestion Technologies in Europe." *BioCycle*. 2004. 45(1): p. 47. (4).

The systems listed in Table 2-3 were examined to determine if any of the systems would be adequate given the criteria for this feasibility study of plants that utilize MSW or some portion of MSW as a feedstock and an operating capacity of 100,000 tons per year. The majority of the systems shown in Table 2-3 do not have a facility with a proven operating capacity of greater than 100,000 TPY. Also, several of the systems have a proven capacity greater than 100,000 TPY, but have not been proven using an appropriate feedstock (SSOM or MSW). Of the systems with a proven operational capacity exceeding 100,000 TPY, most had feedstocks of manure, grey waste, organic industrial waste (OIW), biowaste, or co-digestion of a combination of these. Biowaste may include the putrescible organic fraction of MSW. It should also be noted that the DBA-Wabio process, which uses technology similar to the Waasa process is no longer being actively marketed.[14]

Two vendors had contacted the St. Paul Port Authority, including Doda and Visiam, with branch offices in Minnesota, noted in the table above. These vendors have developed a front-end technology to accompany the AD process. The front-end technology is comprised of mechanical components with the primary functions of size reduction, separation, and homogenizing the waste stream prior to the AD process. According to Doda and Visiam, they have teamed with other vendors to provide an existing AD system, however their websites do not reflect this.

According to Doda and Visiam, the AD providers were using a wet thermophyllic system in conjunction with the Doda and Visiam front-end technology. Their technology may be applicable to an AD process.

2.4.3 Plant Suppliers >100,000 TPY

For the purposes of this study, the feedstock is antcipated to contain approximately 100,000 TPY of SSOM. Since "scaling" a facility based on size is a common problem of complex process designs, this review focused on vendors with full-scale operational MSW anaerobic digestion facilities in this range (> 100,000 TPY). The list of suppliers that have operational facilities treating at least 100,000 TPY of MSW (or OFMSW) using AD was created and is provided in Table 2-4. Additionally, Table 2-4 summarizes the number of stages, system type (wet or dry), and operating temperature of the AD system provided by various vendors.

Table 2-4 Vendor with Plants Greater Than 100,000 TPY[A]

Vendor	No. of Plants	Capacity Range (Thousands of TPY)	Stages	Wet or Dry	Operating Temperature
Arrow Ecology	4	90 to 100	2	Wet	Mesophilic
BTA	23	1 to 150	1, 2	Wet	Mesophilic and Thermophilic
Organic Waste Systems	17	3 to 120	1	Dry	Thermophilic
Entec	2	40	1	Wet	Mesophilic
Global Renewables Ltd.	1	175	1	Dry	Mesophilic
Ros Roca Int'l	13	10 to 90	1	Wet	Thermophilic
Haase	4	50 to 200	2	Wet	Mesophilic and Thermophilic
Wehke-Werk AG	1	100	2	Dry	Mesophilic
Kompogas	38	1 to 110	1	Dry	Thermophilic
Farmatic Biotach	3	25 to 87	2	Wet	Thermophilic
Strabag	8	15 to 150	1, 2	Wet & Dry	Mesophilic and Thermophilic
Valorga International	22	10 to 270	1	Dry	Mesophilic and Thermophilic
CiTec	10	3 to 230	1	Wet	Mesophilic and Thermophilic

[A]Adopted from IEA Energy IEA *Bioenergy*, "Biogas and More: Systems and Markets Overview of Anaerobic Digestion." July 2001. Company website and C.E. Nichols, "Overview of Anaerobic Digestion Technologies in Europe." *BioCycle*. 2004. 45(1): p. 47.

A more detailed description of select vendors and process is provided in the following sections.

2.4.3.1 Arrow Ecology

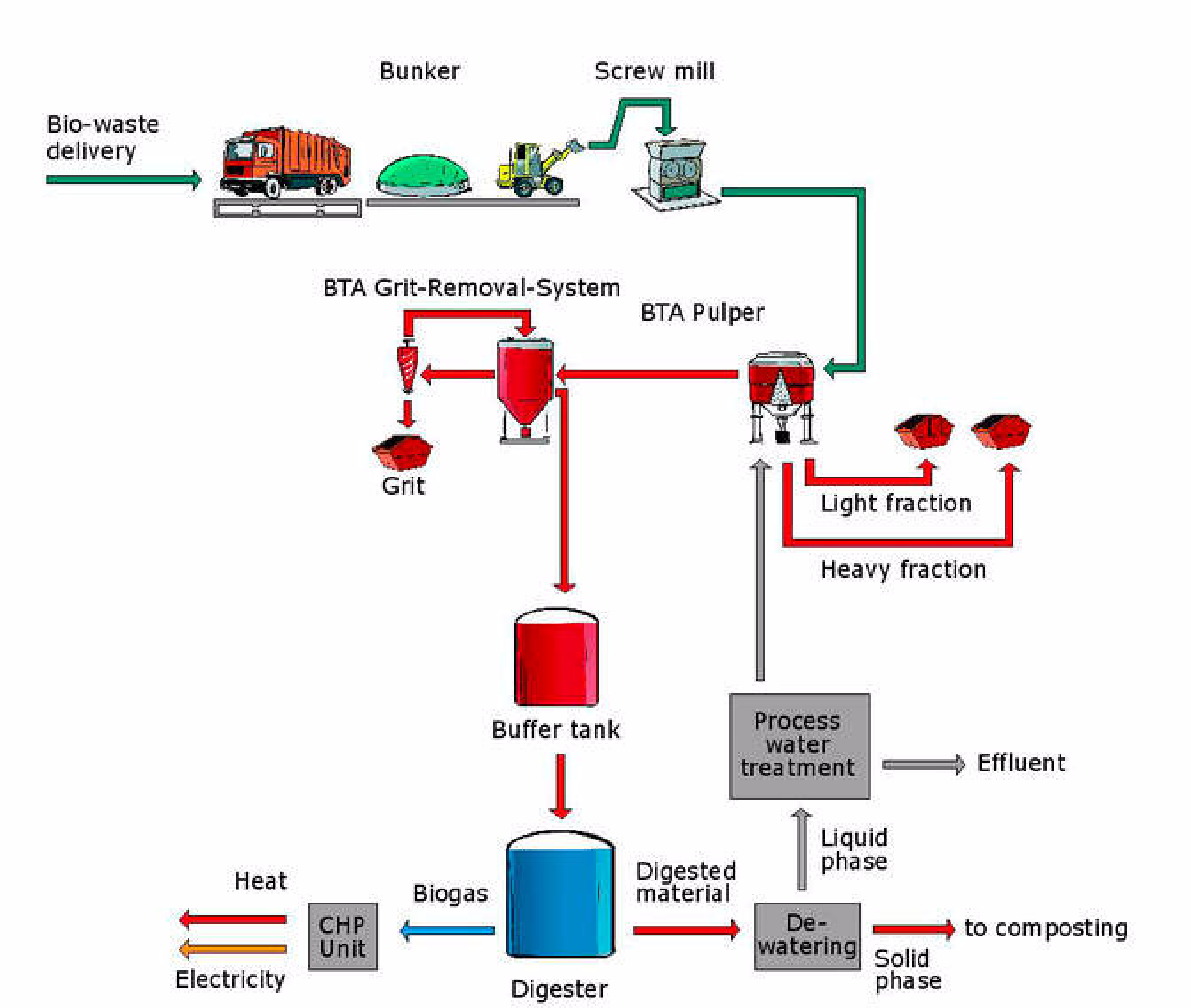
The ArrowBio website (www.arrowbio.com) was researched to determine process specifics and any reference plants currently in operation. The process generally involves an initial dry waste preparation where materials are mechanically and manually separated followed by a liquid-based waste preparation and separation technique. The organic material passes through a trommel on to a conveyor where the material enters a "hydro-crusher". From the hydro-crusher the material enters a bioreactor tank where acidogenic fermentation transforms complex organics into simpler organic and fatty acids. Finally, the acid rich material is heated to mesophilic temperatures and transported to the methanogenic fermentation reactor. Reported facilities include Sydney, Australia (70,000 TPY): New South Wales, Australia; and Tel Aviv, Israel (39,000 TPY) with planned plants in Mexico, Greece and the United Kingdom. The process uses a front end material recovery facility to sort incoming MSW. A float tank further sorts the MSW where the organic fraction is sent to AD. ArrowBio reports that a plant capable of processing 480 tons per day of MSW, would produce 1.5 million cubic feet of biogas per day. Given biogas production rates of 3.6 cubic feet per pound for AD process, the organic loading rate of 215 tons per day would be required or approximately a waste stream with 45% organic materials.

A process flow diagram of the ArrowBio process was not available.

2.4.3.2 BTA International

The largest BTA System, developed by Biotechnische Abfallverwertung GmbH & Co. KG in 2001, is located in Barcelona, Spain. This system is a multi-stage wet system. It receives 250,000 TPY of MSW and 50,000 TPY of biowaste. A process flow diagram of the BTA system process is shown in Figure 2-1.[15]

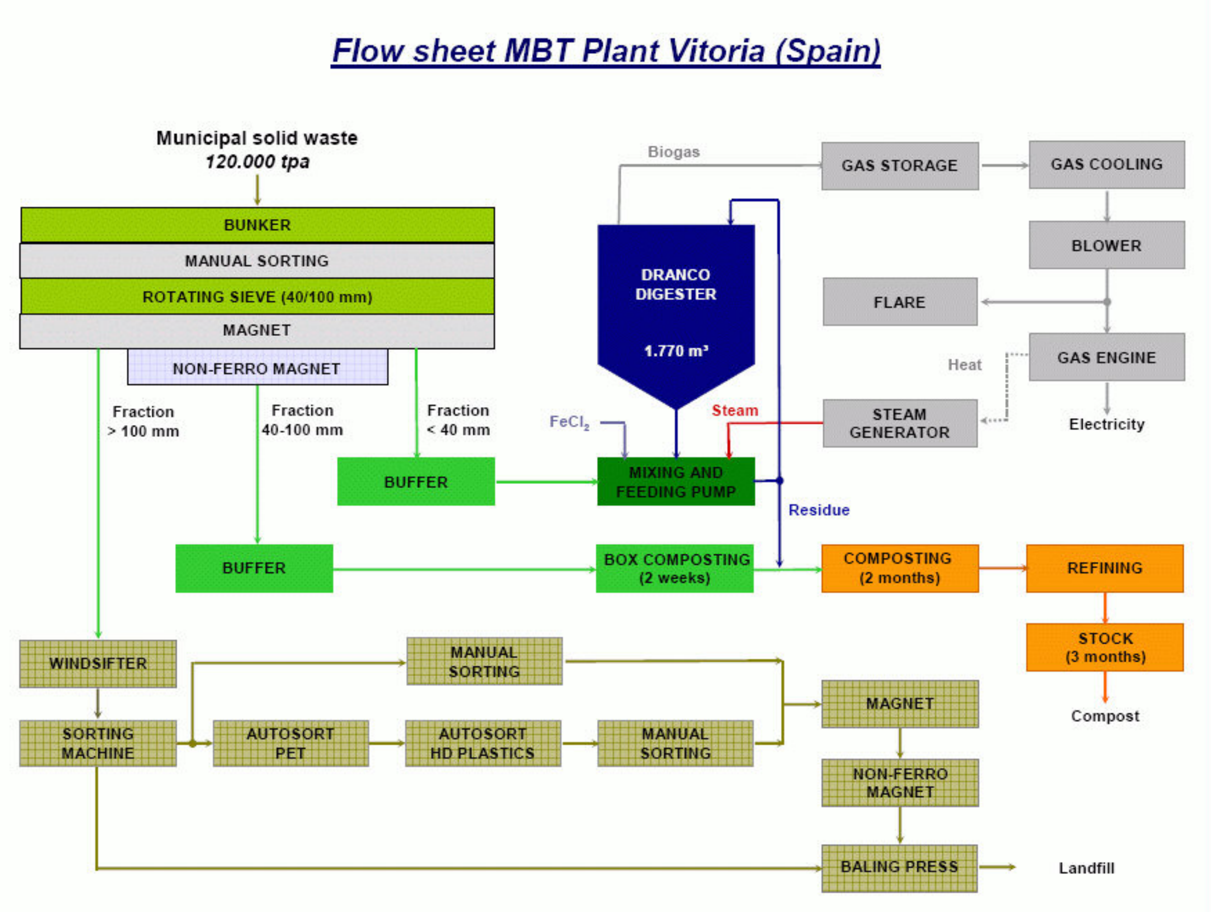
Figure 2-1 Process Flow Diagram for BTA System



2.4.3.3 Organic Waste Systems

The largest Dranco System, developed by Organic Waste Systems in 2006, is located in Victoria, Spain. This system is a single-stage dry system. It receives 120,000 TPY of OFMSW. The total digester volume is approximately 500,000 gallons. A process flow diagram of the Dranco system process in Vitoria, Spain is shown in Figure 2-2.[16]

Figure 2-2 Process Flow Diagram for Dranco System



2.4.3.4 Entec

The largest BIMA digester system, developed by Entec Biogas GmbH in 2002, is located in Lucknow, India. According to the Entec website, it appears that this system is no longer operational as of 2004. Unfortunately, the Entec website only provided limited information regarding this system. It reportedly was a single-stage wet system, processed approximately 170,000 tons/yr of MSW, and used six digesters each approximately 1,000,000 gallons. Entec's other systems generally process less than 100,000 tons/yr or are specifically designed to use a feedstock other than MSW.[17]

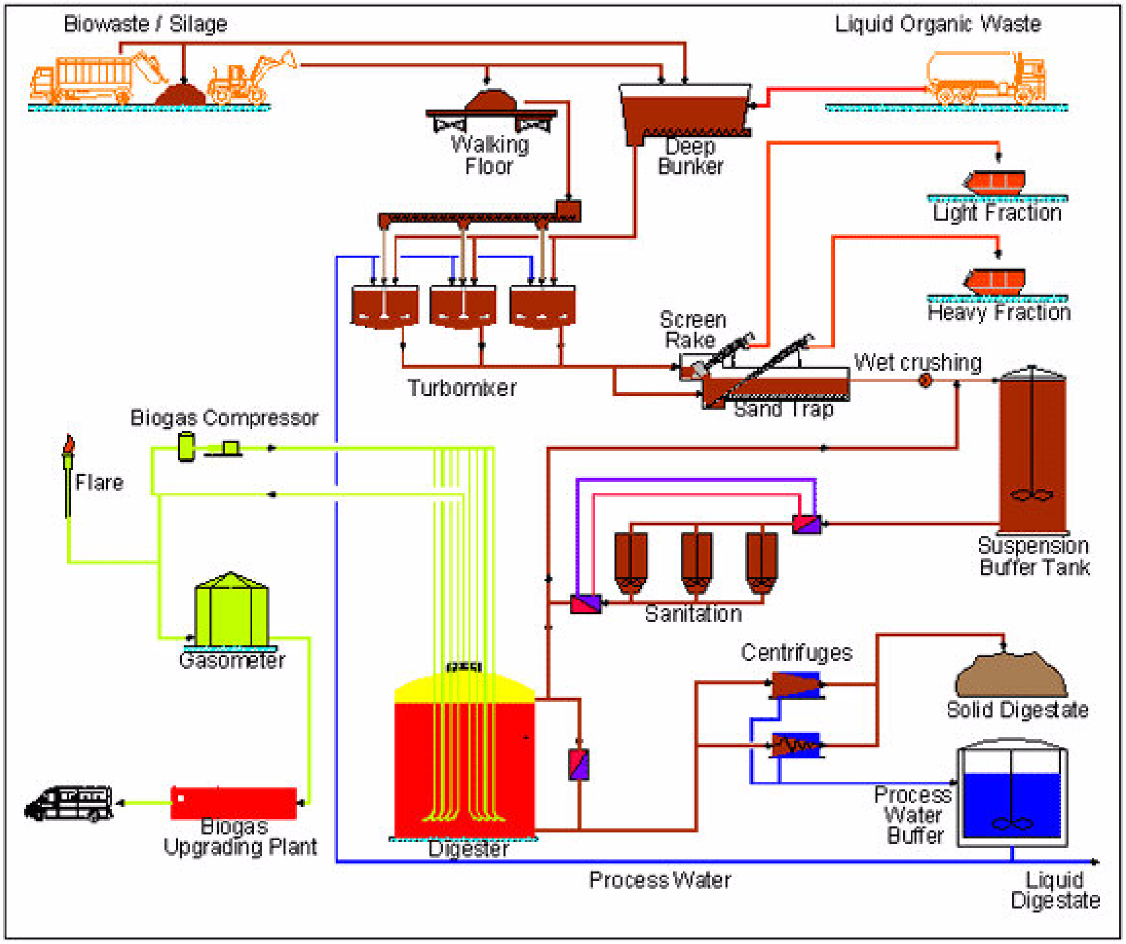
2.4.3.5 Global Renewables Ltd.

It should be noted that the IEA reports that the two of the three Global Renewables Limited facilities using the ISKA process are closed.[18] Also, it was noted by Waste Management News that the facilities using the ISKA process were having issues with odor and cost, thus, operational stability is currently questionable for the ISKA process.[19] Global Renewables now markets the UR-3R process which incorporates MRF technology ahead of an ISKA biopercolate process. Most of the plants using UR-3R process are located in Australia.

2.4.3.6 Ros Roca International

Ros Roca International uses a process known as the Biostab process. This process is a wet technology that uses wet pre-treatment where organic material is mixed with process water in a "turbomixer". The material is then sanitized prior to digestion. During AD, the material is mixed using compressed biogas. The largest operational Ros Roca facility is located in Lommel, Belgium and has a capacity of 150,000 tons/yr of industrial organic material from potato processing as reported by Ros Roca International. Ros Roca International also has a facility in Barcelona, Spain that has a capacity of 90,000 metric tons/yr, which is just below 100,000 tons/yr. A process flow diagram of the Biostab process is shown in Figure 2 -3.[20]

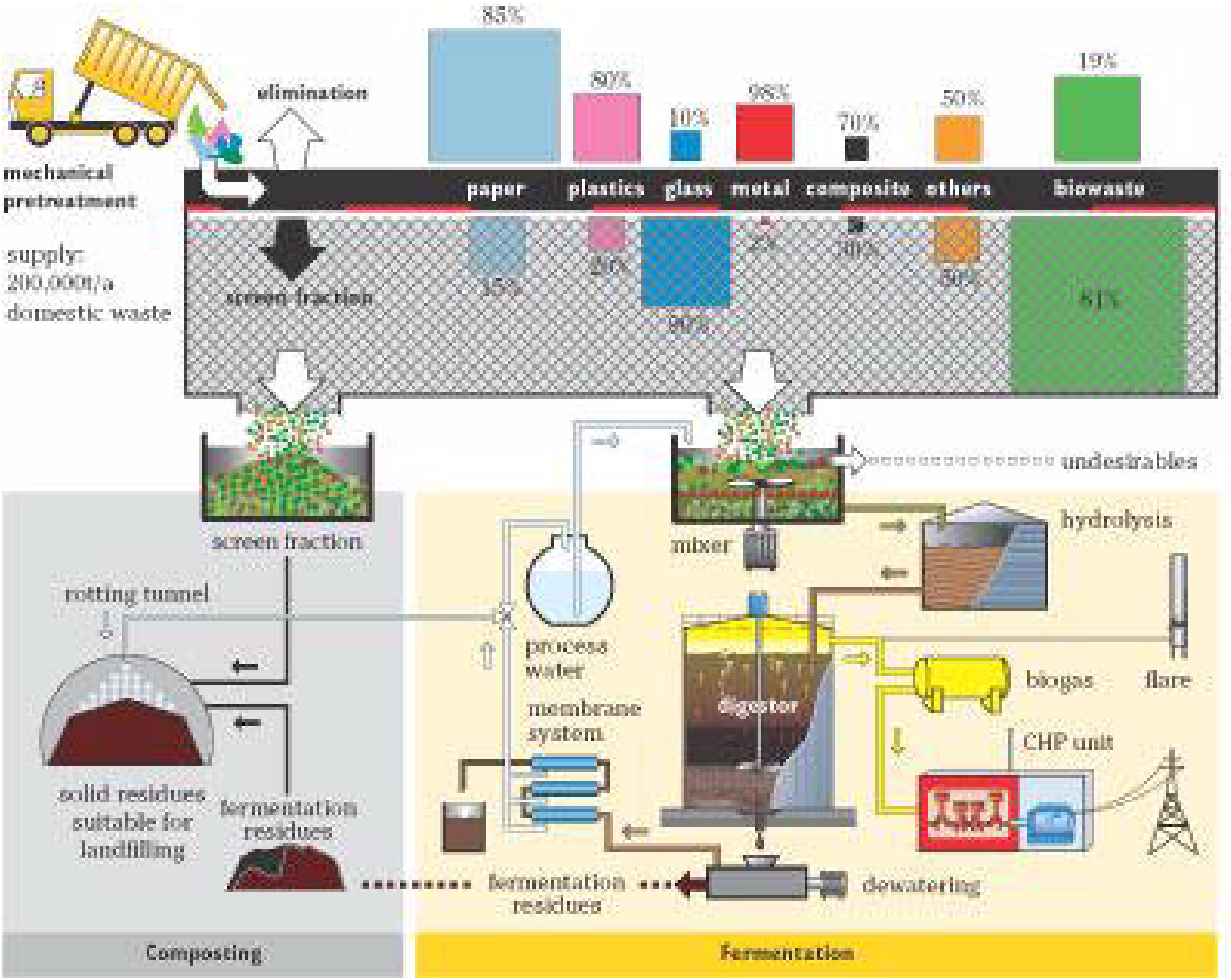
Figure 2-3 Biostab Process Diagram



2.4.3.7 Haase

The largest MBT system, developed by Haase in 2005, is located in Leon, Spain. The MBT system is a dual-stage wet system. It receives 200,000 TPY of OFMSW. The Leon facility operates two digesters in parallel, each with a volume of approximately 700,000 gallons. A process flow diagram of the MBT system process is shown in Figure 2-4.[21] Haase also commissioned a 150,000 TPY facility in Luebeck, Germany.

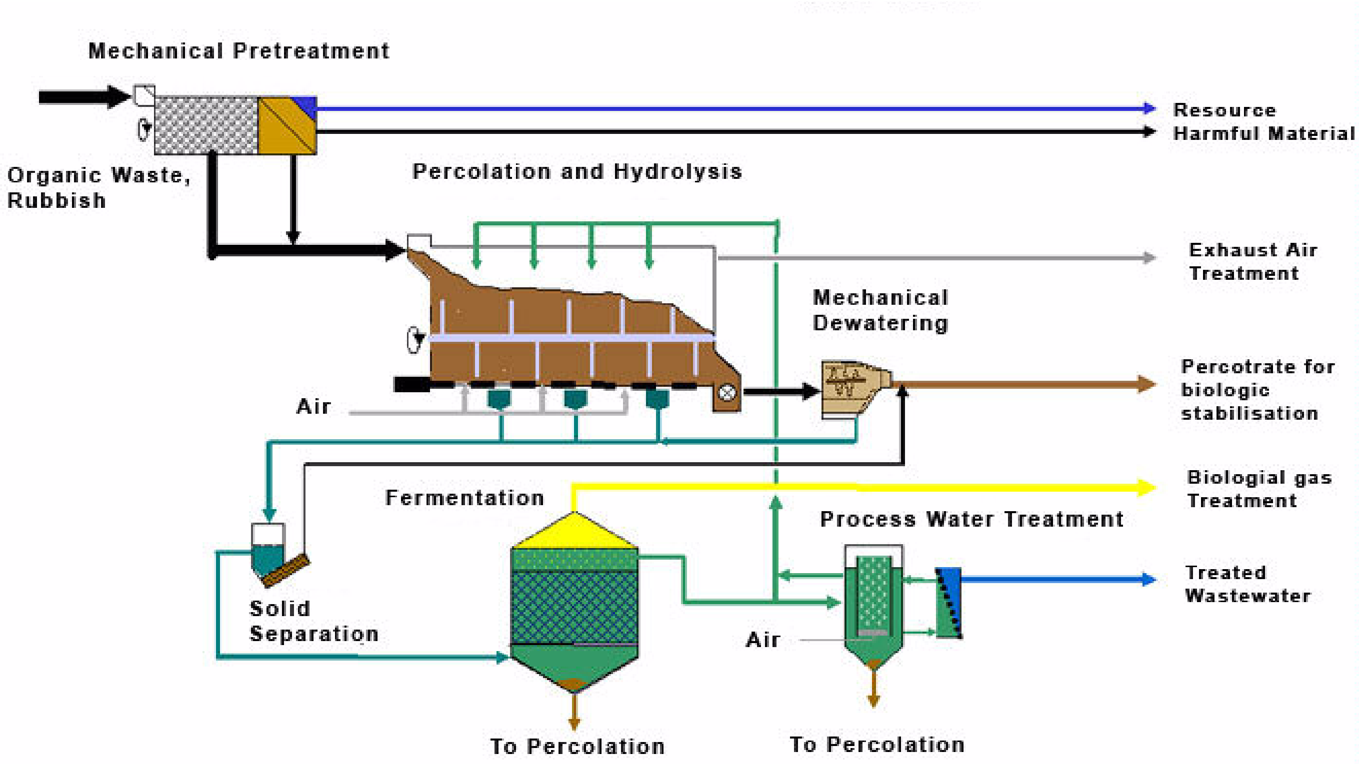
Figure 2-4 MBT System Process Diagram



2.4.3.8 Wehrle-Werk AG

Wehrle-Werk AG developed the Biopercolat process which was first commissioned in 2000. The facility is in Kahlenberg, Germany and was designed with a capacity of 20,000 tons/yr. This facility was designed to mechanically and biologically treat mixed MSW and biowaste and was expanded to a capacity of 100,000 TPYsometime after 2004. The Biopercolat process is a two-stage and two phase operation that links aerobic and anaerobic processes. The material is first mechanically pretreated and the organic fraction enters the percolator where it undergoes aerobic hydrolysis. The material enters a fixed bed reactor that operates anaerobically at mesophilic temperatures. A process flow diagram of the Biopercolat process is shown in Figure 2-5.[22]

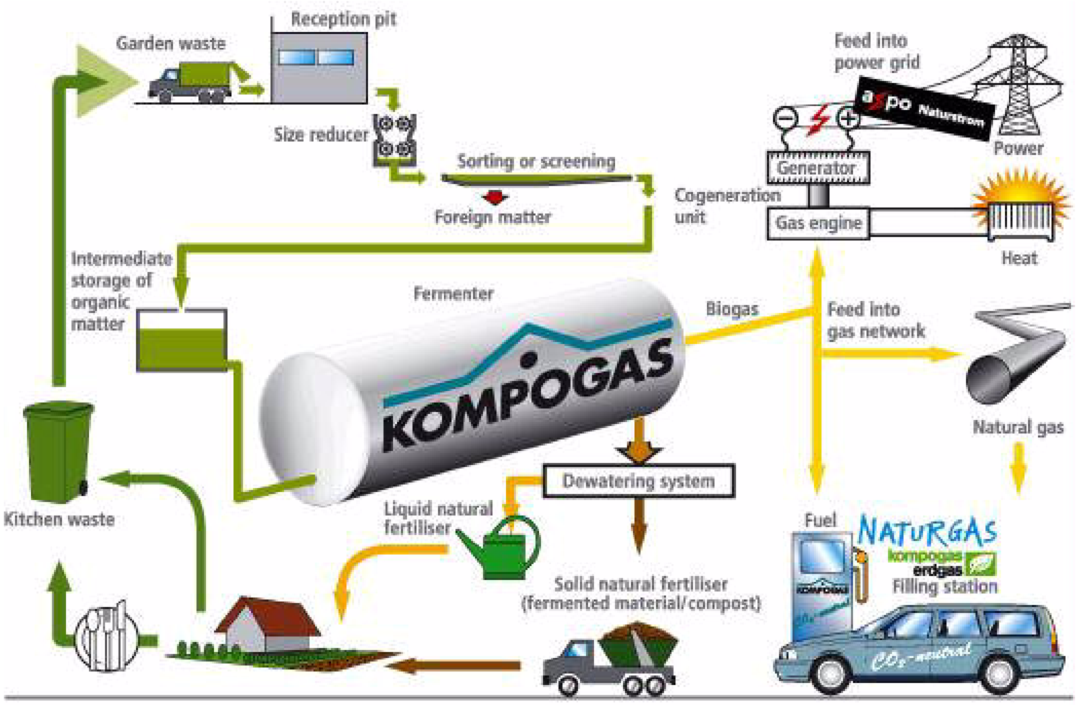
Figure 2-5 Biopercolate Process Diagram



2.4.3.9 Kompogas

The Kompogas system, developed by Kompogas AG, begins by sending the organic material through a shredder. The organic material is then sent to an interim storage area before being forwarded into the fermentation reactor. The fermenter consists of a horizontal plug flow reactor with a mixing and degassing apparatus running down the middle. The largest Kompogas system is located in Montepellier, France. The Kompogas system in Montepellier is a single-stage dry system. It receives 100,000 TPY of MSW. A process flow diagram of the Kompogas process is shown in Figure 2-6.[23]

Figure 2-6 Kompogas Process Diagram



2.4.3.10 Farmatic Biotech Energy AG

Farmatic Biotech Energy AG has been using the Schwarting-Uhde process since Schwarting Umwelt GmbH became a part of Farmatic Biotech Energy AG group in 2001. The largest operational facility was constructed in 2002 in Holsworthy, UK and has a capacity of 200,000 tons/yr. In this system the digester contents are not completely mixed in order to achieve a defined plug flow. Perforated plates in the cylindrical digesters are used to obtain an even flow distribution. The mixing of the digester content is achieved by periodically raising and lowering the column of liquid in the tank, thus creating turbulence at the perforated plates and also enables the separation of the biogas from the liquid.

Raw sludge (primary and waste activated sludge) is fed to the process at a dry solids content of about 4% to 10%. The sludge is preheated by the digested sludge from the second stage and finally heated to mesophilic temperature befoe being fed into the first digester. The retention time in the first digester is about 5 to 6 days, during which the organic solids content is reduced by about 40%. Before entering the second digester, the sludge is heated to operate in the thermophilic range and the retention time of the sludge is also 5 to 6 days, during which an overall organic solids reduction of 55% is achieved. The overall retention time is 10 to 12 days, compared to 20 days for conventional mesophilic digestion. The majority of the Farmatic facilities have a feedstock of manure or biowaste.

2.4.3.11 Strabag

Strabag (formerly Linde-KCA-Dresden GmbH) website (www.strabag.com)makes no reference to MSW AD technology, other than to note that they had purchased Linde-KCA-Dresden GmbH in January 2007. Whether or not Strabag will be building/designing AD technologies is undetermined.

The Strabag process is a dry plug flow reactor that is horizontal. The digester unit can operate as either a mesophilic or thermophilic reactor. The company reports 70 installations, but Strabag also produces compost and waste processing equipment that may be included in the total number of installations reported.

Strabag does include in its portfolio a dry anaerobic digester coupled with a transfer station at Communes de Sequedin et Loos, France. The facility handles 220,000 TPY of waste and completes 108,600 TPY of organic waste treatment. The organic waste load consists of biowastes, green wastes and commercial wastes. The plant became operational in 2006.

2.4.3.12 Valorga International

The largest Valorga system, developed by Valorga International in 2004, is located in Barcelona, Spain. The Valorga system is a dry, continuous plug flow system. It receives 218,000 TPY of MSW and 22,000 TPY of biowaste. The IEA reports that Valorga has a facility in Fos sur Mer, France with a capacity of 497,600 TPY, but no additional information about this particular facility could be found. Finally, Valorga has a plant in Shangai, China with a reported capacity of 227,000 TPY of household waste and 44,000 TPY of biowaste. However, it is unknown if this facility is in operation.

The Valorga system in Barcelona, Spain has manual and mechanical sorting, anaerobic digestion in three 160,000 cubic feet digesters and operates under mesophilic conditions. The gas yield is reported to be 2.01 cubic feet per pound of input waste. The biogas is used for electrical generation to produce 4 Mw of electric power. Thereis also a 182,500 TPY facility in La Coruna Spain that began processing MSW in 2001.[24]

No process flow diagram was available for the Valorga system.

2.4.3.13 CiTec

The largest Waasa system, developed by CiTec in 1989, is located in Groningen, Netherlands. This system is a single-stage wet system. It receives 275,000 TPY of raw MSW, of which 101,000 tons is OFMSW. It operates four digesters in parallel, each with a volume of 725,000 gallons. This process produces 3.2 to 4.8 scf of biogas per wet pound of OFMSW. CiTec has other MSW AD plants in Vaasa, Finland (15,000 TPY) and Pinerola, Italy (30,000 TPY). The most recent plants reported by CiTel are in Japan and process biowaste and sludge.[25,26,27]

2.5 Selected Vendors to Highlight

Based on the information in the previous section, and the demonstrated capabilities within the expected operational range, the following vendors are described in more detail as potential vendors for an SSOM anaerobic digestion facility in metropolitan area. :

- The BTA system, developed by Biotechnische Abfallverwertung GmbH & Co. KG (BAKG)
- The Dranco system developed by Organic Waste Systems (OWS)
- The Valorga system developed by Waste Recovery Systems (WRS)
- The MBT system developed by Haase

Table 2-5 provides a general overview of the performance of full-scale OFMSW anaerobic digestion facilities for the selected vendors.

Table 2-5 AD Process Performance Selected[A]

Vendor	System	OFMSW (TPY)	Digester (Mgal)	Biogas Yield (Ft^3/lb)
BAKG	BTA	150,000	0.9	3.8- 4.6
OWS	Dranco	120,000	0.5	2.0 – 3.0
WRS	Valorga	110,000	3	2.0- 5.1
Haase	MBT	112,000	1.4	1.76 – 3.0

[A]Adapted from "Current Anaerobic Digestion Technologies Used for Treatment of Municipal Organic Solid Waste" CIWMB. March 2008.

2.5.1 BTA

The BTA process was developed in Germany with applications throughout Western Europe and also in select locations in Canada and Japan. The BTA process is one of the oldest and most successful processes in terms of experience with AD.[28]

The BTA process consists of pretreatment of the waste using the BTA Waste Pulper and the BTA Grit Removal System. These systems separate the organic materials using buoyancy of the materials and removes the fine sands (e.g. grit) using the BTA Grit removal system.

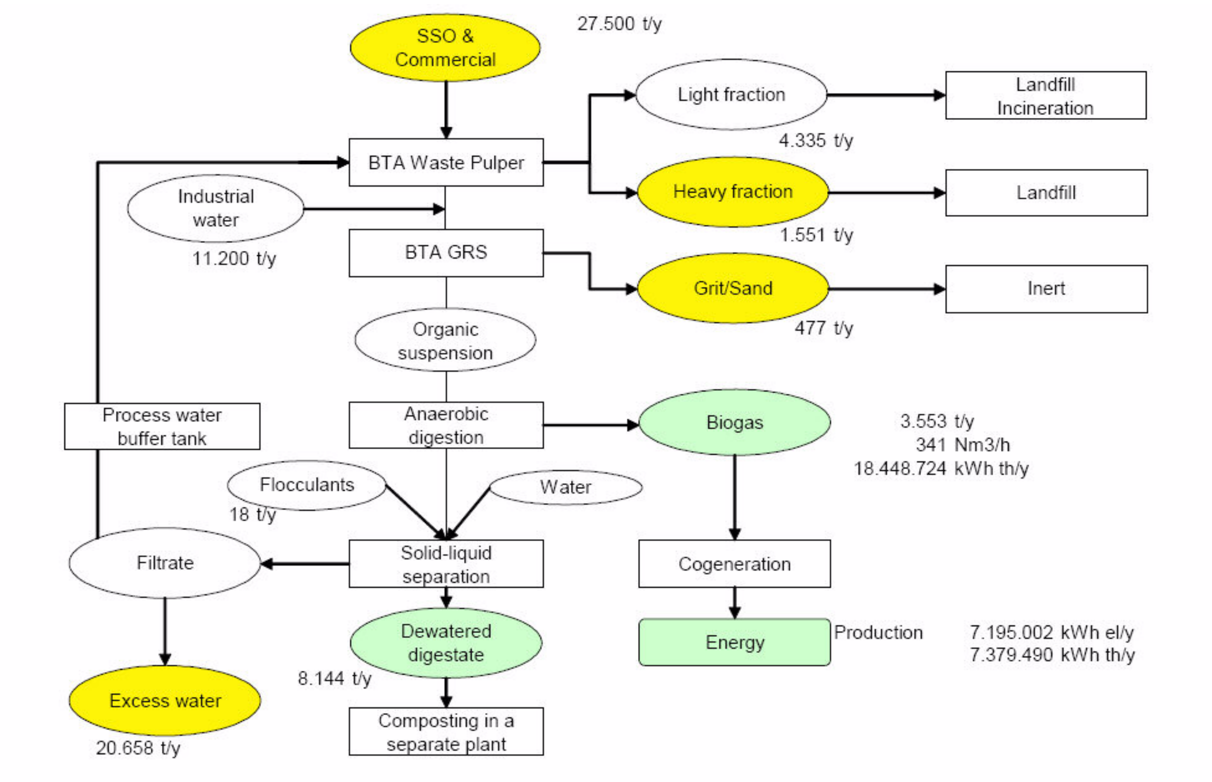
Upon pretreatment, the organic material is fermented and digested in mesophilic conditions (95 – 100 ºF). After digestion of the waste, the material is processed in a centrifuge to separate the liquid from the solid portion. The liquid portion is typically reused in the AD process and the solids are sent for composting.[29]

A process flow diagram of the BTA system is provided in Figure 2-7.

The BTA process is considered a two stage dry mesophilic process which would be suitable for application to the eight county area SSOM supply. However, the process can be easily augmented to a two stage wet system depending on needs of the facility and SSOM supply.

The most recent plant for BTA is a 30,000 TPY source separated organic material AD facility in Toronto. This plant is designed as a single stage wet digester. BTA also designed, constructed and operates an SSOM AD plant in Dufferin, Ontario.[30] This facility is designed for 25,000 TPY of SSOM. The plant began operation in September 2002 starting at a capacity of 1,075 TPY. By 2008, the plant capacity has increased to 11,427 TPY. In 2008, the Ministry of Environment increased the permitted capacity of the plant to 43,750 TPY (about 175 tons per day)

Figure 2-7 BTA Process Mass Flow Diagram for 2006



The figure indicates the following process characteristics:

Table 2-6 BTA Process Characteristics

Component	Tons	Percent
Waste Received	27,500 tons	(100%)
Removed before AD	6,363 tons	(23%)
Total Waste AD	21,137 tons	(77%)
Liquid Added	11,200 tons	-
Compost Remaining	8,144 tons	(30%)
Water Excess	20,658 tons	
Biogas Yield	63,000 MMBTUs	

Staffing of the plant in Dufferin requires 11 people. The plant operates for two shifts with a supervisor, process operator, loader operator and a general laborer needed for each shift. Reference plants for BTA are shown in Table 2-7.

Table 2-7 BTA Reference Plants

Plant	Details
Valorgas (Portugal)	Start-up mid 2009
Input:	Municipal solid waste
Capacity:	50,000 tons/year
Granoliers (Spain)	Start-up end of 2008
Input:	Biowaste, municipal solid waste
Capacity:	45,000 tons/year
Barcelona/Ecoparc 1 (Spain)	Start-up begin of 2008
Input:	Biowaste, municipal solid waste
Capacity:	50,000 tons/year
Mulheim (Germany)	Start-up 2008
Input:	Biowaste, commercial waste
Capacity:	22,000 tons/year
Ypres (Belgium)	Start-up 2003
Input:	Biowaste, commercial waste
Capacity:	50,000 tons/year
Villacidro (Italy)	Start-up 2002
Input:	Municipal solid waste incl. sewage sludge
Capacity:	45,000 tons/year
Newmarket (Canada)	Start-up 2000
Input:	Biowaste commercial waste and organic sludge
Capacity:	150,000 tons/year

2.5.2 Dranco (Organic Waste Systems)

Organic Waste Systems (OWS) was established in 1988 and designs, builds, and operates AD plants in Europe, Japan, and Korea. The Dranco process is a single stage dry system that operates as a plug flow process.

The Dranco process[31] consists of prescreening the waste (size separating) to obtain a uniform size (<40 mm). The organic waste enters a mixer where steam and liquid is added. Typically digestate from the AD process is added at a ratio of one ton organic waste to 6 to 8 tons digestate. A small amount of steam is added to increase the temperature to mesophilic (95 ºF to 100 ºF) or thermophilic (120 ºF to 130 ºF) operation. Once the organic material is mixed with digestate and steam, the material enters the top of the digester. The material then passes through the digester by gravity. The material takes about 2 to 4 days to pass through the digester. Large particles extracted from the tank are mixed with incoming organic material as discussed above. The total estimated residence time in the digester is about 20 days (or 5 to 10 cycles). A process flow diagram for the Dranco process is provided in Figure 2-2.

The Dranco system performance has been published for the Brecht, Belgium plant. The system in Brecht accepted an average of 51,575 TPY between 2002 and 2006.

Specific mass balance for the Dranco process is not available. The reference plants information in Table 2-8 does indicate the Dranco process capacity for digestion is 30,000 tons per year, though the reported plant capacity may be higher. The difference is accounted for by separation of materials before the AD process (front end separation) that occurs at many AD plants.

Table 2-8 Dranco Process Reference Plants

Plants	Capacity	Material	Year (start up)
Alicante, Spain	33,000	Mixed waste	Planned for 2008
Vitoria, Spain	132,000	Mixed waste	2006
Munster, Germany	26,400	Residual waste	2005
Hille, Germany	41,800	Residual waste	2005
Kaiserslautern, Germany	22,000	Residual waste	1999
Bassum, Germany	14,900	Residual waste	1997

OWS also offers a SORDISEP technology.[32] This technology recovers recyclables by sorting the material prior to anaerobic digestion and also using a wet separation process after the AD process to recover sand, fibers, and inerts.

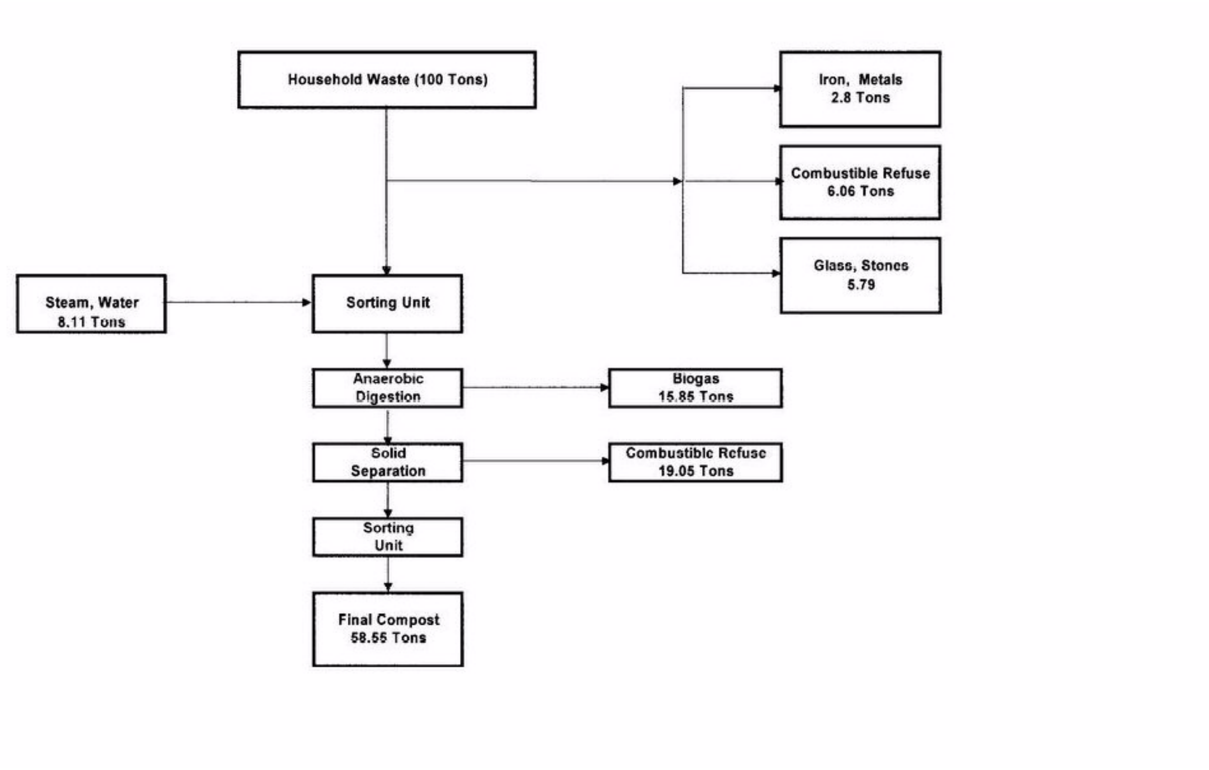
2.5.3 Valorga

The Valorga process uses a single stage dry system operating in thermophilic or mesophilic conditions. The process, developed in 1981, is a continuous single stage plug flow mixer. The unique aspect of the Valorga system is the use of pressurized biogas to mix the materials in the reactor. This is reported to eliminate the inoculation loop in the AD process. Also, the Valorga process feeds the organic waste from the bottom of the AD tank. Reference plants for the Valorga process are provided in Table 2-9. The process flow diagram is provided in Figure 2-8.

Table 2-9 Valorga Reference Plants

Location		Capacity	Start-up Date	Material
Shanghai	China	295,000	2007	Household & biowaste
Beijing	China	115,000	2007	Household sorted waste
Tondela	Portugal	39,000	2007	MSW & biowaste
Calais	France	31,000	2007	Biowaste & greases
Barcelona (Ecopark II)	Spain	132,000	2004	MSW & organic waste
Bassano	Italy	61,000	2003	MSW & industrial waste
Hanover	Germany	138,000	2002	MSW
Cadix	Spain	127,000	2002	Unknown
Varennes-Jarcy	France	110,000	2002	MSW & bowaste
Mons	Belgium	65,000	2002	MSW & kitchen/garden waste
La Coruna	Spain	156,000	2001	MSW
Geneva	Switzerland	11,000	2000	Kitchen/garden waste
Frieburg	Germany	40,000	1999	Biowaste
Engelskirchen	Germany	34,000	1998	Biowaste
Tilburg	Netherlands	57,000	1994	Vegetable/garden/fruit
Amiens	France	94,000	1988	MSW

Figure 2-8 Process Flow Diagram of Valorga Plant



The most published Valorga plant information is from the Valorga plant in Tilburg, Netherlands. This plant has a treatment capacity of 52,000 tons per year of organic waste. The waste is primarily vegetable garden, fruit and other food wastes. The waste received at the plant is pretreated by shredding, screening, and metals separation. The material is then mixed with digestate and pumped into a 116,000 cubic feet digester. The digester is mixed using biogas stored in a buffer tank. The digested matter is extracted from the tank, dewatered and composted for approximately one week. Composting is conducted indoors to eliminate odors from the composting operation. The Tilburg plant is a mesophilic plant with a digester retention time of 24 days. Currently the plant accepts approximately 40,000 tons per year of garden type wastes (77% plant at capacity). The biogas produced from this plant is cleaned and sold to the local natural gas utility. A portion of the biogas produced (18%) is used to maintain process heat. Total energy sold to the utility is 502,000 MMBTUs per year. The general plant mass balance is:[33]

- Tons of garden waste received: 40,000 tons.
- Tons of non-reusable paper – cardboard: 6,000 tons
- Methane Produced: 98 million cubic feet
- Biogas produced: 4,173 million cubic feet
- Residuals: 28,000 tons (61%)

Staffing at the plant was estimated to be 20 people.[34] However, this seems high and would depend on the operating times for the plant.

2.5.4 Haase

The Haase-MBT system consists of a mechanical pretreatment system for MSW that is coupled with an anaerobic digestion facility to treat waste. The system provides a complete solution for MSW processing.

The HAASE process[35] begins by mechanical treatment of the waste stream. This includes separating from the waste stream the paper, plastic, glass, metal and other recyclables. The remaining waste, mostly organic, is placed into a mixer. The mixer hydrates the waste and further removes non-organic material prior to the AD process. Waste leaves the mixer and enters the AD process. The AD process for a Haase facility in Spain that accepts 200,000 tons per year is sized to accept 50,000 tons per year. The HAASE AD process is considered a 2 stage wet process. The initial stage is the fermentation stage. The fermentation stage operates between 100 ºF and 104 ºF and the retention time is approximately 15 days. After the fermentation stage, the mixture is sent to the bioreactor tank for further digestion. The bioreactor tank is a mixed tank where biogas is collected. After the final AD stage, the material is then dewatered (digestate is recirculated) and the solid portion composted. A general process flow diagram for the Haase system is provided in Figure 2-4:

Typical mass balance for the HAASE plant in Leon, Spain is:

♦ Material received	210,000 tons
♦ Recycled materials	98,000 tons
♦ Inerts	76,140 tons

- Other non-organics 7,000 tons
- Materials Entering AD 28,860 tons
- Materials leaving AD to compost 15,682 tons
- Total energy produced: 51,146 MMBTU

2.5.5 Summary

Of the four vendors analyzed with plant capabilities to meet the needs of the eight county metro area, Valorga and Dranco appear to have the most experience with mixed waste, SSOM and OFMSW. The BTA process and Haase process would be better suited for a facility designed to receive MSW rather than SSOM. Both the BTA and Haase processes have up front separating systems to remove recyclables and inerts from the MSW prior to the AD process.

2.6 Biogas Options

There are several different potential uses for the biogas produced and collected during the AD process. Some uses require little treatment prior to use (e.g. direct use) while other uses require more significant treatment prior to use (e.g. pipeline quality). Several of the options that will be evaluated in the next sections include direct use, electrical generation, fuel cells, and pipeline quality.

2.6.1 Direct Use

In most of the AD processes previously described, a portion of the biogas produced during the process is used for some part of the process (e.g. heating, mixing, etc.), which may be considered a direct use. Another potential direct use for biogas is to burn the gas in an existing boiler, such as in an industrial or manufacturing setting in place of or as a partial substitute for natural gas. However, prior to direct use in a boiler, the biogas must be treated to remove moisture, hydrogen sulfide (H_2S), and siloxane. One potential drawback to this direct use is that AD process producing biogas and the boiler need to be relatively close to one another or there needs to be the infrastructure in place to pipe the gas to the boiler. An additional potential challenge is that boilers for industrial/manufacturing tend to need a consistent fuel supply.

2.6.2 Electric Generation

Biogas can also be used for electric generation by operating a generator (or multiple generators) that combust biogas. There are several manufacturers that produce generators (also known as engines or generator-sets) designed specifically to operate using biogas. These engines are often referred to as low energy fuel or gas lean engines. GE’s Jenbacher gas engine division provides engines capable of running on a variety of gases such as natural gas, biogas, and landfill gas. The Jenbacher engines range in power capability from 0.25 to 3 MW.[36] Caterpillar also offers a line of engines for electric generation from the combustion of biogas. The Caterpillar engines range in power capability from approximately 0.1 to 1.6 MW.[37] Another manufacturer that produces engines designed to run on biogas is Waukesha. Waukesha produces a line of engines designed to operate on low Btu fuel such as biogas. The Waukesha engines range in power capability from 0.1 to 1.4 MW. Depending on the amount of biogas being produced, single or multiple engines can be operated.[38]

Depending on the volume of biogas produced, another option for electric generation is the combustion of biogas using microturbines. Microturbines can generally be used if a lower volume of biogas is produced. However, multiple microturbines can be combined to handle larger volumes of biogas. Microturbines have a power capacity of approximately 30 kW to 200kW, depending on manufacturer. Capstone Turbine Corporation and Ingersall Rand are two manufacturers that have experience with designing and building microturbine systems for use with biogas. One potential drawback to the use of microturbines is that for larger systems (above approximately 500 cfm biogas) are generally more expensive then a comparably sized engine/generator.[39, 40]

As with direct use, the biogas must be treated to remove moisture, hydrogen sulfide (H_2S), and siloxane before being combusted in engines for electric generation. Siloxane removal is not required but will shorten the time between major maintenance cycles. There are also add-on emission controls that may be required to treat the exhaust, depending on the local air quality requirements. An additional benefit to combustion of biogas in either a generator or microturbine is that most systems can be built to also capture heat from the combustion process, which can be used in the AD process. These systems, called combined heat and power (CHP) are common at AD facilities.

2.6.3 Fuel Cells

Another potential use for the biogas produced during the AD process is to use the biogas as a fuel for fuel cells. Fuel cells technology is still relatively new and at this point works much like a battery fueled by biogas. The hydrogen in the methane is extracted by the fuel cell and oxygen is mixed in to produce electricity, heat and water. In order to use the biogas as fuel for the fuel cell the gas must first be treated to remove the impurities from the biogas. The ONSI Corporation designed, built and operated a fuel cell project at the Penrose Landfill in Sun Valley, California, which produced 140kW of electricity over a 6 month period using the gas from the landfill. There have also been installations of fuel cell systems used in conjunction with AD of sewage wastes and manure, but no known examples of using fuel cell technology with AD of MSW or SSOM. One potential advantage to fuel cells is that there are no combustible parts to the technology and it is considered a zero emission energy source.[41]

2.6.4 Pipeline Quality

The final biogas option evaluated is to treat the biogas to the standards of pipeline quality (also called renewable natural gas). If the biogas is cleaned to these standards it can be put into the local natural gas piping network for use by a variety of different end users. The main challenge associated with this option is to remove most if not all of the impurities (CO_2, H_2S, and water) as pipeline quality gas typically contains only 1-3% CO_2 and is dry. There are several different techniques used to remove the CO_2 and H_2S from biogas. These technologies include a water scrubber method, polyethylene glycol scrubbing, carbon molecular sieves (CO_2 only), and membrane separation. Generally, these methods involve large volumes of water and the biogas must be under high pressure. The drawback to these technologies is that they require large volumes of water that must be treated or otherwise disposed. The biogas option may be cost prohibitive relative to other potential biogas uses due to significant costs for treatment of the biogas.[42],[43]

2.7 Energy Market Status

As discussed in the previous sections there are several different potential uses for the biogas produced and collected during the AD process. Research into currently operating AD facilities was performed to evaluate what the current market is for use of biogas for electric generation, pipeline quality (renewable natural gas), and direct use. Incentives for different energy markets were also evaluated. The following sections will discuss the status of the current energy markets.

2.7.1 Electric

Currently there are several programs and incentives provided by the federal government to promote the use of alternative methods to produce and provide electric energy. The Energy Independence and Security Act of 2007 provides up to a maximum of 30% of the total cost of construction for renewable energy projects that generate energy from biomass as well as from other sources.[44] The American Recovery and Reinvestment Act of 2009 also has tax incentives, grant programs and loan guarantee programs for development and construction of facilities producing renewable energy.[45] Additionally, the State of Minnesota has the Renewable Development Fund (RDF) which provides grants for renewable energy production projects.[46] One of the main benefits of electric generation is that the energy generated is more simply transferred to the end user relative to a direct use option that requires the user to be relatively close to the facility.

2.7.2 Renewable Natural Gas

Many of the incentives that apply to electric generation would also apply to the development of renewable natural gas. However, the costs and level of effort necessary to clean the gas to natural gas standards is substantial and may be uneconomical. Also, similar to electric generation, the gas can be transferred to multiple end users relatively easily as long as there is a location to tap into an existing natural gas pipeline.

2.7.3 Direct Use

All of the various AD technologies appear to use some of the energy produced during the process to heat and/or power a portion of the process itself. Depending on the location of the facility, direct use by another facility capable of burning the biogas directly and capturing the heat may be a feasible option. The challenge is that the facility must be located relatively near the AD plant and the end user must be capable of burning biogas that is of a lower quality than natural gas.

3 Source Separated Organic Materials

3.1 Previous Studies

A wide variety of studies have been completed that have information on the quantities and qualities of SSOM collected separately from residences or commercial establishments. The most relevant of these studies are summarized in the following sections.

3.1.1 Solid Waste Management Coordinating Board (SWMCB)

The Solid Waste Management Coordinating Board (SWMCB) published a study, *Source Separated Food Waste and Organic Materials Management Report (Food Waste and Organics Report),* in October 2007. This study examined available supplies of food waste and other organic materials as well as estimated current reduction and recovery by various programs. The study concluded that while there are notable recovery efforts in place, there is significant diversion potential remaining.

The *Food Waste and Organics Report* provided a summary of current and potential recovery programs for the six-county SWMCB region that were known at the time as displayed in Table 3-1. County staff compiled this summary from a variety of data sources including consultant reports, annual County recycling (i.e., “SCORE”) data, and personal communications. Staff estimated that about 113,000 TPY of food waste and other organic materials were being diverted in 2007. For purposes of *Food Waste and Organics Report,* “organics” was defined to include food waste and non-recyclable paper, but excluded fats, grease, wood, and yard wastes.

Table 3-1 states that about 113,000 TPY of organic material was being recovered in 2007. The recovery programs included:

- Backyard composting.
- Food rescue (edible food back to people).
- Food-to-animals via direct livestock feeding.
- Food-to-animals livestock feed manufacturing.
- Organics composting facilities (e.g., RRT – Empire).

The *Food Waste and Organics Report* estimated that about 200,000 TPY of residential organics remained in the mixed MSW stream and about 180,000 TPY of commercial organics are not recovered for a total of about 380,000 TPY. About one-half of these organics were estimated to be food waste and the other half were non-recyclable paper.

Table 3-1 Current and Potential Capacity by Management Option for 2007[A] (Tons per Year)

	Current Throughput	Unused Capacity	Potential New Capacity	Remarks
Backyard Composting	4,000	-	6,500 (with additional bins)	Residential only
Food Rescue	1,000	500	Yes, if operational limitations are overcome	Additional future capacity is in strategic plan
Food-to-Animals Livestock Feeding	47,000	12,000	Yes, if market demand is there	Commercial sources only
Food-to-Animals Livestock Feed Manufacturing	61,000 (from region; 240,000 total)	75,000	Yes	Primarily for grain-based products from commercial sources (e.g., bakery goods)
SSOM Composting Facilities	500	23,000	23,500; already permitted but would require new pad	Residential & commercial sources
TOTAL	**113,000**	**110,000**	**30,000+**	

[A.] Sources: *Source Separated Food Waste and Organic Materials Management Report,* by SWMCB County Staff, October 2007 and updated as of December 15, 2008. Original data sources include: for the backyard composting estimates: *2007 SWMCB Residential Backyard Compost Bin Report*; All other data: *An Update on Source-Separated Organics Recyclers Serving the Minneapolis/St. Paul Metropolitan Area*, prepared for Hennepin County by Tim Goodman & Associates, December 2006.

Thus, the total generation of food waste, non-recyclable paper and yard waste in the six county region can be estimated as 493,000 TPY. This is calculated as the sum of recovered volumes (113,000 TPY) plus the volumes as disposed (380,000). The current "recovery rate" of total generation is thereby estimated at about 23 percent.

The report estimated that about 110,000 TPY of unused capacity remains within the existing recovery systems and could be developed with very little or modest investments as part of a SSOM expansion effort. Another 30,000 TPY of potential new capacity exists with modest public and private investments. Such new expansions could include, but are not limited to:

- Additional backyard composting.
- Additional recovery by farmers using food directly as feed supplement to pigs.
- Additional SSOM composting capacity at existing facilities.
- Additional recovery of food waste by companies manufacturing animal feed.

Selected *Food Waste and Organics Report* conclusions include:

- There is significant amounts of organic material that remains in the waste stream that could be recovered, but more organic management capacity will be needed.

- There is very little redundancy in the system today because there are only a few service providers within each organics management option.

- The State, region and counties will need to continue to provide financial and technical assistance and staff resources to increase organics management.

- The development process of residential curbside organics programs is similar to the development of residential curbside recycling programs in the late 1980's.

A series of system-wide, residential sector and commercial sector recommendations were included in the report. Some of the action steps have been initiated, but most are still in the planning/budgeting process.

3.1.2 Solid Waste Association of North America (SWANA) – Curbside Collection of Residential Food Waste

In December 2008, SWANA prepared a research memorandum titled, *Curbside Collection of Residential Food Waste* that provided recycling managers with information on current curbside collection programs for residential food waste.[47] The following is a summary of the information presented in this memorandum.

The SWANA memorandum identified 56 communities in the U.S. that had implemented a curbside collection program for residential food waste. Four larger programs; Alameda County in California; San Francisco, California; Seattle, Washington; and Cedar Rapids, Iowa were discussed in more detail in the memorandum. All four programs collect yard waste, food scraps and food soiled paper as part of the organics collection program and these waste types are co-mingled in one container. Collection is automated using rollout carts on a weekly or every other week basis for all four communities. Weekly collection reduces odor issues and allows the waste to be removed prior to the completion of the fly-breeding cycle. If a city utilizes every-other week collection, they often prohibit materials such as meat, fish and dairy food. These materials may also be prohibited from a program if the receiving facilities are not equipped to handle these food types.

In San Francisco, the collection of all materials is completed simultaneously using one collection truck with separate compartments for the different materials (recyclables, MSW and organics). It was unclear if the organics were co-collected with the MSW and other recyclable materials for the other three communities. In most cases the participation in the organics collection program is voluntary. In April 2009, San Francisco was planning on making organics collection mandatory. The City's website implies this service is still on a subscription basis. The cost for recycling and organics collection in San Francisco is included in the household monthly bill.

In Seattle, it is estimated that the cost charged to residents only covers approximately 50% of the true cost for the service.

Cedar Rapids uses municipal crews to collect organics from residents. The costs to cover these services are also included in the resident's monthly bill.

3.1.3 Linden Hills

A report titled, *Linden Hills Power & Light - Anaerobic Digester Feasibility Study* (Linden Hills study) developed in June, 2008[48], included a section focused on securing a Feedstock and Collection possibilities to support an AD facility. The following summarizes the information provided in the Linden Hills study.

For this Linden Hills study the feedstock sources considered included source separated organics and grease trap waste. Source separated organics for the purposes of the Linden Hills study included yard waste, food waste, paper towels, tissue paper, paper packaging, other nonrecyclable paper, disposable diapers, kitty litter and pet feces.

The Linden Hills study highlighted several collection options and determined that it would need to work with the city of Minneapolis to create a residential organics collection program that will maximize recovery rates and also minimize costs. The study recommended targeting the recovery of organic waste produced from commercial businesses such as restaurants, grocery stores, and food processing facilities. Also, the study recommended targeting institutions such as schools, nursing homes and other large establishments that provide hot lunches.

The city of Minneapolis conducted a pilot organics collection program in Linden Hills in 2008. This pilot study focused on collecting organic materials from residents. However, the targeted materials for the pilot project did not include all the materials that could be used as feedstock for an AD facility. Organic materials that were NOT collected as part of the pilot study included:

- Diapers and pet feces
- Yard Waste (leaves and grass clippings)

At the time of the pilot study, they could not include yard waste due to state permitting and other legal issues, but the City hopes to include yard waste as part of residential organics collection in the future. Assuming Linden Hills is able to collect food waste, paper packaging and yard waste from residents, they estimated they would recover approximately 808 tons of organic material on an annual basis. These assumptions were based on collection records from the city of Minneapolis. The study acknowledged the extreme variability of volume based on the seasonality of yard waste.

The study also acknowledged the potential source of organic materials from commercial business and institutions. The Linden Hills study conservatively estimated that they could collect 122 tons of material on an annual basis from these types of generators.

3.1.4 Wayzata

The city of Wayzata conducted a pilot project for a curbside collection program among City residents for SSOM. The pilot project ran from April 2003 – June 2005.

During the pilot study, the organics material collected from residents included food scraps and non recyclable paper. Residents separated the acceptable organics materials from the rest of their garbage. Each resident was provided with a special sealable food container to keep in their kitchen to collect food scraps on a daily basis. Residents were also provided with a dedicated organics cart to keep and set out next to their regular garbage can.

Residents set out their organics cart next to their garbage cart for collection on a weekly basis. After separate collection of the SSOM, the material was taken to the Hennepin County Recycling Center and Transfer Station in Brooklyn Park. SSOM was tipped and inspected to ensure that non biodegradable contaminants were below threshold levels. After the material was inspected, it was transported by Hennepin County to the SSOM composting facility in Empire Township in Dakota County. The organics that Wayzata residents placed out on the curb was turned into compost, returned to the City and used in its community gardens.

During the pilot program, 70% of the households (1,200 total households) in the City participated at least once and a total of 189 tons of organic material were collected and composted. The amount of material collected weekly was typically between 1.5 to 2 tons. Weekly set out rates were between 42% and 48%. About 525 and 600 households set out each week. On an annual basis households are estimated to produce between 260 to 396 pounds per "participating" household per year. This is the equivalent of about 87 to 173 pounds per household served per year.

When the pilot project ended in 2005, the city of Wayzata added organics collection to the City's residential curbside collection program. Wayzata was the first city in the Twin Cities metro area to offer curbside collection of organics to all its residents.

To cover the additional cost associated with the organics collection program, i.e. adding curbside collection, transportation and disposal of organics; the City plans to increase garbage and recycling fees. As one means to help residents offset this additional cost, the City will be offering the option of every-other-week garbage collection A more detailed summary of the Wayzata pilot project is provided in Appendix B.

3.1.5 Summary of Curbside SSOM Programs

Table 3-2 displays the known curbside SSOM collection programs in Minnesota organized by County. This information was summarized from a variety of sources and reflects readily available data from published reports such as those summarized earlier in this section and personal communications with County staff.

Table 3-2 identifies 16 cities in and around the metro area that are conducting pilot SSOM curbside collection studies and/or have implemented the service city wide. The table also indicates whether the service was provided to all residents under contract or in the service area or under a "subscription" basis. Only four cities currently provide citywide, curbside SSOM collection services on an ongoing basis under contract (Loretto, St. Bonafacious, Wayzata and Hutchinson).

Four other cities are "citywide" but structured to collect SSOM curbside on a "subscription" basis (Medina, Minnetonka, Orono, and Medicine Lake). These are "open" MSW hauling communities whereby residents contract directly with their trash hauler for all collection services. In general, such subscription SSOM collection service is an option provided by a private hauler for an additional fee. Most often, the subscription services piggyback on the separate yard waste collection services and the two materials are commingled into the same cart and same compartment on the hauler's truck.

Table 3-2 Curbside SSOM Collection Programs in and around the Twin Cities Metropolitan Area[a, b, c,d]

City	Neighborhood	County	Pilot vs. City Wide	Timeframe	Contract vs. Subscription
Chanhassen, Chaska, Waconia, Watertown	Parts	Carver	Pilot	2007	Subscription
Burnsville ["phase one"]	N. River Hills	Dakota	Pilot	2002 - 2007	Subscription
Burnsville ["phase two"]	N. River Hills	Dakota	Pilot	2007 - 2008	Subscription
Loretto	City Wide	Hennepin	City Wide	Current service	Contract
St. Bonafacious	City Wide	Hennepin	City Wide	Current service	Contract
Edina	Morningside	Hennepin	Pilot	Current service	Subscription
Minneapolis	Linden Hills	Hennepin	Pilot	Current service	Contract
Medina	City Wide	Hennepin	City Wide	Current service	Subscription
Minnetonka	City Wide	Hennepin	City Wide	Current service	Subscription
Orono	City Wide	Hennepin	City Wide	Current service	Subscription
Medicine Lake	City Wide	Hennepin	City Wide	Current service	Subscription
Wayzata	City Wide	Hennepin	City Wide	Current service	Contract
Hutchinson	City Wide	McLoed	City Wide	Current service	Contract
Saint Paul	Highland	Ramsey	Pilot	2001	Contract

Sources:
(a) Madole, John C. *Linden Hills Power & Light Anaerobic Digester Feasibility Study*, June 2008.
(b) Eureka pilot study report: *A Comparative Analysis of Applied Recycling Collection Methods in Saint Paul.* May 2002.
(c) Personal communications with County staff.
(d) SWMCB Food Waste and Organics Report, Oct. 2007.

On a national basis, there are a number of other relevant case studies that address feasible means of supplying residential SSOM via curbside collection programs. However, only a few of these national and Metro Area programs report actual program performance in any form of standardized manner.

Four communitiesin the U.S. have reported data that allows for a calculation of comparable recovery rates in terms of pounds of SSOM recovered per household served per year. This is a more standard measure used with other curbside recycling program evaluations and is based on the actual tonnage divided by all households served rather than just the households participating. Thus factors such as participation rate and per household recovery of available food waste are considered into one comparable recovery rate ratio.

The four communities with curbside SSOM service reporting in this manner include San Francisco and Alameda County in California; and St. Paul and Wayzata in Minnesota. The range of calculated recovery rates ranges from 97 to 264 pounds of SSOM per household served per year. This wide range is indicative of the variance in program types and performance. The average recovery rate, 162 pounds per household per was used for preliminary estimates of potential SSOM recovery depending on the assumpton of service areas and corresponding household counts.

3.1.6 Commercial SSOM

For purposes of this study, “commercial” refers to those typically categorized as commercial, industrial and institutional. Some commercial sector industries such as restaurants, hotels, supermarkets, schools, hospitals and prisons produce a sizable amount of food waste. A portion of the food waste generated by the commercial sector is already being recovered and converted into a more valuable end use rather than landfilling. Examples of programs that benefit from food waste or excess food are food banks, farmers, the rendering industry and composting facilities. In 2007, approximately 510 tons of organics materials were collected from 50 schools and several businesses in Hennepin County. Additionally, 55 Ramsey County and 3 Washington County schools collected organic materials.[49]

A report titled, *Food Waste Recovery: AModel for Local Government Recycling and Waste Reduction* (June 2002)[50] discusses the food waste recovery programs for the commercial and residential sectors currently in place in three cities in California; San Francisco, Berkeley and Santa Cruz. This report provides a model for other local jurisdictions to help facilitate development of new food recovery programs. The following is a summary of current programs in California as described by the report.

The city of San Francisco contracts with a consulting firm to help manage the food recovery program among the various participating commercial businesses. Two different haulers offer food waste collection services to the commercial businesses in San Francisco. Both of the haulers deliver the food waste to the same composting facility that is permitted to compost all food materials, including meat and post consumer residuals. However, the two haulers have different collection requirements. One hauler requires the generators to separate their organics material from the rest of their waste. This hauler provides containers specifically for the organics and collects material from customers up to six times a week. The other hauler only requires that the generators do a decent job of recycling glass and cans. The remainder of the waste can all be disposed in one container. Because this hauler’s customer base is mostly restaurants and markets, the majority of the waste is organic. Generally the waste collected is within the acceptable contamination limits at the compost facility. Also mingling this contaminated waste with the clean waste from the other hauler at the compost site dilutes the effects of the contamination. These programs are funded through the rates charged to customers.

In addition to these two haulers collecting food waste from commercial businesses, the San Francisco food bank collects edible food from 25 wholesalers at the San Francisco Produce Terminal. This food is used to feed thousands of people in the City on a daily basis. The food from the wholesalers that is no longer edible is collected by a local farmer that uses it to supplement his livestock feed.

The city of Berkeley has been operating a pilot organics collection program to its residents and commercial businesses since 1997. Berkeley currently has a municipal collection system in place and uses two city employees to actually perform food waste collection services among the participating commercial businesses. The customer base includes super markets, restaurants, bakeries, coffee shops, juice bars and diners. To establish a client base, Berkeley made personal visits to some of the largest food generating businesses. The food waste collected includes and all food scraps except red meat. Customers may also dispose of flowers and waxed cardboard boxes with their food waste material. Berkeley supplies the commercial customers with containers and collects material up to six times per week. The food waste collected is composted and portions are returned for use in community gardens. This program is also funded by collection fees collected from residents and businesses.

The city of Santa Cruz has started food composting programs at various schools, camps and businesses. Instead of collecting and composting food waste, this material is composted on site at the facilities using verma-composting (worms) or other on-site composting methods. Food waste generators have also been provided a list of end users (farmers, food banks, etc.) to establish relationships as they see fit. For example, Coast Produce supplies the local food bank with edible leftover fruits and vegetables. Excess food waste remaining after this donation is delivered to a worm farm as a feedstock for the worms.

In addition to the commercial food waste collection described above, three colleges in California, U.C. Davis, U.C. Berkeley and San Francisco State, and a number of elementary schools in California use either verma-composting or in-vessel composting systems to manage their cafeteria wastes.

Table 3-3 is from the CIWMB *Food Waste Recover Model Report* and lists various food-related industries and the portion of waste disposed that is food. The table also shows an estimate of the volume of food produced per employee per year for the various industries. The first column in Table 3-3 is the Standard Industrial Classification (SIC) code that is used to identify the specific industry.

Table 3-3 Commercial Food Waste Generators

SIC Code	Industry	Food (% of Waste Disposed)	Food Disposed (tons/employee/yr)
54	Retail Trade – Food Stores	45.1%	1.25
58	Retail Trade – Restaurants	43.9%	1.10
51	Wholesale Trade – Nondurable Goods	29.6%	0.40
82	Services – Education	24.2%	0.13
20	Manufacturing. – Food & Kindred Products	23.0%	0.41
70	Services – Hotels/Lodging	15.3%	0.18
(Varies)	Public Administration	11.4%	0.05
80	Services – Medical/Health	7.0%	0.04

This data is based on sorting garbage samples from individual businesses in Southern California. Material recycled is not included. Figures may not reflect the composition at a particular business or in a particular area. Source: Business Group Waste compositions, Solid Waste Characterization Database, CIWMB www.ciwmb.ca.gov/WasteChar/BizGrpCp.asp (February 2000)

3.2 Estimates of SSOM as Disposed as Solid Waste

A key element in the feasibility of this project is the amount and composition of SSOM that may potentially be available as a supply feedstock for the AD facility. Two different estimates were calculated: (1) the amount of SSOM "as disposed" in mixed MSW facilities (including both landfills and resource recovery plants); and (2) the amount of eligible material that could potentially be recovered given adequate investments in new SSOM collection systems.

The Environmental Protection Agency (EPA) reports that food waste comprises 12.4 percent of MSW generated and yard waste comprises 12.9 percent as generated on a national basis[51].

3.2.1 Amount of Total MSW Tons Disposed

According to the historical county recycling reports known as "SCORE" data, the six SWMCB counties (Anoka, Carver, Dakota, Hennepin, Ramsey and Washington) disposed (landfilled and processed) on an average of 1,950,000 tons per year of MSW over the past five years.[52, 53] Data provided by the MPCA shows 130,821 tons of MSW disposed (landfilled and processed) in Wright and Scott counties in 2007.[54] Therefore, it is estimated that these eight metro counties dispose of over 2,000,000 tons of MSW on an annual basis. It is important to note that these tonnages include waste from both "commercial" and residential generators. (For the purposes of this project, "commercial" refers to industrial, institutional and commercial generators.) This project also assumes that multi-family housing units (e.g., buildings with five or more units per structure) are considered as "commercial" accounts and not residential.

Few studies have been completed to determine each sector's residential versus commercial relative contribution to the MSW tons in the metro area. The statewide MSW composition study (2000) estimated the percentage of disposed MSW from residential generators versus commercial generators.[55] The research estimated approximately 47.5% of disposed MSW is from commercial generators and 52.5% of disposed MSW is from residential generators. These percentages were used in this AD feasibility study to estimate the total MSW tons as disposed from residential and commercial sources.

3.2.2 Composition

The SWMCB *2007 Food Waste and Organics Report* included the information in Table 3-4 as it relates to the composition of disposed MSW in the metro area.

Table 3-4 Relative Composition of SSOM and Yard Waste (+ Smaller Wood Waste; % of MSW as Disposed)

Material Type	Residential	Commercial
Source Separated Organic Material	23.1%	20.2%
Yard Waste (+ smaller wood waste)	4.3%	1.3%
TOTAL	**27.4%**	**21.5%**

The yard waste percentages above include grass, leaves, and smaller woody material. Note Minnesota law prohibits the disposal of yard waste mixed with MSW (Minnesota Statute 115A.931). Yet some yard waste still is collected with regular trash and ends up at landfills and MSW processing facilities. These composition percentages were applied to the residential and commercial tonnages to estimate the amount of SSOM and yard waste as disposed in the metro area.

3.2.3 Amounts of SSOM and Yard Waste as Disposed

Based on the MSW tonnage and composition estimates from Table 3-4, the amounts of residential and commercial SSOM and yard waste were calculated for the eight county metro area. Table 3-5 summarizes the estimated tonnage as disposed

Table 3-5 Estimated Amounts of SSOM and Yard Waste (+ Smaller Wood Waste) As Disposed by Sector Type (Tons per year)

Material Type	Residential (tons)	Commercial (tons)	TOTAL (tons)
Source Separated Organic Material	189,000	200,000	389,000
Yard Waste (+Smaller Wood Waste)	47,000	13,000	60,000
TOTAL	236,000	213,000	449,000

3.2.4 Seasonal Variation

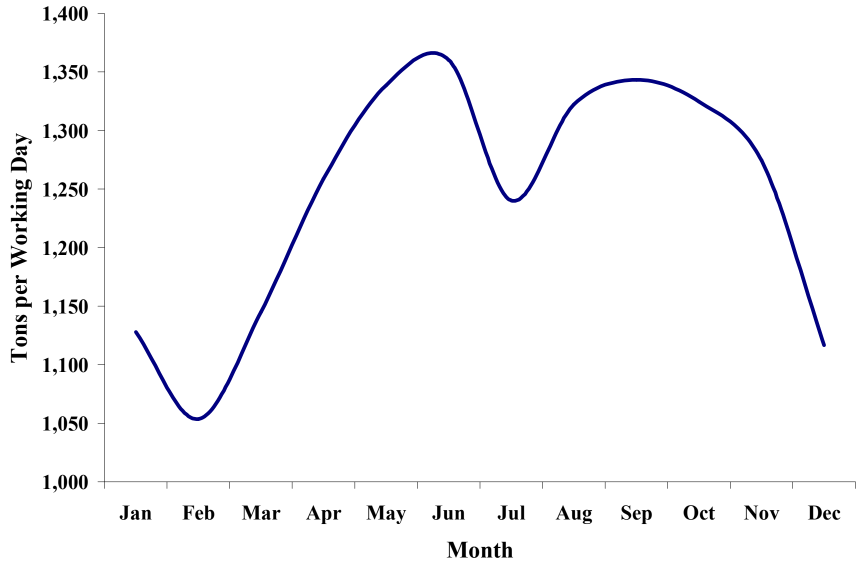
The seasonal variation of mixed MSW, SSOM, yard waste and other organic materials that may serve as feedstock for the AD facility will be a critical design element. If yard waste (including smaller wood waste) is a key supply feedstock material, the facility will need to accommodate the relatively extreme variability. Yard waste volumes range from very heavy volumes including peaks in October due to leaf collections, during the growing season (approximately May through September) to no yard waste during the winter months (approximately December through March).

The seasonal variation of SSOM from residences will be much less extreme than yard waste seasonality. While the data is very limited, one can expect that food waste generation will be more constant regardless of month or season.

SSOM from schools will be generated during the regular school year (approximately September through June). Notable exceptions to this general rule will be the schools that operate on a year-round, 12-month calendar instead of the traditional nine-month school calendar. This seasonal variability from schools, however, is expected to be mitigated by the assumption that these materials will be targeted for food-to-livestock recovery programs and therefore not a preferred feedstock for the AD facility.

Preliminary seasonal MSW and yard waste data was examined as a part of this study. Figure 3-1 displays the average monthly tons per working day of MSW totals as reported delivered to the Ramsey/Washington County Resource Recovery Facility (R/W RRF) at Newport.

Figure 3-1 Average Monthly MSW Delivered to the R/W RRF at Newport (Tons Per Working Day – Average for Years 2007 – 2008)



As mentioned in Section 3.2.2. despite the fact that yard waste is prohibited by state law from disposal with the MSW, incidental amounts still remain in MSW as disposed. Residents are able to “sneak in” bags of yard waste. Thus, the seasonal “peaks” shown in Figure 3-1 may at least be partially attributed to yard waste spikes in May and around September.

Figure 3-2 displays the total, average monthly tons of MSW per working day as managed by the Hennepin County MSW management system. This figure is derived from the sum total of MSW for all facilities receiving MSW, including the Brooklyn Park Transfer Station, the Flying Cloud Transfer Station, direct loads delivered to the Hennepin Energy Recovery Center (HERC), and material transferred from the Elk River Resource Recovery Facility. Again, this graph of seasonal volumes shows peaks around May and September.

Figure 3-2 Average Monthly MSW Delivered to the Hennepin County System of Facilities (Tons Per Working Day – Average for Years 2007 + 2008)

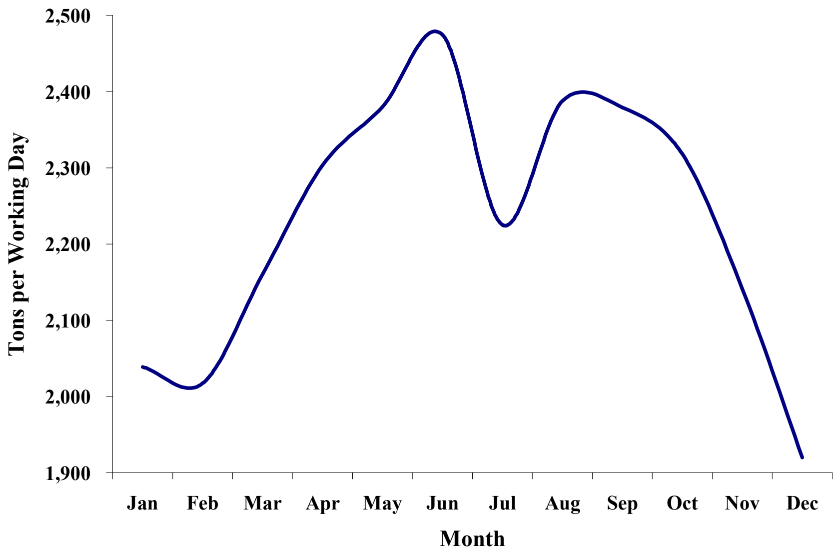


Figure 3-3 displays the seasonal variations in yard waste for the Ramsey County composting system. The Ramsey County yard waste program is a drop-off for County residents only (i.e., no contractors or non-County residents). This data provided by County staff was purposely grouped into three seasons of the year: spring (April through May); summer (June through September); and fall (October through November) because of the distinct differences in types of yard waste delivered within each season. Residents deliver leaves during the spring and fall seasons and primarily grass during the summer months. This data is for yard waste only including grass and leaves, and excludes brush. The same data set indicates that grass and leaves comprise about 47 percent of the total volume of residential yard waste delivered to these sites and brush is about 53 percent by volume (cubic yards).

Figure 3-3 Average Monthly Yard Waste Transferred from Ramsey County Compost Facilities (Percent of Annual Total – Average for Years 1996 to 2008)

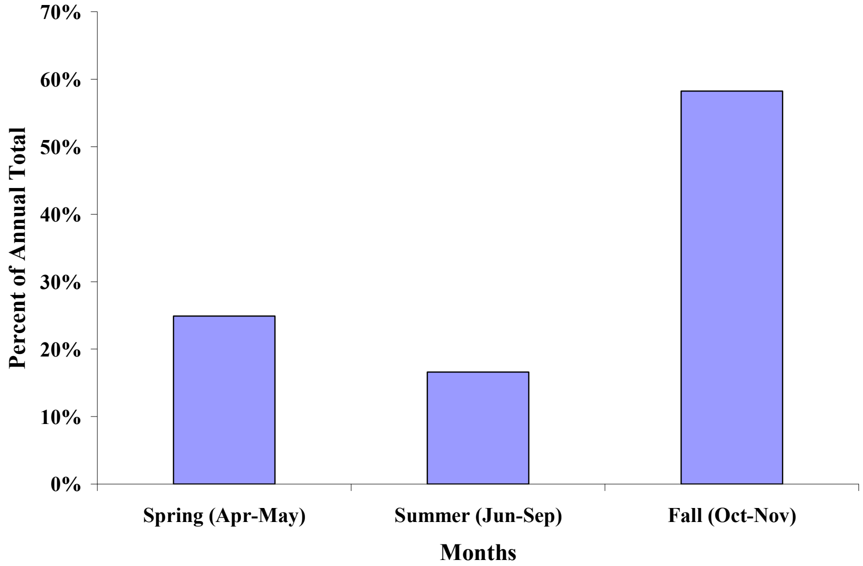
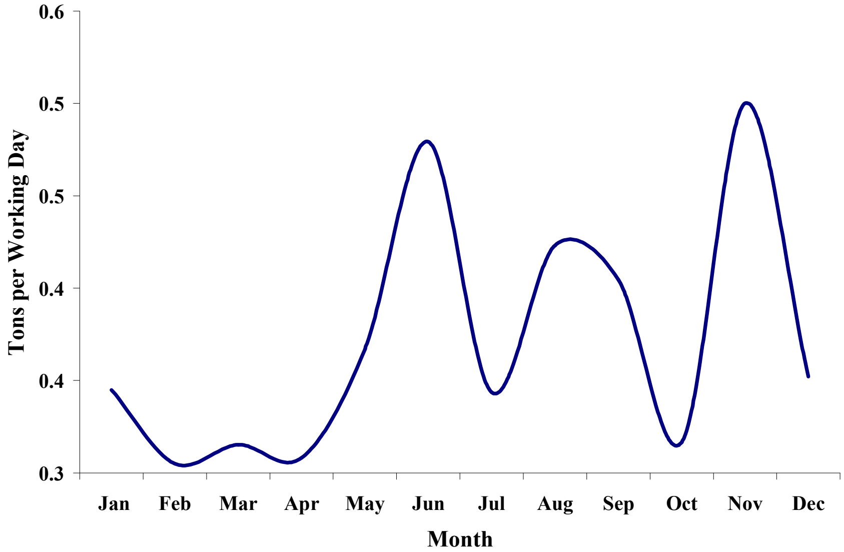


Figure 3-4 displays the seasonal nature of SSOM according to the Wayzata program reports. This data is for the period from April 2003 through December 2005 only. It is important to note that yard waste is not included in this data. Yet there are three visible "peaks" around May, August and November. This data is very limited and should be updated and supplemented with other sources.

Figure 3-4 City of Wayzata Program - Average Monthly SSOM Collected (Tons Per Working Day – Average for April 2003 through December 2005)



3.3 Other Types and Sources of Organic Material

The focus of this study was on using SSOM that would have otherwise been disposed of as solid waste for feedstock for the AD facility. But there are a large variety of other types and sources of organic material each with their own relative feasibility of supplementing SSOM as the primary supply for the AD facility. These include, but are not limited to, the following other types and alternative sources of organic waste materials.

3.3.1 Food Waste as Disposed into the WWT Sewers

Some residents and commercial establishments (restaurants, institutions, etc.) dispose of limited amounts of food waste via municipal wastewater treatment (WWT) systems. In the seven-county Metropolitan Area this food waste is placed into the Metropolitan Council Environmental Services (MCES) municipal WWT system, known as the Metropolitan Disposal System. Such food waste is either sewered directly or first "processed" via garbage disposal "grinders" installed at the generator's site.

MCES has promulgated its MCES waste discharge rules for the Metropolitan Disposal System intended to protect human health, human safety and the environment based on authority from State and Federal laws and regulations. Section 406 of these rules identifies a series of prohibited waste discharges and subsection 406.21 specifically addresses the sewering of food waste:

406 (No person shall discharge into public sewers…)

406.21 “Garbage, discarded material and grease from non-domestic sources which results from handling, processing, storage, preparation, serving and consumption of food, when the effect of such disposal into public sewers is the avoidance of off-site solid waste disposal; provided however, that this section does not prohibit sink-fed garbage disposal units used for incidental food waste disposal.”

Thus, MCES allows the installation and use of residential and small institutional garbage disposals and other sewering of food waste. However, MCES prohibits the use of large commercial grinders installed with the intent of avoiding regular, ongoing disposal of bulk food waste as solid waste. Such large-scale, bulk grinders of food waste have the potential to cause obstruction, interference and organic loading problems within MCES’ Metropolitan WWT Disposal System. MCES has taken enforcement actions against such larger, commercial establishments using such bulk food waste grinders.

MCES does not have readily available data about the amount or quantity of food waste that is currently being sewered into its Metropolitan WWT Disposal System. At this time, there are no problems with management of incidental food waste in the MCES system. There are limited advantages of incidental food waste disposal in the MCES system to some of the biological treatment systems utilized by MCES. Nonetheless, MCES staff may be willing to discuss alternative policy options with County and State solid waste management staff.

3.3.2 Food Waste from Mixed MSW

Mixed MSW recovery facilities could be designed to remove the fraction of targeted food waste and other organic material utilizing a “front-end” separation system (e.g., screens, sorting conveyor lines, etc.). This option was not considered within the scope of this study in part because of the added capital costs and greater potential for contamination. Also, the Metro Counties have reduced authority and influence over the mixed MSW resource recovery facility design and operation. If adding such a “front end” food waste separation system is economically feasible, the facility contractors may be willing to consider such investments.

3.3.3 Residuals from Mixed MSW RDF Resource Recovery Facilities

The Ramsey/Washington Counties’ Resource Recovery Facility in Newport and the Anoka County Refuse Derived Fuel (RDF) facility in Elk River both produce a residual material. This RDF residual is largely heavy articles and other smaller particles passing through the screens (i.e., screening “unders”) and the heavier fraction from air classifiers. This RDF by-product material has been studied to determine feasibility of composting, but not necessarily AD. At this preliminary stage, this RDF residual could be tested for its methane generation potential to see if further evaluation may be appropriate.

3.3.4 Other Organic Waste Streams

There are a number of secondary organic waste streams that were not fully analyzed for purposes of this AD feasibility study. These additional materials may provide some additional value in cumulative total, but alone may not be available in significant enough quality or quality to make a difference in the minimum facility supply requirements.

These secondary organic waste streams include materials such as:

- Agricultural crop residues (including silage).
- Biosolids from municipal WWT plants (see Section 3.3.4.1.).
- Feedlot manures.
- Grease waste (such as material already recovered by rendering plants in the Twin Cities area).
- Lake weeds.
- Livestock carcasses and parts from slaughterhouse waste.
- Paper mill sludge.
- Septage and other liquid waste (see Section 3.3.4.2.).
- Whey.

3.3.4.1 Biosolids from Municipal WWT Plants

Biosolids from municipal WWT plants include residual sludge byproducts. There are two forms that MCES currently produces. The anaerobic digester sludge (e.g., from MCES' Empire WWT Plant) is currently land applied as part of a specified recovery program. The dried, pelletized sludge (e.g., from MCES' Blue Lake WWT Plant) is sold to a private vendor as a "Class A" fertilizer supplement.

3.3.4.2 Septage and Other Liquid Waste

A variety of liquid wastes are trucked to various receiving stations owned and operated by the MCES as part of the Metropolitan Disposal System service. For example, septage is hauled from private wastewater treatment systems. These private systems may include individual sewage treatment systems (ISTS) and community or cluster systems.

Liquid wastes from other MCES WWT plants include primary or secondary effluent. These wastes from smaller, more rural WWT plants are trucked to MCES's central Metropolitan Disposal System (based in St. Paul). Effluent from MCES' Cottage Grove, Hastings, and Stillwater WWT plants are trucked in this way.

Other hauled liquid wastes include material from holding tanks, portable toilet waste, landfill leachate, commercial wastes and other approved industrial waste loads.

The preliminary technical and economic review of septage and these other liquid wastes indicate that these would not be suitable feedstocks for the proposed AD facility. These liquid wastes will be high in water content. Some may have variable chemical quality. Plus, the nutrient content may cause problems with the digester. Thus, the additional costs of receiving, storing (e.g., holding tanks), handling and blending of these other liquid waste materials is cost prohibitive and was not considered in the feasibility study..

3.4 Securing a Supply of SSOM in the Eight County Metro Area to Support AD

The scope of this study was to look at the feasibility of an AD facility that could handle approximately 100,000 tons per year of SSOM.

The policy framework for developing this new supply is based on the concept of continuing to encourage the existing food waste reduction and recovery programs and initiatives.

This amount of feedstock will require a comprehensive supply development plan that includes several pro-active strategies for developing a reliable supply of SSOM:

- Residential curbside collection options
- Commercial collection options
- Economics and financing
- Legal and political barriers
- Policy initiatives

3.4.1 Residential Curbside Collection Options

One primary supply option under consideration is a major, new expansion of residential curbside collection. The assumed SSOM collection concept plan is for the following phased sequence for an implementation roll-out:

1. Separate collection of SSOM within cities with contract recycling.
2. "Co-collected" SSOM, separate from yard waste collections.

   [And/or "co-collected" SSOM + MSW or SSOM + recyclables]
3. "Commingled" SSOM + yard waste

This sequence follows the generalized SSOM experience of several cities in the greater Twin Cities metropolitan area (e.g., Burnsville, St. Paul / Eureka, Minneapolis / Linden Hills, and Wayzata). As a general rule, initial SSOM pilot collections start at the easiest collection structure (i.e., separate collection, no co-collection) and evolve towards the more comprehensive collection designs (i.e., "commingled" SSOM + yard waste). This generic sequence is driven in part by economics and in part by policy. The easier separate collection programs can be more costly if separate carts, trucks and routes are dedicated to SSOM only. The more comprehensive "commingled" SSOM + yard waste design is more complex, has more technical and policy barriers, but is also more cost-effective if the same yard waste collection infrastructure (i.e., carts and trucks) can be utilized for SSOM.

Commingled SSOM + yard waste collection and composting facilities are still at a very young stage of development in the Twin Cities metropolitan area. New legislation was passed in the 2008 session that helped clear some of the legal barriers to commingled collection and composting of SSOM + yard waste. Commingled collection of SSOM + yard waste can be considered in the “infancy stage” of development with only a few pilots and some limited private subscription service offered by a few haulers in Hennepin County.

Comparatively, separate yard waste collection and composting programs have been implemented for over two decades and can be characterized as in a “very mature stage” of development. The original disposal ban of yard waste was passed by the Legislature in 1988. “Composting of yard waste and food waste” was added to the “Legislative Declaration of Policy; Purposes” (Minn. Statute 115A.02(b) also sometimes referred to as the Minnesota waste management “hierarchy”) in the 1992 Legislative session. The composting of yard waste and food waste management practice was slotted as a new number three (3) position in the hierarchy after (1) waste reduction / reuse and (2) recycling, but before (4) resource recovery through mixed MSW composting or incineration and (5) land disposal. Also, the 1995 Legislature amended Minn. Statute 115A.551 to provide for a means for counties to get SCORE recycling “credits” for specified yard waste program initiatives (e.g., education, drop-off collection services) that are likely to reduce the amount of yard waste generated and increase on-site composting.

Just recently, the 2009 Legislature passed a ban on non-biodegradable plastic bags used for metropolitan area yard waste collection or source separated compostible materials (SSCM) collection (2009 Laws, Chapter 37, HF2123). This bill states:

> “Section 44. Minnesota Statutes 2008, section 115A.931, is amended to read:
> **115A.931 YARD WASTE PROHIBITION.**
>
> (a) Except as authorized by the agency, in the metropolitan area after January 1, 1990, and outside the metropolitan area after January 1, 1992, a person may not place yard waste:
>
> > (1) in mixed municipal solid waste;
> > (2) in a disposal facility; or
> > (3) in a resource recovery facility except for the purposes of reuse, composting, or co-composting.
>
> (b) [Renumbered 115A.03, subdivision 38]
>
> <u>(c) On or after January 1, 2010, a person may not place yard waste or source-separated compostable materials generated in a metropolitan county in a plastic bag delivered to a transfer station or compost facility unless the bag meets all the specifications in ASTM Standard Specification for Compostable Plastics (D6400). For purposes of this paragraph, "metropolitan county" has the meaning given in section 473.121, subdivision 4, and "ASTM" has the meaning given in section 296A.01, subdivision 6.</u>
>
> <u>(d) A person who immediately empties a plastic bag containing yard waste or source-separated compostable materials delivered to a transfer station or compost facility and removes the plastic bag from the transfer station or compost facility is exempt from paragraph (c).</u>

(e) Residents of a city of the first class that currently contracts for the collection of yard waste are exempt from paragraph (c) until January 1, 2013, if, by that date, the city implements a citywide source-separated compostable materials collection program using durable carts."

Thus, the state legislative policy framework for yard waste collection and composting was established at a very early stage similar to the timeframe of many curbside recycling programs. Subsequent county policies and programs for yard waste collection and composting services were established over the past 20 years. In many communities in Minnesota, the local county or city provides drop-off sites for specified, residential yard waste materials during the growing season (April through November). In a number of cities, source separate yard waste is collected "curbside" (or in the alley) in a dedicated truck as part of a bundled contract with MSW collection. Many private haulers offer similar separate yard waste collection as a subscription "option" within open hauling cities where the homeowner contracts for their own trash collection.

These mature separate collection and processing systems (residential yard waste collection / composting infrastructure and the parallel curbside recycling services) have provided precedents for SSOM and SSCM. Given the early indications from pilots and initial citywide programs, the collection and recovery of organics may be the next major frontier of new residential recycling services to come on line. Development of a full scale collection infrastructure will likely follow the development of an additional processing capacity. Technical specifications for resident sorting and food waste preparation requirements will continue to evolve over time.

The following types of co-collection design options are possible. SSOM can be theoretically collected in a separate compartment on the truck with:

- Yard waste;
- Recyclables; and/or
- Mixed MSW

SSOM could be collected in a separate compartment on the truck with two of more of the above commodities similar to San Francisco's program where commingled SSOM and yard waste is co-collected with recyclables and MSW (i.e., three compartments on the truck).

One of the incentives behind new SSOM programs is the potential for such a new collection service to reduce the resident's MSW. If a resident is able to switch to a smaller MSW cart, or, where allowed, switch to every-other-week MSW collection service, the added costs of separate SSOM collection may be partially offset by the reduced MSW collection fees. More analysis may be needed of existing MSW, yard waste, recycling and SSOM fees to more fully understand the current competitive market for prices for these services. In many cases, contract "bundling" of multiple services by the same hauler may help increase efficiencies and allow a hauler to be more competitive. For example, providing bundled MSW, yard waste, and SSOM collection services as part of one overall account may help provide for reduced overhead and improved routing and fleeting efficiencies.

Several private haulers in the region are currently providing subscription services for SSOM, usually as a commingled option if the customer already has separate yard waste service.[56]

To the extent possible, standardized public education designs will help maximize the cost-effectiveness of any multi-county or regional campaign that may be considered. Even such details as standardization of cart color will help "brand" new SSOM collection (e.g., similar to San Francisco's color coded, three-cart design[57]).

3.4.2 Commercial Collection Options

Commercial SSOM collection options will follow a more standardized approach for collection system design similar to mixed MSW collection systems. These could include (but are not limited to):

- Carts
- Dumpsters
- Roll-off boxes
- Fully enclosed compactor boxes

Like mixed MSW collections, the new collection SSOM system design should be tailored to the needs of each specific establishment.

There are a number of food processing manufacturers and produce operations in the great Twin Cities Metropolitan Area that may not yet have their organic waste recovered. A survey of these food processors was beyond the scope of this feasibility study but could be conducted as part of a next phase of research and facility planning.

3.4.3 Quality/Quantity

The quantity of SSOM that may be available to an AD facility was estimated using two methods. The first was to examine the total amount of SSOM as disposed (as described earlier) and then estimate an approximate recovery rate. This analysis used a range of theoretical recovery rates of 10%, 15% and 25%. (See Table 3-6) These levels of recovery indicate that a sum total from both residential and commercial sources of SSOM could result in a collection tonnage from 38,900 TPY (at the 10% recovery level) to 112,300 TPY (at the 25% recovery level).

The second method of calculating residential SSOM recovery levels was to use an average recovery rate of 162 pounds per household served per year and apply it to various service level ranges. The eight county region has about 854,000 eligible households that could receive curbside service. If corresponding service levels are assumed, the residential recovery amounts would be from 6,900 TPY (at 10% of the regional households served) to 17,300 TPY (at 25% of the total regional households served). Of course, higher per household recovery rates and higher service levels will increase these estimates. But even if all households in the eight county region were served, about 69,200 TPY of residential SSOM could be theoretically recovered (at the 162 pounds per household served recovery rate).

Table 3-6 Theoretical Recovery Rates of SSOM and Yard Waste (+Smaller Wood Waste)

(Tons per year)

Material Type	Total as Disposed [a]	Theoretical Recovery Rates 10%	15%	25%
Source Separated Organic Material	389,000	38,900	58,400	97,300
Yard Waste + Smaller Wood Waste	60,000	6,000	9,000	15,000
TOTAL	**449,000**	**44,900**	**67,400**	**112,300**

Notes:
(a) Total as disposed from Table 3-5.

3.4.4 Opportunities and Constraints

There are a number of key opportunities and constraints relative to securing an adequate supply for this AD facility. There is a limited amount of SSOM that can be reasonably expected to be recovered from the residential and commercial sectors. A fraction of the SSOM available is already recovered through existing programs (e.g., food waste to livestock, etc.). The volumes of SSOM remaining in the waste stream will require new investments in both the collection and processing systems.

There is significant interest in the Twin Cities area in the separate collection and recovery of food waste. In the past, the primary processing technology considered was aerobic composting. Several private facilities are currently in operation in and near the Twin Cities region that compost SSOM. While their current cumulative capacity is limited to about 23,000 tons per year, this technology has significant expansion potential of its own. The *Food Waste and Organics Report* stated that with modest investments, these SSOM composting facilities could be expanded to another 23,500 tons per year.

3.4.4.1 Economics and Financing

The economics of the supply system are dependent on the design assumptions such as whether the SSOM is commingled with yard waste or collected separately and not commingled with yard waste. Separate collection of SSOM may likely necessitate additional capital investments of SSOM – dedicated carts. Also, depending on the specific collection system, separate collection of SSOM will require modification to trucks (e.g., split body for co-collection), or separate, dedicated SSOM trucks and SSOM routes.

Past experience from existing programs has demonstrated that residents are willing to participate in SSOM curbside collection. Some residents may be willing to pay more for increased recycling services, but the potential market share of such residential customers is sensitive to the amount of the increased price. This price sensitivity is apparent in the response to subscription based SSOM collection programs offered by several haulers in Hennepin County.

Multiple forms of financing sources could be considered to help fund the added costs of the new collection services, including (but not limited to):

- Direct charge to residents similar to current recycling fees on private hauler bill, municipal utility bills (e.g., water, sewer, solid waste/recycling), or real estate tax statements.
- Dedicated recycling funds including credits from revenue sharing;
- General fund appropriations.
- County and State grants (e.g., SCORE funds).

A principal theory in the overall economics is that waste generators participating in SSOM programs will be able to save on the costs of MSW collection service. If generators "recycle" their SSOM, residents and commercial establishment should be able to elect for a lower level of MSW service. For example, residents could down size their MSW cart or, if allowed, switch to an optional "every-other-week" (EOW) schedule for MSW service. Commercial establishments could down size their MSW dumpster or other container (e.g., compactor box) and/or reduce the number of MSW "pulls" per week.

This broader concept of integrating MSW and recycling services is sometimes referred to as "resource management". Resource management approaches the planning delivery of overall solid waste/recycling services in a more comprehensive fashion that capitalizes on the integration and optimization of three or more separate collection systems as an integrated whole rather than as competing elements. Resource management is based on the precept that the waste generator will be able to realize direct and significant cost savings in trash services as new recycling and waste reduction practices are implemented.

3.4.4.2 Legal and Political Considerations

In 1991 the Minnesota legislature explicitly added "composting of yard waste and food waste" to the waste management hierarchy. (See earlier discussion in section 3.4.1.). Part of the intent was to legally define SSCM as a recoverable commodity and begin to further define the waste hierarchy to give SSCM a higher, preferred status over composting of mixed MSW.

In the 2008 Minnesota legislative session, the definitions of MSW and Source Separated Compostable Material (SSCM) were changed (2008 Session laws, Chapter 357. This relevant section of the bill stated:

> "Section 32. Minnesota Statutes 2006, section 115A.03, subdivision 21, is amended to read:
>
> > Subdivision 21. **Mixed municipal solid waste.** (a) "Mixed municipal solid waste" means garbage, refuse, and other solid waste from residential, commercial, industrial, and community activities that the generator of the waste aggregates for collection, except as provided in paragraph (b).

(b) Mixed municipal solid waste does not include auto hulks, street sweepings, ash, construction debris, mining waste, sludges, tree and agricultural wastes, tires, lead acid batteries, motor and vehicle fluids and filters, and other materials collected, processed, and disposed of as separate waste streams~~, but does include source-separated compostable materials~~."

"Section 33. Minnesota Statutes 2006, section 115A.03, subdivision 32a, is amended to read:

Subdivision 32a. Source-separated compostable **materials.** "Source-separated compostable materials" means ~~mixed municipal solid~~ waste materials that:

(1) ~~is~~ are separated at the source by waste generators for the purpose of preparing ~~it~~ them for use as compost;

(2) ~~is~~ are collected separately from ~~other~~ mixed municipal solid ~~wastes~~ waste, and are governed by the licensing provisions of section 115A.93;

(3) ~~is~~ are comprised of food wastes, fish and animal waste, plant materials, diapers, sanitary products, and paper that is not recyclable because the commissioner has determined that no other person is willing to accept the paper for recycling; ~~and~~

(4) ~~is~~ are delivered to a facility to undergo controlled microbial degradation to yield a humus-like product meeting the agency's class I or class II, or equivalent, compost standards and where process residues do not exceed 15 percent by weight of the total material delivered to the facility; and

(5) may be delivered to a transfer station, mixed municipal solid waste processing facility, or recycling facility only for the purposes of composting or transfer to a composting facility, unless the commissioner determines that no other person is willing to accept the materials."

Part of the intent of the 2008 legislative change was to remove a legal barrier for SSCM to be defined as a recovered commodity separate and distinct from mixed MSW. Prior to this legislation, SSCM was defined as part of MSW. Therefore, facilities that recycle SSCM into compost were previously required to be licensed as MSW composting facilities. Also, given that yard waste is prohibited from mixed MSW, haulers were not allowed to commingle SSCM with yard waste. One hope of the 2008 bill was to reduce the cost and other legal barriers for source separated materials composting.

3.4.4.3 Policy Initiatives

There are a number of policy questions to be addressed to formulate clearer assumptions for further supply analyses.

Ramsey and Washington Counties, together with the SWMCB and MPCA, have been working very proactively to define and implement a food waste hierarchy as discussed in earlier sections. This food waste hierarchy should be further refined and then reaffirmed. For example, centralized recovery of SSOM at a composting or AD facility could complement other food waste reduction and recovery strategies (e.g., food to people charity programs, backyard compost bin distribution programs; food-to-pigs programs at schools; other food wasteto livestock feed manufacturing processes; etc.). It is assumed for this feasibility study that these other strategies and public investments will continue into the future.

The region's overall food waste management infrastructure is currently more diverse, with more private service providers, within these other SSOM and yard waste strategies (e.g., reuse, recycling, and yard waste composting). The region is lacking in adequate capacity for centralized, larger-scale SSOM processing facilities such as composting operations or the proposed AD facility. This lack of adequate centralized SSOM processing capacity has been the major barrier to further development of new and expanded SSOM collection programs.

As planning for new SSOM collection services continues, all SWMCB Counties and other stakeholders will likely continue to discuss the best collection system design. A central issue is whether to commingle SSOM with yard waste or co-collect SSOM. Co-collection involves additional expense in carts, modified or new trucks, and separate receiving bunkers for separate SSOM and yard waste. Commingling of SSOM with yard waste has the disadvantage of a highly seasonal supply of yard waste. One option that could be considered is the subsidizing of carts for residents to be used for commingling household SSOM together with or separate from yard waste.

Ramsey County, Washington County, SWMCB, and MPCA solid waste staff should meet with MCES staff to discuss alternative policy options affecting the sewering of incidental food waste. One policy option is a ban on all new garbage disposals (phased in over time once an adequate and preferred food waste collection and recovery system is in place). Another policy option is to develop a collaborative approach for a technical assistance and outreach program. One of the targets for such a program could include the food processing companies and institutions that generate a large volume of food waste. Some of these companies and institutions may still sewer incidental amounts of food waste as part of their MCES discharge permits.

4 Anaerobic Digestion Facility

The original intended approach to the AD facility for this feasibility study was to work with experienced system vendors to develop a facility description and related cost estimates. However, AD system vendors did not provide this type of information. Apparently, AD system vendors have not yet developed this capability for U.S. projects (similar to other waste processing system vendors for waste-to-energy/or recyclable processing).

In order to develop an AD facility description and cost estimates pertinent to this project, Foth developed the preliminary facility description and design assumptions provided in this section and the facility cost estimates provided in Section 6.

4.1 Process Flow and Scalability

Each of the AD system vendors identified previously have scalable plants available. The key issue is the scalability of supporting facilities. For example, the receiving area should be sized for the estimated maximum SSOM supply versus the initial or intermediate supply quantity.

The ideal plant would have scalable and redundant facilities. However, the scalability and redundancy will increase capital costs. One option is to size the initial plant mechanical and AD systems for the 10 year plan for SSOM deliveries. The receiving building and residuals storage area would be sized for the largest SSOM quantity anticipated. The 10 year size should provide enough capacity to allow for growth of SSOM without significant initial capital being invested. Furthermore, most plants have the capability of operating above rated capacity with little impact on biogas production. This is conducted by reducing the resident time of the material in the digester. Reducing the resident time in the digester will reduce biogas production per ton of material. However, more tons will be processed so the total biogas production remains steady, but the biogas production per pound is reduced.

The proposed plant design includes additional features that lend themselves to scalability. The receiving building includes 2 parallel receiving areas, each with 4 truck bays. Each of these receiving areas feeds parallel but separate classifying and shredding lines, including conveyors, bag breakers, trommel screens, and magnets/metals separators, with material that does not pass through the trommel screens being fed into a single shredder. The shredder can operate with any feedrate up to and exceeding the design basis; it has essentially 100% turndown capability, or it can be run batchwise. From the shredder, parallel “recycle” conveyors can return the shredded material back to one or both trommel in-feed conveyors.

Size-sorted materials are conveyed to one of two feed blending/hydrating tanks. Each has capacity for 8 hours at maximum design rate of 225 tons/day. Although the spill containment/support pads, pipes and power supply should be installed for both tanks, one tank can be installed initially, and used at as little as about 25-30% of design capacity. The second tank can be added as demand ramps up. Blended/hydrated feed is fed to the digester tanks one at a time for a specified period of time per day, in order to retain the minimum processing time in each digester. Although the proposed full-capacity system includes eight (8) digesters, digesters can be added two at a time as additional capacity is needed.

Even biogas conditioning equipment (CO_2 scrubber, condensers, hydrogen sulfide absorber, etc.) can be operated at reduced floor rates, either batch-wise or at lower flowrates. The scrubber, for instance, can have baffles installed to effectively reduce the cross-sectional flow area, the fans can be shieved or have dampers set to reduce flow.

Installing only half of much of the equipment will not cut the cost by half, but it will reduce the initial capital installation and operating costs.

4.2 Mass Balance

A key component of any AD facility is a steady supply of SSOM to support the process. Digesters work optimally when the organic material is uniform in size and consistency and is delivered to the digester at a uniform, consistent rate.

For the proposed digester, this may not always be the case due to operational limitations on collection of SSOM (not every day collection) and facility staffing (not operating 7 days per week). This non-uniform supply of SSOM will require the AD facility to either store material for uniform processing or require the AD process to accept material as SSOM is received. Since SSOM can be difficult to store in sufficient quantities for even short periods of time due to odor concerns, the facility would need to be designed to accept SSOM as it is received so that it can be processed. Therefore, the facility would have limited storage capability for the SSOM.

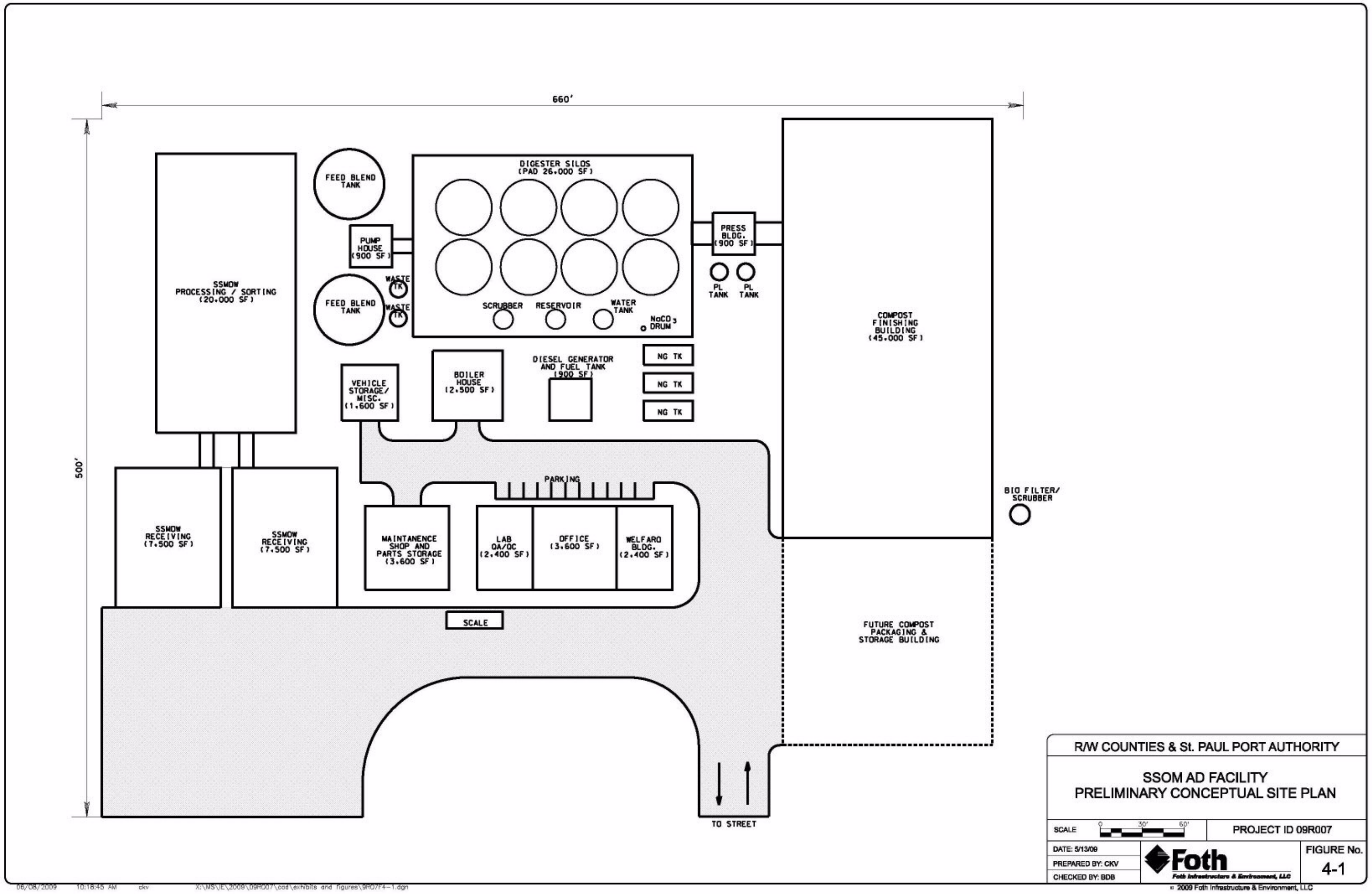
If not targeting leaves, the seasonality of the SSOM supply should not significantly impact AD facility operations or viability. It appears from previous studies, SSOM (i.e. food waste and non-recyclable paper) supply would be relatively uniform throughout the year. Seasonality of feedstock becomes more prevalent when SSOM is coupled with leaves. Since the AD process prefers a steady, uniform supply of material to effectively operate, the facility is not proposed to accept leaves or other yard debris. There are sufficient existing markets to effectively transform yard debris into compost.

The proposed plant is designed to accept 450 tons per day of SSOM, approximately 250 days per year. This would mean a total annual plant capacity of 112,500 tons per year. Based on the information in Section 3, it appears there is adequate feedstock available in the metro area to support the proposed plant. However, it is expected the plant would not initially reach full capacity until after SSOM collection matures.

4.3 Receiving SSOM

Receiving SSOM at an AD facility uses some of the same concepts as a transfer station or MSW processing facility. There needs to be a building with a tipping area for vehicles to unload the SSOM. Access to the building should be such that typical waste collection vehicles (front loaders, side loaders, rear loaders) can enter the building, dump the SSOM in designated areas, and exit the building in the most efficient method possible. Figure 4-1 provides a preliminary conceptual site plan.

Figure 4-1 Ramsey/Washington Counties & St. Paul Port Authority SSOM AD Facility Preliminary Conceptual Site Plan



A typical receiving area would consist of an area for trucks entering the facility to be staged; a scale area where incoming vehicles are weighed, and; a main receiving building where SSOM is unloaded. Given that some trucks may also carry other materials (for example, a truck containing SSOM and recyclables), it is anticipated an outbound scale may also be needed to capture the weight of SSOM delivered. The outbound scale would be an automated scale where drivers would enter their truck number into a remote station and receive their weigh ticket.

The receiving building is anticipated to be 15,000 square feet. The main tipping area used by the trucks delivering SSOM would be 10,000 square feet. Materials would be unloaded onto the floor or into a conveyor for processing. Given the nature of SSOM, unloading SSOM onto a conveyor or chute would be preferable to handling SSOM that is dumped on a floor that would need to be moved to the processing area.

Storage of SSOM would be limited to only times when plant or equipment shutdowns occur. Storing SSOM for more than a few days can cause significant odor issues. If the plant is anticipated to be out of service for more than two days, SSOM should be routed to other disposal or composting facilities.

Upon receiving SSOM, the material is conveyed into the plant using an infloor conveying system. This allows SSOM to be unloaded onto a conveyor and reduces handling.

4.4 Processing SSOM

Figure 4-2 shows a Processing Line Schematic. The process described in this preliminary design is representative of a dry-thermophilic type system described in Section 2. Once in the plant, the SSOM is screened to provide uniform particle size to enter the AD process. Oversized materials are shredded and rescreened to limit the amount of rejected materials.

Figure 4-2 SSOM AD Facility Processing Line Schematic

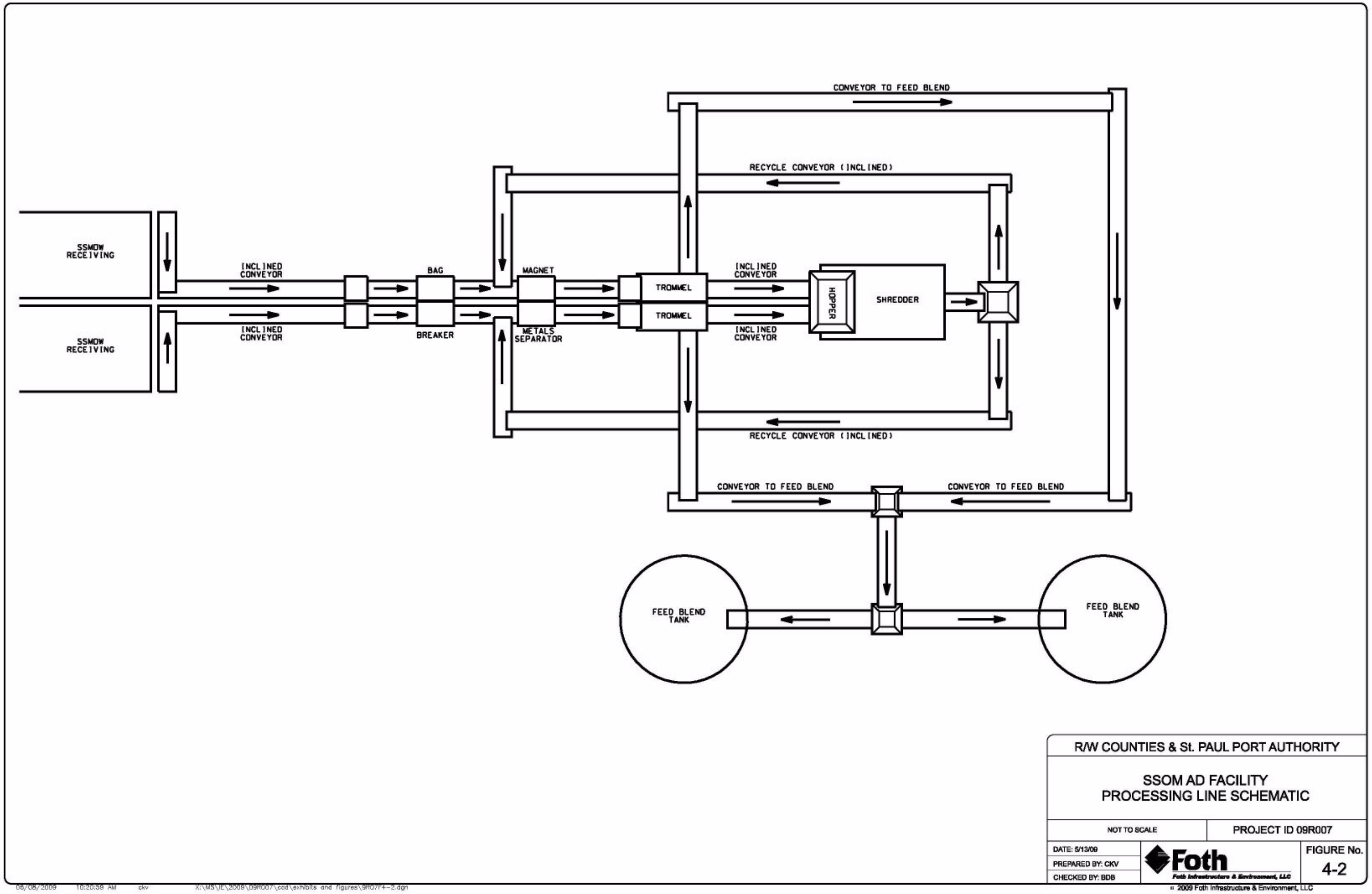
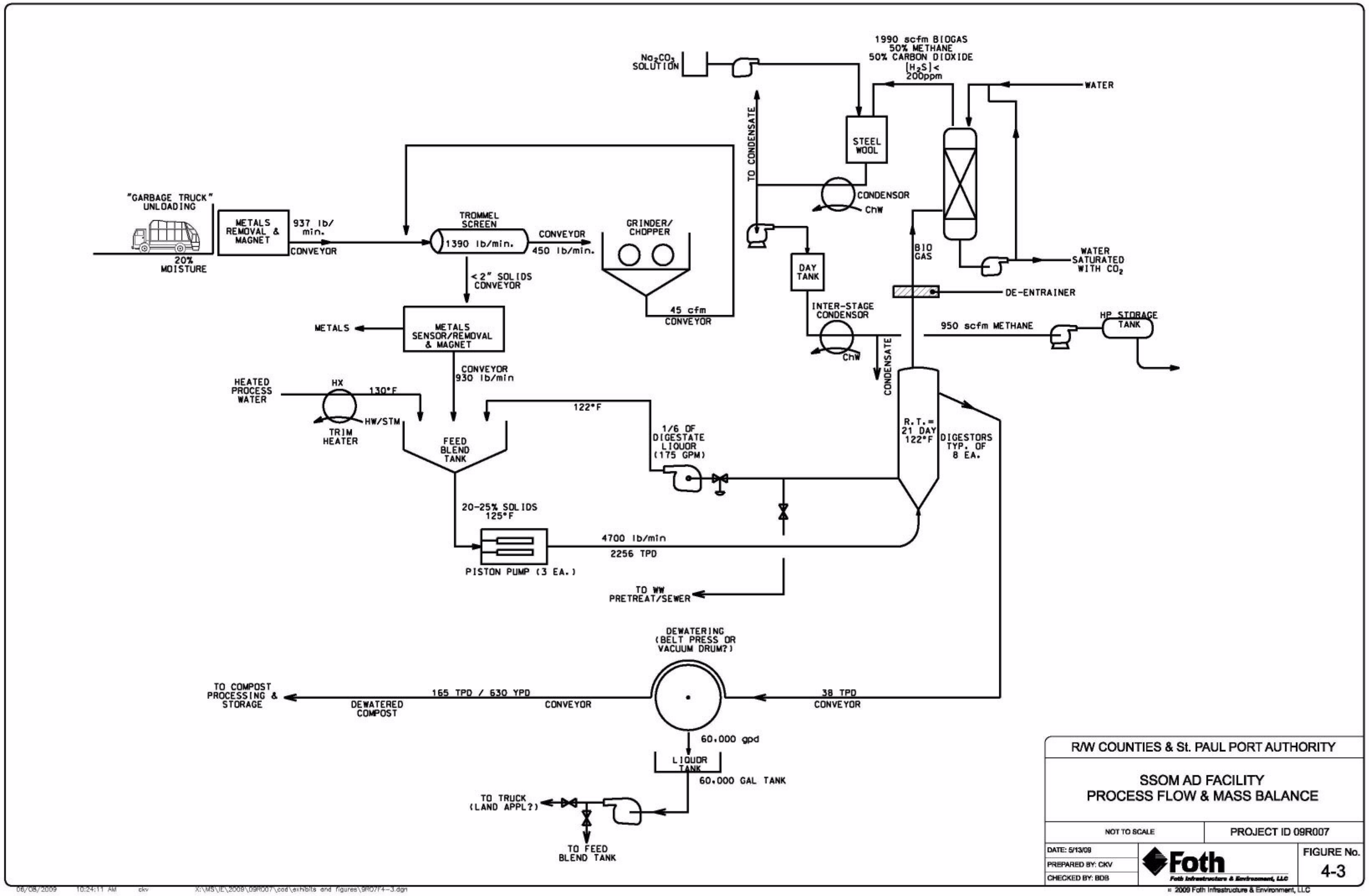


Figure 4-3 SSOM AD Facility Process Flow & Mass Balance



Shredded and screened SSOM is conveyed to a Feed Blend Tank (FBT) where heated water and recycled digestate liquor is added. There are two (2) FBTs, sized and designed to prepare eight hours of received organic waste for injection into the digesters. The FBTs have a working capacity of 41,500 cubic feet (about 50 feet diameter, 20 feet deep), and are insulated and covered to retain heat. They have an electric driven mechanical stirring mechanism and look much like a clarifier in an activated sludge wastewater treatment system. Feed and digestate are added continuously, and when one FBT is "full", its contents are pumped into the digesters, while the other FBT is put into service receiving, wetting, and blending the feed.

Digestate is added in the FBT to provide:

- The bacterial innoculant to get the digestion started.
- Water to raise the overall moisture level of the feed from 20% to approximately 75%.
- Heat to the incoming SSOM to raise the temperature prior to the AD process.

Additional heated water is also added as necessary to bring the mixture to thermophylic temperatures (120 °F to 130 °F). A fraction of one-sixth of the free (flowable) digestate is used in this operation; this fraction is documented as the optimal rate. Overall moisture must be approximately 75% to allow the feed to blend uniformly and be pumped (and flow) into the digesters. The only way heat is added to the feed to the digesters is from the hot water and digestate. It must be heated to at least 120º F prior to entering the digesters.

Specially designed piston pumps are used to transfer the prepared feed to the digesters. The pumps are hydraulicly driven. The blended feed has unique flow characteristics, in that it does flow, but retains the shape of the pump outlet and transfer pipe.

Blended feed enters the digesters from the bottom. The digesters are designed much like a grain storage silo. A diverter is designed into the inlet to direct the feed and flow of the contents much like a piston, (i.e. the wetted organic solids of the same "age" move up through the digester at the same rate). The same volume of feed is pumped into each digester each day. With 8 digesters in service, each will receive new feed for 2 hours each day. In order to maintain temperature, "free flowing" some digestate will be drawn off the bottom and be either heated or cooled and reintroduced into the digester continuously. Additional low pressure steam injection might also be needed in winter. Gas, either methane, biogas, or carbon dioxide, will be injected near the bottom of the digesters in order to provide some mixing and help in heat distribution.

After 21 days, digested solids (raw compost) will spillover to be collected, dewatered, and final processed. Continuously, biogas will bubble through the digester, and collect at the top. The biogas will be a blend of CO_2 and methane, saturated with moisture. There will be one part CO_2 for every part of methane, and some other contaminants such as hydrogen sulfide (H_2S). There are combustion systems that can burn biogas (it has about half the energy or heating value of natural gas). The biogas may be "conditioned" (dried, and the impurities removed). In this way it can be transmitted in natural gas pipelines and used as natural gas. Conditioning the biogas is a complex chemical process. The process includes stripping the CO_2 by using water; drying the biogas; and finally compressing the biogas to pipeline pressure. About one hour of biogas production is stored on site, and metered into a pipeline, or used on-site.

Biogas production will result in approximately 400,000MMBTu/yr to 525,000 MMBTu/yr, based on documented ranges of methane generation per pound of SSOM received, and assuming a methane energy value of 1,000 Btu per standard cubic feet of methane.

Raw compost comes off the digester with some trace absorbed methane and saturated with water (estimated 35% solids). There will be some smell associated, as the digestion and bacteria change from anaerobic to aerobic. It is desirable to reduce the total moisture to 50% or less. This will require a screw press, belt press, or other dewatering equipment

The resulting filtrate liquor from pressing the compost (estimated at up to 60,000 gal/day) is expected to be high in soluble metals, requiring oxidation and removal prior to discharge to either POTW or land application. One 60,000 gallon tank is included in the design costs. This stream may also require an aeration tank and flocculant addition.

The compost will have to be "finished" for about a week, under cover, to keep it dry and capture and contain odors. The exhaust will require capture and scrubbing for odor removal. About 630 yards (165 tons of compost) will be produced each day. The "pile" of compost will require an area of 200 feet by 80 feet, plus access ways and temporary storage, or at least one acre under roof.

4.5 Site Needs

An AD process facility of this capacity will require 7 to 8 acres of contiguous land, depending on support systems, roads/access, security needs, and set-backs. The process area (not including wastewater pretreatment, roads, scales, or compost handling) requires about 2.4 acres. Receiving operations (security, scales, turn-around area, etc.) will require about 0.4 to 0.5 acres. Compost finishing will be at least one acre under roof, plus access, area for exhaust controls (scrubbers, etc), and other support facilities, plus run-off management, for a total of about 1.5 acres. There are facility and process support functions, such as offices, maintenance shop, equipment storage garage and shed, utilities/boiler house (small chiller, water softener, boiler, compressor, associated storage tanks and controls), a QC laboratory, restroom/shower/locker facilities, spare/replacement parts, lay-down yard, access for fuel delivery and waste pickup, adding another 2 acres. Figure 4-1 shows the overall conceptual site plan.

Due to their size, the digesters require very high soil loading support. A soil loading of about 9,000 lb/sq ft. is required. Typically soil compaction alone will not be sufficient to achieve the anticipated loading requirements. It is likely significant structural support will be needed to support the digesters.

Utilities needed for processing include 850 kW of electricity, 15 psi steam, chilled water (to about 35°F), and 90 psi compressed dry, oil-free air (for some valve actuators and instrumentation, and sewer connection. Approximately 18MMBTu/Hr of steam will be needed for start up in winter. Normal operation steam demand is probably more on the order of 1 MMBTu/Hr. Provision should be made in the design for at least a 500 HP rental boiler for startup, including a concrete pad, 1.5 inch water connection, blow-down connection, and gas service pipe and meter (4 inch). Total cooling for a chiller system was sized for ~1.75 tons of refrigeration. Fuel for the compressor/dryer, heavy equipment and other vehicles may be either diesel or recovered methane. If methane is used as a fuel for onsite use, conditioning of the biogas to pipeline quality is required.

Site security includes perimeter fencing, cameras, and lighting. Some of the cameras can also be used for process support, especially at the SSOM receiving and weighing areas.

4.6 Preliminary Design Assumptions

Figure 4-3 provides the preliminary process flow and mass balance. The following is a listing of the preliminary design assumption.

- Maximum size of solids through trommel screen and into digester is 50 mm (2 inch).
- Digester diameter is ~35 feet. This is based on a variety of data points: photos and documentation of similar digesters are ~28-38 feet, plug flow can be managed up to about 35 ft, total digester height above grade is manageable only to ~150 feet, and residence time in digester mandates a ratio of height to diameter of 3 or longer.
- Design is based on 450 TPD of SSOM (received at 20% moisture), 16 hrs/day, 5 days/week, digester plant operation minimum of 250 days per year.
- Minimum of 20% solids in digester; design based on 25% solids for material balance and retain flowability.
- Density of SSOM assumed to be 290 pounds per cubic yard based on data found at: Gould, M., R. Garrison & S. Foster, "Source Separation and composting of Organic MSW", *Resource Recycling*, July 1992; confirmed by several other sources, including manufacturers of equipment used on processing SSOM.
- Biogas may be treated to pipeline quality as part of design scope.
- Hydrogen sulfide, or total sulfur, in biogas or methane, must be less than or equal to 200 ppm to be useable in most combustion systems, and less than 3 ppm for pipeline quality. CO_2 must be less than 2%, and methane must be greater than 95% for pipeline quality.
- Alberta Department of Agriculture & Rural Development reports that the cost of cleaning up biogas to pipeline quality is approximately \$3-\$6/MMBTu.
- Cost of Natural Gas (therefore value of pipeline quality biogas) is approximately \$6/MMBTu.
- Containment under digester "farm" assume 5 ft high wall, 190 ft x 135 ft. Includes CO_2 scrubber system and other auxiliary tanks.

- Biogas generation rate is taken from literature, at 3 to 4.8 standard cubic feet per pound of SSOM input.

- "Digestate" recycle (contains inoculant for feed blend tank) ratio is 1 to 6 (~17%) of liquid free water not retained by raw compost from the digester.

- Raw compost is 35% solids.

- Two batches per day of blended feed, each in a separate blend tank, ~50 ft diameter. Add water as batch tank fills.

- Conditioned, or cleaned, biogas will be compressed to 300 psi and 1 hour average production will be stored in receiver tank. From this tank, biogas can be injected into pipeline, used on-site as needed, or used to "fluff" or "mix" the contents of the digesters.

- Design based on 8 digesters to assure capacity; this is a minimum requirement for full scale size. New feed to be added to each digester for 2 hours per day.

- Biogas formed and collected continuously, and conditioned, compressed.

- CO_2 saturated water coming off CO_2 scrubber may have some nominal value for soda pop and other beverage manufacturers, but the value varies significantly by area, and is assumed to have value equal to shipping cost (no net value).

- Raw compost will require finishing under cover and will have odor as the compost bacteria change from anaerobic to aerobic. Storage for 7 days is assumed.

- Initial source of heat for digestion will be supplied by hot water added to shredded material in feed blend tank.

- Soil strength for digester tanks will need to be an estimated 9,000 pounds per square foot. Significant effort (cost) may be required to prepare for such a loading.

- Valorga typically lists 25-30 days retention time. For this study, design basis assumption is 21 days.

- Raw compost density is 80 pounds per cubic foot.

- Digesters must have ~20 feet of vapor space above raw compost level to allow biogas to collect.

- Vapor in the digester will be drawn off by slight vacuum.

- CO_2 scrubber operating temperature is 68° F.

- Non-electrical utilities needed include low pressure steam at 15 psi or higher, chilled water at a maximum temperature of 35-36° F, and compressed air at 90 psi minimum pressure.

- Materials of construction of rigid components are limited to 304/304L SS, carbon steel (A-36 or equal), and concrete. No "exotic materials" are called out.

- Budgetary estimates obtained from equipment or system suppliers on most major items.

- Wastewater obtained from raw compost can be discharged to sewer or land-applied after aeration and settling/agglomeration of metals.

5 Permitting and Environmental Considerations

The following sections describe the potential permitting and environmental considerations that will need to addressed to site the AD facility and operations.

5.1 Environmental Assessment Worksheet (EAW)

The Environmental Assessment Worksheet (EAW) is defined by state statute as a "brief document prepared in worksheet format that is designed to rapidly assess the environmental effects which may be associated with a proposed project" (Minn. State Statute 4410.1000). The EAW is primarily used to determine whether an Environmental Impact Statement (EIS) is required for a proposed project. The purpose of the EAW process is to determine adequate information about potential environmental impacts of a proposed project and is not to be considered an approval process. The EAW also serves as the first step in scoping an EIS if an EIS is required for a project. Information obtained during the EAW process not only helps determine if there is a need for an EIS but, it also helps to indicate how the project might be modified to lessen its environmental impacts. Any potential modifications may be imposed as permit conditions by regulatory agencies.

The EAW process involves four main steps:

1. The intent is that the project proposer supplies all necessary data to the Responsible Governmental Unit (RGU), which is assigned responsibility to conduct the review according to the Environmental Quality Board (EQB) rules.

2. The RGU prepares the EAW by completing the standard form supplied by the EQB

3. The EAW is distributed along with public notice of its availability for review. The comment period for the EAW is 30 calendar days. Certain state, federal and local agencies always receive EAWs for review. Additionally, any person may review and comment in writing on an EAW. The RGU may decide to hold a public meeting to receive verbal comments about the EAW, but public meetings are not commonly held.

4. The RGU responds to the comments received and makes a decision on the need for an EIS based on the actual EAW, comments received on the EAW and responses to the comments. The RGU and other units of government may require modifications to the project to mitigate environmental impacts as discovered through the EAW process.

An EAW would be required for an AD facility based on the mandatory EAW categories listed in Minn. State Statutes 4410.4300. It is believed that the facility would fall under subpart 5 (Fuel conversion facilities) which requires an EAW to be filled out and that the MPCA would be the RGU. It should be noted that if the facility has the capacity to utilize 250,000 dry tons or more per year of input (for fuel conversion) an EIS is mandatory (per Minn. Statue 4410.4400). If an EIS is a mandatory, an EAW is still required as a scoping tool for the EIS.

State law directs that no final governmental decision may be made to grant a permit, approve or begin a project and that construction on the project may not begin until environmental review is completed. The project proposer is required to supply the RGU with all data necessary for the RGU to adequately fill out the EAW. The data collection costs incurred are the responsibility of the project proposer. Once the EAW is complete there is a 30-day comment period followed by a 3 to 30-day response to comment period. After these milestones are complete, the RGU will make a determination whether or not an EIS will be needed.

5.2 Environmental Impact Statement (EIS)

When an EIS is required or otherwise determined as being needed by the RGU, the information for preparation of the EIS comes from three mainsources: th e EAW, comments made on the EAW and responses by the RGU and project proposer to the comments. The project proposer is responsible for providing all data necessary to complete the EIS. The RGU is responsible for preparation of the EIS, but the project proposer pays the costs associated with preparation of the EIS. Typically, the RGU will contract with a third party for preparation of the EIS.

An EIS should include discussions of the purpose of and need for the action, alternatives, the affected environment, the environmental consequences of the proposed action, lists of preparers, agencies, organizations and persons to whom the statement is sent, an index, and an appendix (if any). The main purpose of the EIS is to prepare a detailed statement assessing the environmental impact of and alternatives to a project that may significantly affect the environment.

Since the EAW serves as the first step in scoping an EIS, if an EIS is required for a project, the list of factors that need to be included in the EIS may be minimized. The reason for this is that factors in the EAW that do not pose an adverse impact have been addressed in the EAW and thus do not need to be addressed in the EIS. However, some of the potential factors that may need to be addressed in the EIS include:

- Compatibility of current and future land use
- Disruption of human communities
- Social or socioeconomic impacts
- Air quality
- Water quality
- Historic, Architectural, Archeological, and Cultural Resources
- Biotic Communities (where mitigation measures may include):
    - Erosion controls to protect adjacent biotic areas and aquatic communities
    - Phasing of construction to avoid breeding or nesting periods and to promote escape routes for mobile species
    - Landscape restoration to reconstitute existing habitat or create new habitat
    - Design adjustments to minimize impact on sensitive areas or species
    - Purchase of contiguous habitat as a preserve for dislocated wildlife or as a buffer zone
- Light emissions
- Solid waste impact
- Construction impacts
- Recreation

Once scoping has been completed (i.e. the EAW is finalized), the RGU has 45 days after receiving payment for preparation of the EIS from the project proposer to publish the EIS preparation notice. The notice must be published in the Environmental Quality Board (EQB) Monitor, and a press release shall be provided to at least one newspaper of general circulation in each county where the project will occur. The notice shall contain a summary of the scoping decision. The EIS must be prepared and its adequacy determined within 280 days after preparation notice unless the time is extended by consent of the parties or by the governor for good cause. The RGU will determine the adequacy of the EIS, unless within 60 days after notice is published that the EIS will be prepared, the board chooses to determine the adequacy of the EIS. If the EIS is found to be inadequate, the RGU will have 60 days to prepare an adequate EIS.

Within 90 days after final approval of the EIS, a final decision will be made by the appropriate governmental units on those permits which were identified as required and for which information was developed concurrently with the preparation of the EIS. Provided, however, that the 90-day period may be extended where a longer period is required by federal law or state statute or is consented to by the permit applicant. The permit decision shall include the reasons for the decision, including any conditions under which the permit is issued, together with a final order granting or denying the permit.

5.3 Emissions

5.3.1 Air

Due to the nature of the feedstock for the AD facility, it is anticipated that odor control will be required at the facility. Depending on the moisture content of the feedstock, control of wind dispersed particulate matter may need to be controlled at the facility. If the biogas produced at the AD facility is going to be used in generators to produce electricity, the generator will likely be considered an emission unit and will have to be permitted with emissions controlled accordingly. Biogas treatment equipment used to remove the hydrogen sulfide may require additional consideration as an air emission depending on the method used to remove and destroy these contaminants.

5.3.2 Water

It is anticipated that the water used at the facility for the AD process will be recycled within the process and minimal amounts of water will leave the site. However, any water that leaves the site will be considered leachate and will leave the facility in a controlled manner such that the leachate can be treated by a publicly owned treatment works (POTW) such as the Metropolitan Council Environmental Services' Metropolitan Disposal System. Additionally, any liquid in contact with waste (stored feedstock) will have to be diverted to a leachate collection and treatment system or a collection system with a tank that allows for the controlled transport of leachate to a POTW.

5.3.3 Solids

The main solids emissions anticipated from the AD process are the rejected contaminants and residual materials that are inorganic in nature that are anticipated to be removed prior to processing and the residual "compost" material that remains after the AD process. The "compost" material will require testing to classify the compost as defined in Minn. Rules section 7035.2836.

5.4 Permitting

Since there are currently no AD facilities operating in Minnesota with MSW as a feedstock, it is anticipated that at least portions of several Minnesota administrative rules will be considered applicable to the AD facility. Portions of the rules regarding refuse-derived fuel processing and solid waste transfer facilities are anticipated to be applicable. Additionally, based on discussions with staff at the MPCA, it is understood that the majority of the requirements for the AD facility would fall under the requirements for composting facilities. In the past, the MPCA used these requirements for an anaerobic composting operation in St. Cloud and thus MPCA staff indicated that the majority of these requirements would be most applicable. This includes, but is not limited to the rules covered in the following sections:

- 7001.0210 General Permits
- 7001.3000-7001.3550 Solid Waste Management Facility Permits
- 7035.0400 Solid Waste General Requirements
- 7035.0800 Collection and Transportation of Solid Waste
- 7035.255 Solid Waste Management Facility Location Standards
- 7035.2565 Groundwater Quality, Surface Water Quality, and Air Quality and Soil Protection
- 7035.2585 Annual Reporting Requirements
- 7035.2655 Postclosure Care and Use of Property
- 7035.2836 Compost Facilities
- 7035.2855Solid Waste Storage Standards
- 7035.2860 Beneficial Use of Solid Waste

The following sections will discuss the potentialpermitting requirements for the AD facility.

5.4.1.1 MPCA

Based on Minn. Rules section 7007.0200 it is anticipated that the MPCA will require the proposed facility to apply for a federal part 70 operating permit. Part 70 refers to the section in the Clean Air Act where program requirements are listed (refer to the Code of Federal Regulations, Title 40 for more detail). In Minnesota, the Title V air permit is based on the part 70 operating permit and the permitting process can run concurrently with the EAW/EIS process. Thus, unless there were major changes in the facility as a result of the environmental review process, one can expect a Title V permit soon after the environmental review receives the final adequacy determination.

During the Title V permitting process, a project is typically reviewed, in part, by examining potential air emissions such as those that can be expected if the plant is operated 24 hours per day, 365 days per week without any control equipment. These emissions are designed to establish an upper limit for air emissions. Actual air emissions are generally much lower than potential air emissions due to the use of emissions control devices and fewer operating hours.

The Part 70 operating permit for the facility would be issued by the MPCA. This permit would potentially contain conditions and requirements that are specific to the project and information obtained during the EIS development that may require permit conditions to address environmental impacts identified. Specifically, it is anticipated that the Federal New Source Review, Prevention of Significant Deterioration (40 CFR 51 and 52) rules will be contained in the Part 70 operating permit.

New Source Review (NSR) is a pre-construction review program that consists of the Prevention of Significant Deterioration (PSD) program andhe Non-Attainment Area program. Before a new facility is constructed, or prior to the expansion or modification of an existing facility, emissions of regulated NSR pollutants resulting from the project must be analyzed to determine if the project is subject to NSR.

Also potentially applicable to the AD facility are EPA and State of Minnesota established National and Minnesota Ambient Air Quality Standards (NAAQS and MAAQS, respectively), which are not to be exceeded. These standards are designed to be protective of public health and the environment.

To determine compliance with the NAAQS and MAAQS, an air dispersion modeling assessment will be completed during the air permitting process. Air dispersion modeling is the primary predictive tool used by regulatory agencies for evaluating air impacts from facilities. Air dispersion modeling uses comprehensive facility information (emission rate, stack height, stack diameter, and stack gas temperature and velocity) coupled with representative meteorological data (such as temperature, wind direction, and wind speed) to predict ambient air concentrations at and beyond the facility boundary.

The NAAQS are human health or welfare-based standards that set the maximum concentrations allowed in the ambient air (i.e., the air that the general public is exposed to). These six pollutants are referred to as the criteria pollutants and are listed below:

- Nitrogen oxides (NOx)
- Sulfur dioxide (SO_2)
- Ozone/Volatile Organic Compounds (VOCs)
- Particulate matter less than 10 microns in size (PM10)
- Carbon monoxide (CO)
- Lead (Pb).

The NAAQS are used with monitoring and modeling data to determine if an area is in attainment or non-attainment with a particular NAAQS. More information on the NAAQS can be found in 40 CFR section 51 and 52. The PSD program applies to facilities that are located in geographic areas that are deemed to be in NAAQS attainment or are unclassified. Attainment refers to the ambient (i.e., measured) air quality concentrations being lower than the PSD ambient standards for either NOx, PM_{10}, or sulfur oxides. In order for a facility to be subject to PSD, the proposed pollutant's emission increase must exceed the PSD Significance Levels.

In addition to the modeling performed to determine compliance with the NAAQS and MAAQS, the MPCA has also developed a tool for assessing risk associated with a project in regards to air quality, which may also be applicable. The tool developed by personnel at the MPCA is the Air Emission Risk Analysis (AERA) process, which addresses public demand with respect to air quality.

The AERA process involves risk analysis for certain air pollutants at point sources. The process identifies sources, source groups, chemicals and associated exposure pathways that do not appear to pose an unacceptable risk or hazard to the public.

An AERA analysis includes both quantitative and qualitative facility review. In general, the analysis determines if a plant has a risk of all carcinogenic chemicals added together being less than 1 chance in 100,000 of additional life time cancers.

If the project shows a risk in excess of acceptable levels, the MPCA may determine further risk analysis is needed or the project should be modified to bring risks to acceptable levels. Detailed information on the risk analysis process can be found at www.pca.state.mn.us/air/aera.html.

5.4.1.2 Local

The main concern with local permitting is somewhat dependant on the location of the facility, because various localities will have different zoning requirements relative to an AD facility. Additionally, many of these localities will have little to no experience with siting an AD facility and thus pre-determined permitting requirements may not be in place for this specific scenario.

However, it is anticipated some local permits and approvals will be required, which may include:

- Site development plan review
- Conditional use permit
- Demolition Permit (if demolition of structures are required)
- Industrial storm water permit (if wastewater volumes will increase)
- Building and zoning permits
- Grading permit

The city where the facility is to be located would be consulted during the EAW development process to provide input to specifics of each permit. In general, the permit process for local approval for the AD facility is not anticipated to be as complicated as the EAW or EIS. However, it is typical to have local siting approvals prior to initiating the EAW process.

The environmental review process will also determine if any city or county solid waste licenses are required.

5.4.1.3 Public Utilities Commission

Depending on the end use of the biogas produced at the AD facility it is anticipated that a site or route permit from the Public Utilities Commission (PUC) may be required. The general requirements pertaining to siting are addressed under the Power Plant Siting Act (Minn. Statutes

§§216E), which states that a site permit from the PUC is required to build a large electric power generating plant (LEPGP). An LEPGP is defined as power plant and associated facilities capable of operating at a capacity of 50 megawatts or more. The rules for the administration of power plant site permits are found at (Minn. Rules Chapter 4400). Current estimates for the AD facility are that the anticipated biogas produced will be enough to produce 4 to 6 megawatts. Thus the siting permit will likely not be required unless the substantially more biogas is produced.

A routing permit is applied for through the PUC and is required for the construction of certain pipelines (Minn. Statute 216G.02). The PUC has jurisdiction over pipelines with a diameter of six inches or more that are designed to transport hazardous liquids like crude petroleum, and those that are designed to carry natural gas and be operated at a pressure of more than 275 psi. Thus if the biogas is treated to the standards necessary to introduce the gas into a pipeline, the pressure is at or above 275 psi, and the pipeline has a diameter of at least 6 inches, a routing permit form the PUC will be necessary.

The PUC rules establish the requirements for submitting and processing a permit application. The procedure to be followed in considering a route permit for a pipeline depends on the size and type of the pipeline. The full review process is applicable to pipeline projects expected to have significant environmental impacts (Minn. Rules 7852). The applicant must identify a preferred route. The Department of Commerce, Office of Energy Security holds public information meetings and solicits comments on the proposed pipeline project. The PUC considers alternate routes, orders a comparative environmental analysis of routes, and orders a contested case hearing. The PUC has up to nine months from the time the application is accepted to complete the process and make a decision on the permit.

Therefore, if biogas from the AD facility is to be cleaned to pipeline quality and piped, it will be important to limit the scope of any gas pipeline to reduce potential permitting requirements for a natural gas pipeline.

6 Economic Analysis

6.1 Capital Costs

To determine the range of costs for an AD facility capable of processing 450 tons per day of SSOM, two approaches were used. The first approach was to conduct literature searches to identify AD facility cost information from previous studies. The second approach is to develop costs based on the components used in an AD facility. The second approach broke down the AD facility into its parts. The parts costs were then estimated as to the cost for the part and the cost to install the part. This "sum of parts" approach was based on the AD facility discussed in Section 4.

A third approach of obtaining cost information from vendors was attempted. However, this approach was not successful in obtaining specific cost information for an AD facility. It appears that AD system vendors were not prepared to provide costs for large scale plants located in the United States.

6.2 Published Sources

Some AD feasibility studies have estimated capital costs for AD facilities. The costs were based on numerous factors and are summarized in the following sections.

6.2.1 Iowa Study[58]

The Iowa study projected costs for two potential AD facilities capable of taking MSW feedstocks: a 69,000 TPY facility and a 36,000 TPY facility. To determine the anticipated costs for the facilities, surveys of capital costs were obtained from 11 plants in Europe ranging in size from 4,410 TPY to 160,965 TPY. Both wet and dry plants were surveyed. Only one 2 stage plant was surveyed for the Iowa study.

The data from the Iowa study indicated the weighted average capital cost per ton to be $228 per plant ton. However, given the size of the proposed plant in the metro area, two survey points in the Iowa study are of interest. The Buchen plant is a wet single stage plant using ISKA technology to process 110,250 TPY. Total capital costs for this facility was $15,500,000. Another plant surveyed in the Iowa study was the Holsworthy plant. This plant is a wet system that uses Farmatic technology and processes 160,965 TPY. The total capital cost for the plant was reported to be $8,000,000. However, this plant's feedstock is primarily manure, which is why the capital costs are lower than other plants.

The Buchen plant processes primarily MSW wastes and the capital cost of $15,500,000 is considered reliable for this study. The cost was in $2004, when converted to $2009, the capital cost is $17,380,000. Of the other AD plants presented in the Iowa study, most of the plants accepted yard waste only; yard and food waste (garden residue); biosolids and/or manure. A smaller plant (17,640 tons per year) in Braunschweig accepts only kitchen wastes (similar to SSOM) and had capital costs of $10,200,000 ($2004). The adjusted cost would be $11,437,000 ($2009). It appears from the capital cost data that for AD facilities there is some economy of scale. This seems logical since most of the upfront processing equipment is needed for an AD plant regardless of size. The size limitations for an AD facility are reflected in the size and number of digesters at the facility. Since digesters are primarily tanks, the cost for the digester compared to the rest of the plant facility and equipment are not significant to have large variation in capital costs based on size of the facility.

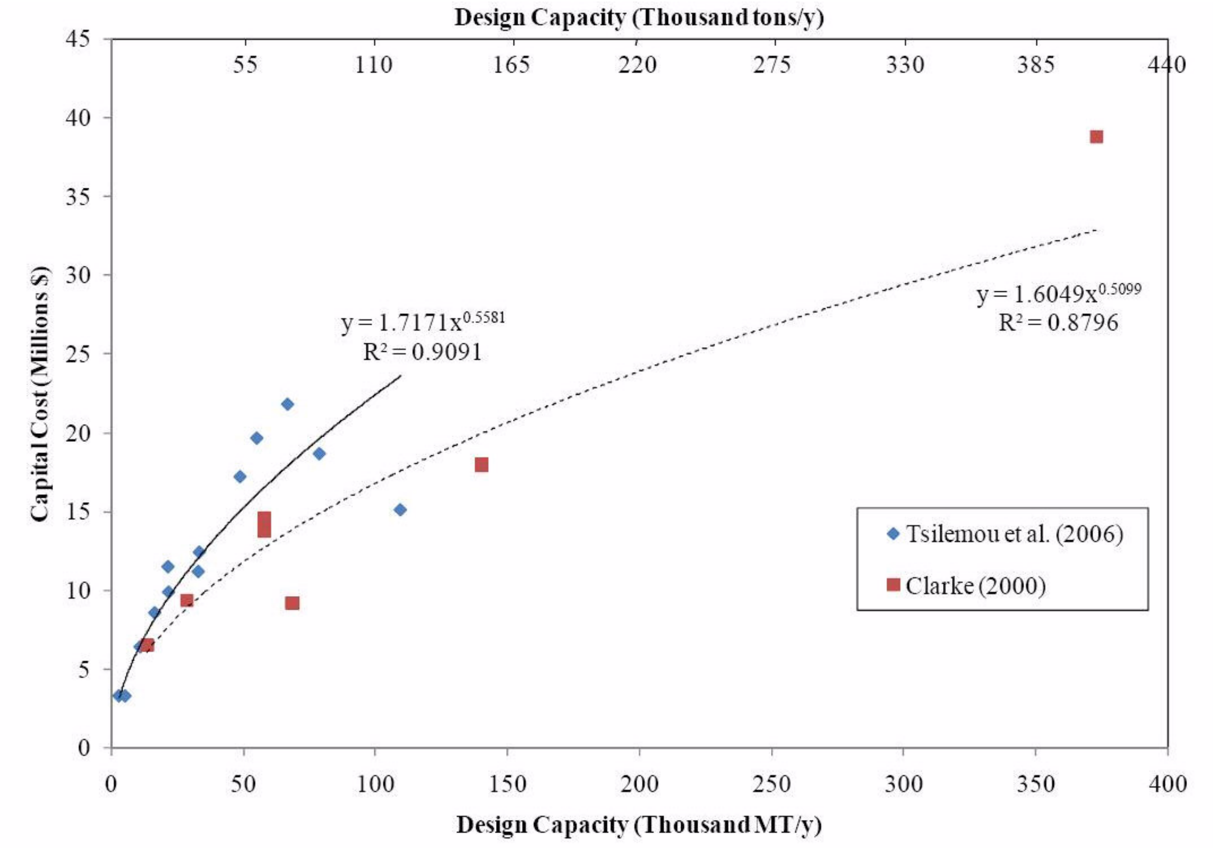
The Iowa study used the information gathered to estimate costs for two different AD facilities. A mid-sized facility capable of processing 36,128 TPY and a large AD facility capable of processing 68,690 TPY. The Iowa study published capital costs for the midsized facility was $9,433,014 ($2004) and for the large facility a capital cost of $14,240,840 ($2004) was estimated. Adjusting the costs for $2009 would yield capital cost estimates of $10,577,158 for the midsized facility and $15,968,133 for the large facility. The costs did not include land purchase for the facility or gas utilization equipment to convert the methane to energy or fuel.

6.2.2 CIWMB Study[59]

The CIWMB study used other published studies to generate projected capital cost curves for AD facilities based on the expected throughput. The curves presented in Figure 6-1 were generated. The study conducted by Tsilemou, et al. used data from 16 plants in Europe that use AD technology in MSW (organic portion). The costs considered the pre-development and construction costs.

The second study by Clarke also examined European AD facilities. The costs were reported in 2003 Euros. The data presented shows the costs in $2007.

Figure 6-1 CIWMB Capital Cost



For the proposed AD plant in the metro area, a capital cost of $16 to $23 million would be expected using the data presented. However, the data source for the CIWMB study appears to be clustered below 100,000 TPY. The capital cost data for plants larger than 100,000 TPY as shown in Figure 6-1 may be lower due to the influence of the data on smaller plants.

6.2.3 Sacramento/RIS International Study[60]

The Sacramento/RIS International Study presented four options for a 100,000 tons per year facility to digest garden wastes and food wastes. The options included both wet and dry AD processes and the study also examined capital cost for a greenfield site or co-location with other waste handling sites (transfer station, MRF, landfill).

The results of the study are presented in Table 6-1

Table 6-1 Sacramento/RIS International Study Capital Cost Summary for 100,000 TPY Facility

Type	Location	Estimated Capital Costs ($2005)
Dry/Thermophilic	Greenfield	$30,960,000
Dry/Thermophilic	Co-located	$27,670,000
Wet/Mesophilic	Greenfield	$34,400,000
Wet/Mesophilic	Co-located	$31,090,000

The costs were developed using detailed cost information supplied by one technology vendor and supplemented by the study team for component specific costs. It was assumed that since the vendors of AD technology are cost competitive, the costs provided were representative. The costs presented above if they were adjusted to $2009 would range from $30 million to $37 million.

6.2.4 Toronto Study[61]

The Toronto study obtained cost information from suppliers of Dranco and Kompogas AD technology to develop "ballpark" cost estimates. Dranco indicated its technology is sized to 50,000 tons per year so multiple plants would be needed. Kompogas Technology is sized for 10,000 tons per year and it utilizes a horizontal process versus vertical tanks in the Dranco process. For both Dranco and Kompogas multiple modules would be required for a 100,000 TPY AD facility that accepts only source-separated organic materials.

The Toronto study examined two different capital cost scenarios. One scenario examined the capital costs for multiple module plants as discussed above. The second scenario estimated capital costs for a single plant to process 150,000 TPY of SSOM. Capital costs estimated for the multiple module plants capable of processing 150,000 TPY of SSOM ranged from $46 to $72 million ($2001 Canadian). Estimated capital costs for the single module 150,000 TPY AD facility ranged from $37 to $41 million ($2001 Canadian). Converting the $2001 Canadian to 2001 U.S. dollars[62] and adjusting for inflation[63] would provided multiple module plant capital costs ranging from $37 to $58 million ($2009) and single plant capital costs from $30 to $33 million ($2009).

6.2.5 Other Sources

There have been other studies and papers published that have included capital cost information for AD facilities. The studies included general capital costs but provided limited information on how the costs were developed. The published estimated capital costs for specific AD plants provided by other sources is presented in Table 6-2.

Table 6-2 Published Capital Costs for AD Facilities

Source	Size	Vendor	Estimated Capital Cost
Niessen/CDM[1]	300,000 TPY	N/A	$152,500,000
Tolley & Berry[2]	52,000 TPY	Valorga	$24,150,000
Tolley & Berry	12,000 TPY	Dranco	$8,418,000
CRA/Canada[3]	60,000 TPY	BTA	$34,500,000

[1]Waste to Energy (WTE) using Combustion and Conversion Technologies, Powerful Alternatives to Waste Management. Niessen, Walter R. Illinois Recycling and Solid Waste Management Conference and Trade Show. Peoria, Illinois. June 11-13, 2007.
[2]A Cost-benefit Analysis of Different Waste-to-Energy Technologies for the Management of Municipal Solid Waste in Singapore. Tolley, George and Stephen Berry.
[3]Toronto Moves Forward with Anaerobic Digestion of Residential SSO. *Biocycle*. Sept. 2008.

6.2.6 Literature Review Capital Cost Summary

The following Table 6-3 provides a summary of capital costs data from published sources.

Table 6-3 Summary of Cost Data

Source	Plant Size (TPY)	Estimated Capital Costs ($2009)	Feedstock Type
Iowa Study	110,250	$17,380,000	MSW
Iowa Study	17,640	11,437,000	Kitchen Waste
Iowa Study	36,128	10,577,158	SSOM
Iowa Study	68,690	15,968,133	SSOM
CIWMB Study	100,000	16-23 million	MSW
Sacramento/RIS	100,000	33,841,000	Garden waste, dry Thermophilic, Greenfield site.
Sacramento/RIS	100,000	30,245,000	Garden waste, dry Thermophilic, Co-located
Sacramento/RIS	100,000	37,601,000	Garden waste, wet Mesophilic, Greenfield
Sacramento/RIS	100,000	33,983,000	Garden Waste, Wet, Mesophilic, Co-located
Toronto	150,000	$37 to 48 million	Multiple Module Plant
Toronto	150,000	$30 to 33 million	Single Module Plant
Niessen/CDM	300,000	155,689,000	MSW
Tolley & Berry	52,000	24,655,000	MSW
Tolley & Berry	12,000	8,594,000	MSW
CRA/Canada	60,000	34,500,000	MSW

From the published data sources, it appears the capital costs for a 100,000 TPY AD facility for SSOM in the 8 county metro area would range from $30,000,000 to $45,000,000.

6.3 Plant Build Up Estimate

The second method used to estimate the capital costs for the proposed AD facility was to develop a preliminary design and flow diagram based on similar AD designs, estimate the costs to purchase and install the equipment, estimate the site, infrastructure and building, and establish a contingency for unknown costs.

The following section describes how the capital costs were developed and provides a summary of the estimated capital costs.

6.3.1 Receiving Area

The basic plant size was based on receiving 450 TPD or SSOM. To receive this amount of waste, a receiving area/building would be required. The building was estimated to be 120 feet by 100 feet (12,000 square feet). The building cost estimate is $90 per square feet for a total receiving area cost of $1,080,000. There would also be site work such as a scalehouse, asphalt roads, general earthwork, fencing, scales, etc. that were estimated to be $1,000,000.

6.3.2 Processing Area

The processing area is defined as the area, mostly inside a building, that contains the receiving conveyors, bag breakers, trommel screens, shredders, and includes the feed blend tanks. The building to house the dry-side process area was estimated to be 20,000 square feet at $90 per square foot yields a cost of $1,800,000.

The processing area equipment cost is provided in Table 6-4. Processing equipment includes the in-feed conveyors through the feed prep tank.

Table 6-4 Processing Area Equipment Capital Cost

Equipment/Component	Quantity	Size/Rate	Unit Equip Cost	Total Equip Cost
Bag breaker	2		$25,000	$50,000
Trommel Screen (50 mm screen)	2	Total 1,500 lb/min (750 lb/min ea)	$176,630	$353,260
Shredder	1	500 lb/min	$285,000	$285,000
Magnet	2	950 lb/min	$21,800	$43,600
Receiving conveyor	2	110 ft L x 8 ft W (with Hopper)	$48,000	$96,000
Metals sensor/remover	2	950 lb/min	$20,000	$40,000
Conveyor - incline in-feed	2	950 lb/min; 70 ft L x 8 Ft W; cleated	$39,250	$78,500
Conveyor - Trommel feed	2	950 lb/min	$28,000	$56,000
Trommel in-feed	2	15 ft L x 4 ft wide	$18,200	$36,400
Conveyor - 1st stage to feed blender	1	950 lb/min; 40 ft L x 8 ft	$28,000	$28,000
Conveyor - 2nd feed to feed prep	1	Incline, 100 ft L x 8 ft	$49,700	$49,700
Conveyor - recycle/reject	1	40 ft L x 6 ft W	$28,000	$28,000
Feed prep tank (blending; covered, bottom discharge)	2	50 ft dia x 21 ft deep; 41,500 cu ft; 8 hr batch	$150,000	$300,000
Total				$1,444,460

6.3.3 Digesters

After the SSOM is sized and blended in the processing area, the material is sent to digestion tanks for a 21 day cycle. In the digestion tanks, anaerobic activity converts the organic materials to methane and carbon dioxide.

The equipment in this section includes a variety of specialty pumps, heaters (to bring the digester temperature to 122 ºF) and the digestion tanks. The capital cost summary for the digesters is shown in Table 6-5.

Table 6-5 Capital Cost Summary for Digesters

Equipment/Component	#	Size/Rate	Unit Equip Cost	Total Equip Cost
V-ram piston pump	3	50 cfm feedrate, 2 on, 1 spare	$200,000	$600,000
Digestate recycle pump	8	25 gpm, 175 ft WC, SS	$3,000	$24,000
Steam injection system	8	1" sch 40 pipe manifold, Custom	$7,500	$60,000
Recycle digestate heater/cooler	8	TBD	$18,000	$144,000
Digesters (2x4 arrangement, slip-form concrete, insulated)	8	35 ft diameter x 150 ft total; ~150,000 cu ft each		$5,250,000
Total				$6,078,000

For the proposed plant, each digester is sized to be 35 feet in diameter and approximately 150 feet tall. For the proposed plant, capable of processing 100,000 TPY, a total of 8 digesters are required. However, this portion of the plant is scalable depending on the SSOM supply. Since each tank has approximately 150,000 cubic feet, the total plant digester capacity is 1.2 million cubic feet. If the plant initially only receives 50,000 TPY, the number of digesters can be reduced to four. For a smaller plant, the capital costs for the digesters would be proportionate to the volume required. Therefore, the digester cost component for an AD plant capable of processing 50,000 TPY is half of the cost shown in Table 6-5.

It is important to note the digester tanks were designed in this capital cost estimate to be 35 feet in diameter and 150 feet tall. The height of the digesters, which are constructed using slip form concrete methods for cost effectiveness, much like grain silos, would require significant ground preparation to support the weight of the digesters. The initial estimate for ground preparation to support the digesters is $10 million.

6.3.4 Gas Management System

Digesters operate in an anaerobic environment much like landfills and produce biogas. Biogas from an anaerobic digester contains methane and carbon dioxide. Typically, the percentage of each gas is 50%. However, some digesters have reported methane percentages as high as 65%. This gas would be collected from the digesters under slight vacuum and dewatered (the gas is considered saturated and the water is removed to increase gas quality and use). The digesters designed for 100,000 TPY are estimated to produce 2,000 cubic feet per minute of biogas. This amount of biogas has an approximate thermal value of 530,000 MMBTu's per year at 50% methane.

Capital costs for the collection and dewatering of the gas are provided in Table 6-6.

Table 6-6 Capital Cost for Gas Collection and Dewatering

Equipment/Component	#	Size/Rate	Unit Equip Cost	Total Equip Cost
Biogas de-entrainer (5.5 ft diameter x 12 inch thick)	8	750 cfm, SS mesh	$2,200	$17,600
Biogas condenser (Remove H_2O)	1	120,000 BTU/hr condensor, glycol cold side	$8,500	$8,500
Exhaust Fan (Fiberglass inclined vane)	1	4500 scfm, 12 inch static	$7,500	$7,500
Gas Flare	1	For startup, upsets, fugitives; 2000 cfm	$15,000	$15,000
Ducting, Dampers & Supports (Welded 304 SS)			$45,000	$45,000
Total				$93,600

The Table 6-6 includes the cost for a flare since all the biogas use options would require a flare as either primary or backup to support the use of the biogas.

Once the biogas is collected and dewatered, there are several beneficial use options that could be used to convert the biogas into energy (thermal or electric). These options include direct use, biogas to electricity using engine/generator sets, biogas cleanup to pipeline quality and fuel cells. The estimated capital costs for each of these options are presented below.

6.3.4.1 Direct Use

Typically, direct use of the biogas offers the best economics for the supplier and user of the biogas. A direct use option for the biogas would require compression of the biogas depending on the supply pressure needed by the users and potentially some upgrades to the user's equipment to make it compatible for biogas from the digester. These upgrades typically involve nozzle change to support biogas from a digester versus natural gas.

The only significant capital cost for a direct use option would be the pipeline from the AD plant to the user of the gas. The estimated cost per mile of pipeline is $260,000. This cost is highly variable depending on the routing of the pipe, utility interference along the route, easements, street and rail crossings and other obstacles along the route. The capital cost provided does not consider these potential obstacles or the estimated costs to overcome the obstacles. A more detailed cost estimate could be developed when the plant siting is conducted and biogas users are identified.

6.3.4.2 Gas to Electricity

Converting the biogas from the digester to electricity is a proven technology and has been developed at landfills for decades. This experience provides for accurate cost estimates for capital expenditures to convert the biogas from the digester to electric power.

Several manufacturers offer engine/generator sets designed to operate on biogas from digesters (and landfill gas). The basic engine/generator sets require 500 cfm of biogas that is 50% methane to generate 1.2 Mw of electricity.

The anticipated biogas quantity available from the digesters operating at 100,000 TPY is 2,000 cfm. Since each engine/generator set requires 500 cfm, a total of four generators would be utilized. This would generate a total of 6.4 Mw of electricity. Each generator is estimated to cost $1.3 million. This cost includes an allowance for connection of the generator to the electrical grid. Therefore, the total capital costs for the engine/generator set would be $5.2 million.

The electricity option is scalable according to the amount of SSOM received and the biogas generated. The capital cost required to convert biogas to electricity is proportionate to the biogas produced in 500 cfm increments (the minimum biogas required for one engine). The excess biogas produced (above the nearest 500 cfm increment) would be flared.

6.3.4.3 Gas Clean up to Pipeline Quality Natural Gas

The biogas as it exits the digesters is saturated and contains about 50% methane and 50% carbon dioxide. The biogas will also contain some impurities like hydrogen sulfide, or volatile organic compounds. In order for the biogas from the digesters to be sent to a natural gas pipeline, the biogas must be dry (dewatered) and the carbon dioxide and other impurities removed. The biogas, when leaving the digester, is scrubbed to remove the carbon dioxide, dewatered using a chiller to bring the biogas to approximately 34 ºF to condense most of the water in the biogas. If the biogas is to be sent to a natural gas pipeline, further biogas drying may be required. Biogas clean up is the most costly option reported by Agriculture and Rural Development of Alberta to cost $3 to $6/MMBTU in overall O&M costs.

The capital costs to transform the biogas to pipeline quality are provided in Table 6-7. Note that this table includes the parts and components shown in Table 6-6, as they are all required for cleanup to pipeline quality.

Table 6-7 Capital Costs for Pipeline Quality Gas Cleanup

Equipment/Component	#	Size/ Rate	Unit Equipment Cost	Total Equipment Cost
Biogas scrubber (Remove CO_2)	1	4,500 scfm inlet; 38 inch dia x 42 ft high	$7,500	$7,500
Scrubber water reservoir (Sealed)	1	4 ft diameter x 6 ft high, HDPP	$2,800	$2,800
Scrubber water pump (SS centrifugal)	1	50 gpm	$3,600	$3,600
Scrubber exhaust fan (Fiberglass inclined vane)	1	4,500 scfm, 12 inch static	$7,500	$7,500
Gas flare	1	For startup, upsets, fugitives; 2,000 cfm	$15,000	$15,000
Biogas de-entrainer (5.5 ft dia x 12 inch thick)	8	750 cfm, SS mesh	$2,200	$17,600
Biogas condenser (Remove H_2O)	1	120,000 BTU/hr condensor, glycol cold side	$8,500	$8,500
H_2S reactor (Remove H_2S from ~200ppm to <3ppm)	1	2,750 scfm; 45 inch dia, 16 ft high, sacrificial steel wool packing	$60,000	$60,000
Sodium bicarb tank (H_2S reactor)	1	100 gal, SS	$1,200	$1,200
Sodium bicarb pump	1	5 gpm	$750	$750
Exhaust fan (Fiberglass inclined vane)	2	2,750 scfm, 20 inch static; one spare	$5,500	$11,000
Gas compressor	1	Pressurize gas to 300 psi	$30,000	$30,000
Gas storage (Low pressure to feed compressor)	1	14 ft x 28 ft horiz	$6,000	$6,000
Gas storage (8,250 cu ft)	2	Metering and hold tank; 300 psi, 1 hour surge capacity (14 ft x 28 ft horiz)	$25,000	$50,000
Total				$221,450

6.3.4.4 Fuel Cells

Another option for the biogas generated by the digesters are fuel cells. Fuel cells use biogas from the digester to convert the biogas to electricity. However, fuel cells require nearly pipeline quality biogas to be fed to the fuel cells. Therefore, the costs provided in the previous section would be required in addition to the costs for the fuel cells. Often the gas cleanup components are sold as an integral part of the fuel cell.

Fuel cells work like a battery powered by the biogas generated by the digesters. The fuel cell extracts hydrogen from the methane and mixes it with oxygen to produce electricity. Use of fuel cells on biogas is new. A small demonstration project for fuel cells using landfill gas in Groton, Connecticut demonstrated the application of fuel cells to landfill gas is technically achievable. The demonstration project generated 140 kw of electricity.[64]

The capital costs for fuel cells are considerable. Reported capital costs of $700 to $1,000 per kilowatt are common.[65] Fuel cell efficiency for methane is 7,260 Btu/Kwh.[66] The proposed AD plant generates approximately 59,700,000 BTU/hr. This equates to 8,223 kwh and a capital cost of $5.7 million to $8.2 million.

Fuel cells require the biogas to be brought to pipeline quality which was not included in the estimate above. Costs for biogas cleanup would be in addition to the fuel cell costs. Conversion of the biogas to fuel cells is not economical compared to other options and will not be considered further.

6.3.5 Residual Management

Capital costs to manage the estimated 165 tons per day of digester residuals, include dewatering the materials; managing the liquid; storing the material in an enclosed building to further dewater the material; and, finish steps to complete the composting process. Capital costs for the residuals management portion of the plant are provided in Table 6-8.

Table 6-8 Residuals Management Capital Costs

Equipment/Component	#	Size/Rate	Unit Equipment Cost	Total Equipment Cost
Covered compost finishing storage barn		(Allowance for 1 acre structure)		$1,000,000
Turner	1		$300,000	$300,000
Loader	1		$300,000	$300,000
Scrubber/biofilter	1		$150,000	$150,000
Screener	1		$125,000	$125,000
Screw or belt press (Dewatering)	2	900 tpd (1,875 lb/min) at 35% solids, target 50% solids	$350,000	$700,000
Transfer conveyor into press	1	900 tpd (1,875 lb/min) at 35% solids, 50 ft x 48 ft	$50,000	$50,000
Dewatering unit infeed	1	90 ft L x 48 in W	$47,000	$47,000
Conveyor to compost pile	1	665 tpd (625 ypd) at 50% solids; 150 ft L	$80,300	$80,300
Filtrate liquor pump (Centrifugal, SS)	2	75 gpm, 50 ftWC	$3,600	$7,200
Filtrate liquor hold tank (12,000 gal each)	5	60,000 gal total (12 ft dia x 20 ft each), CS (1 day hold)	$35,000	$175,000
Filtrate transfer pump (Centrifugal, SS)	2	250 gpm, 75 ftWC	$5,000	$10,000
Total				$2,944,500

6.3.6 Miscellaneous Components and Contingencies

The capital costs presented in the previous section do not include controls, instrumentation auxiliary buildings, miscellaneous valves and fittings, permitting, utilities, grading, site security, and contingencies. The following Table 6-9 provides estimated capital costs or allowances for these items.

Table 6-9 Miscellaneous Capital Costs and Contingencies

Equipment/Component	#	Size/Rate	Unit Equipment Cost	Total Equipment Cost
Water storage tank (20,000 gal, CS)	1		$50,000	$50,000
Transfer pump (Centrifugal, SS)	2	350 gpm, 200 ftWC	$7,500	$15,000
Waste tanks (20,000 gal, CS)	2	350 gpm, 200 ftWC	$50,000	$100,000
Transfer pump (Centrifugal, SS)			$7,500	$7,500
Emergency generator (Diesel or CNG)	1	250 kW	$80,000	$80,000
Diesel storage tank (2,000 gal)	1		$2,500	$2,500
Feed/inlet pipe (20 in sch 20)	500 Lft	insulated	$35,000	$35,000
Gas product/vent pipe (8 gauge duct, SS)		140 LF 3 inch, 70 LF 6 inch, 300 LF 20 inch; 100 LF 16 inch	$9,500	$9,500
Digester mixing return gas pipe (1” sch 80 CS)	550 LF		$18,000	$18,000
Digestate return pipe (1” sch 40 CS)	450 LF	Insulated	$7,800	$7,800
Utility and support piping (2” sch 40 CS)	4,500 LF	Steam, condensate, etc.	$16,000	$16,000
		Waste transfer, water transfer, etc.	$32,000	$32,000
Wire, conduit, raceway (4" sch 40 CS)	1,500 LF		$18,000	$18,000
Controls system, HMI, etc.			$35,000	$35,000

Equipment/Component	#	Size/Rate	Unit Equipment Cost	Total Equipment Cost
Instrumentation			$375,000	$375,000
Valves and fittings			$250,000	$250,000
Subtotal				$1,051,300
Allowances				
Engineering				$2,600,000
EAW/EIS, permitting				$500,000
Grading (Basic site work)				$500,000
Utilities (Boiler, chiller, compressor, drier)				$2,500,000
Office, shop, lab, garage				$750,000
Wastewater pretreatment (oxidation/settling for metals removal)				$500,000
Security (cameras, fence, alarms)				$1,000,000
Contingency	20% of Installed Costs			$5,038,000
Allowance Total				$12,888,000

6.3.7 Summary

Table 6-10 summarizes the total capital costs. The top section of the table includes costs regardless of final use or cleanup of the biogas, and the bottom section presents a summary of the cost of the use options. Regardless of how the biogas is used, the preliminary capital cost estimate is $38,580,000. This total is about the mid-point of the range reported in paragraph 6.2.6, or between $30,000,000 and $45,000,000, but was developed without reference to that range.

The least costly option (capital cost) for use of the generated biogas is “direct use”, if a user can be identified who will accept the wet biogas as is, within two miles of the AD facility. Most costly is to use fuel cells, where the biogas must be treated to near pipeline quality, and then generates roughly the same electricity as the engine/generator set discussed in Section 6.3.4.2.

Table 6-10 Total Installed Facility Cost Summary

Item	Estimated Cost	Installed Cost
AD Facility Components		
Receiving Building	$1,080,000	$1,080,000
Site Work	1,000,000	1,000,000
Processing Bldg	1,800,000	1,800,000
Processing Equipment	1,444,460	2,888,920
Digesters	6,078,000	12,156,000
Gas Collection/Dewatering	93,600	187,200
Residuals Management	2,944,500	3,977,400
Miscellaneous Equipment	1,051,300	2,102,600
Subtotal	$15,473,560	$25,192,120
Installed Cost		$5,038,000
Subtotal		$30,230,120
Allowances		
Engineering		2,600,000
EAW/EIS Permitting		500,000
Grading (basic site work)		500,000
Utilities (boiler, chiller, compressor, dryer)		2,500,000
Office, shop, lab, garage		750,000
Wastewater Treatment		500,000
Security (fence, cameras, alarms)		1,000,000
Allowance Subtotal		8,350,000
Total AD Capital Costs		$38,580,000
Biogas Use Options		$520,000
Direct use (off-site user). Pipeline cost per mile (assume 2		5,200,000
miles)		742,900
Biogas to Electric Generation (4 engine/generators)		$6,300,000
Pipeline Quality Gas Clean up (plus new pipeline)		
Fuel Cell (plus new pipeline)		

6.4 Operation and Maintenance

Operation and maintenance (O&M) costs are detailed in the following section. Two primary approaches were used to establish an estimate for O&M costs for an AD facility. The first approach is to obtain published values from other AD feasibility studies. The second approach is a "build up" approach based on estimated operation and maintenance for the equipment at a typical AD facility.

6.4.1 Published Sources

Some AD facility feasibility studies have estimated O&M costs for an AD facility. The following sections provide a summary of the data available on O&M costs from the published sources.

6.4.1.1 Iowa Study[67]

The Iowa Study projected capital costs for two AD facilities; a 69,000 ton per year facility; and a 36,000 ton per year facility. O&M costs for the two facilities were based on the throughputs of the facilities. The Iowa study identified the following O&M costs:

- Fiber hauling $3/ton
- Filtrate treatment $0.075/gallon
- Facility labor $17.80 to $19.00/hour
- Engine/generator $0.0126/kwh
- Digester plant O&M 2.25% of capital and installed costs
- Contingency 10%

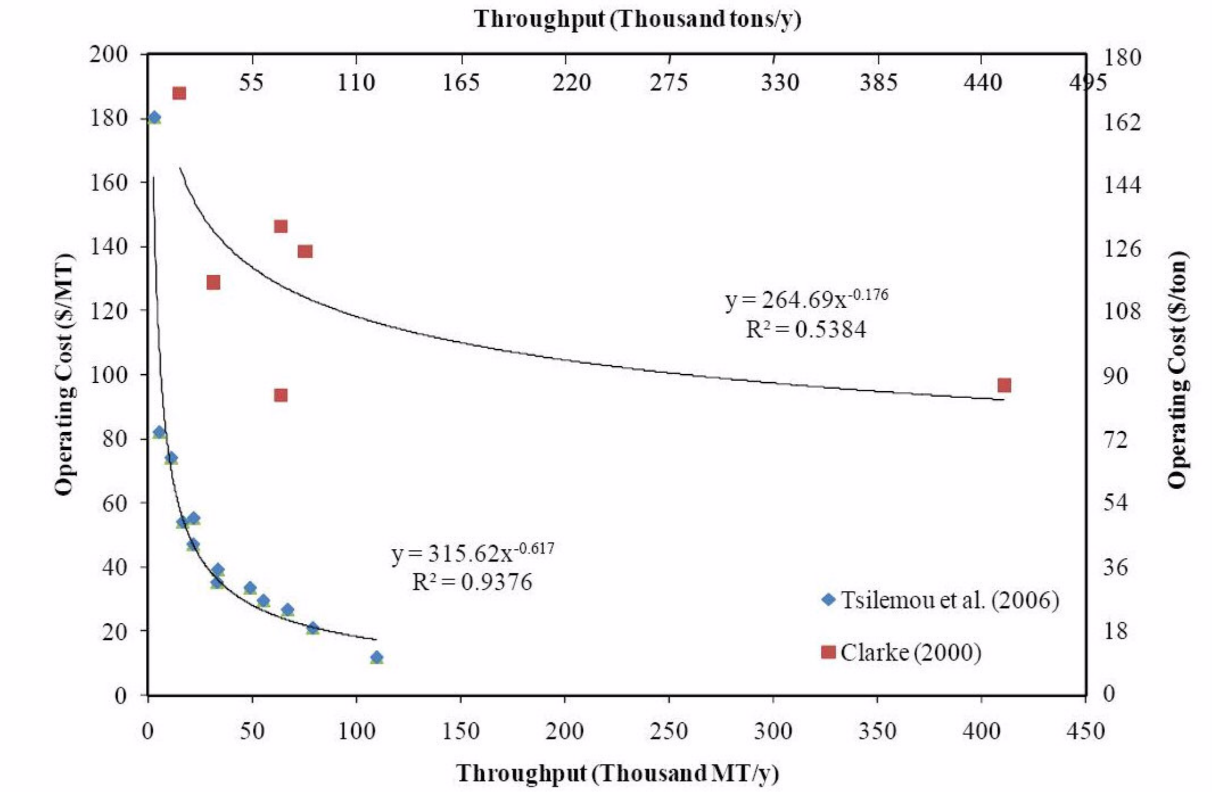
Staffing of both facilities were assumed to require a manager. The large plant was assumed to have four laborers, while the smaller plant has two laborers. Hourly costs for the manager were assumed to be $25 per hour and laborers at $16 per hour. A salary benefits adjustment of 30% to 40% was added to the hourly rates.

Residuals management costs (e.g. fiber hauling) was assumed to be just the $3/ton for hauling. Residuals were to be mixed with compost and marketed with the existing compost programs. The pro forma prepared had O&M costs at $10.11/ton for large AD facility (69,000 TPY) and $11.45/ton for the smaller AD facility (36,000 TPY).

6.4.1.2 CIWMB Study

O&M costs were presented in the CIWMB Study as shown in Figure 62 .

Figure 6-2 O&M Costs for an AD Facility



The figure indicates for a 100,000 TPY plant as developed in this feasibility study, the estimated operating cost would rage from $18/ton to $110/ton. This high variability is a result of the amount of thermal energy sold. It is also important to note, the Clarke study shown in Figure 6-2 is suspect due to the outlier data point for a 440,000 TPY AD facility.

6.4.1.3 Sacramento/RIS Study

The Sacramento/RIS study provided estimates of capital and O&M costs for four types of plants. A summary of the plant types and O&M costs are provided in Table 6-11.

Table 6-11 Sacramento/RIS International Study O&M Cost Summary

Type	Size (TPY)	Location	Annual O&M Costs	Per Ton O&M Cost
Dry/Thermophilic	100,000	Greenfield	$2,460,000	$24.60
Dry/Thermophilic	200,000	Greenfield	$3,957,000	$19.8
Dry/Thermophilic	100,000	Co-located	$1,905,000	$19.05
Wet/Mesophilic	100,000	Greenfield	$2,836,000	$28.36
Wet/Mesophilic	100,000	Co-located	$2,281,000	$22.81
Dry/Mesophilic	100,000	Co-located	$1,905,000	$19.05
Dry/Thermophilic	50,000	Co-located	$1,341,000	$26.41

The O&M cost estimates included labor costs using a 1.5 multiplier for benefits, utilities and fuel (electricity was assumed at no cost since the methane was converted to electricity), plant maintenance (assumed to be 5.5% of capital costs) and other services including waste water treatment, administrative and legal fees, residual disposal and greenhouse gas credits.

6.4.1.4 Toronto Study

The Toronto Study examined O&M costs for a single 150,000 TPY plant and also multiple smaller plants that could process 150,000 TPY (three 50,000 TPY plants). O&M costs were broken down into:

- Plant O&M
- Building O&M
- Residue Disposal
- Profit (assumed private operator)
- Compost curing

O&M costs for the multiple AD facility were reported at $24.66/ton. For the single AD plant, the estimated O&M costs were $20.32/ton. Both figures are reported in ($2001). Excalated for inflation yields 2009 costs for the multiple plant facility of $30.03/ton and for the single plant of $24.75/ton.

6.4.1.5 Other Studies

Other studies have published O&M costs for AD facilities. The O&M costs from other studies are provided in Table 6-12 below.

Table 6-12 Estimated O&M Costs for AD Facilities

Study	Size	O&M Cost ($2009)
Niessen CDM[1]	300,000 TPY	$53.14 to $75.81 per ton
Tolley & Berry[2]	52,000 TPY	$40.25 to $49.21 per ton
Tolley & Berry	12,000 TPY	$52.34 to $63.97 per ton
CRA/Canada[3]	60,000 TPY	$100.91 per ton

[1]Waste to Energy (WTE) using Combustion and Conversion Technologies, Powerful Alternatives to Waste Management. Niessen, Walter R. Illinois Recycling and Solid Waste Management Conference and Trade Show. Peoria, Illinois. June 11-13, 2007.
[2]A Cost-benefit Analysis of Different Waste-to-Energy Technologies for the Management of Municipal Solid Waste in Singapore. Tolley, George and Stephen Berry.
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6.4.2 Plant Build Up O&M Costs

Using the theoretical AD plant build up as described in previous sections, O&M costs were estimated based on anticipated staffing, utilities, by products handling and disposal and energy options. The O&M cost estimate is provided in Table 6-13.

Table 6-13 O&M Cost Estimate for Plant Build Up

Staffing	Annual Cost	
Operators (10@$18/hr)	$584,064[1]	
Maintenance (3@$30/hr)	292,032[1]	
Manager (1@100,000/yr)	100,000	
Clerk (1@$16/yr)	42,264[1]	
Engineer	150,000	
Contract	175,000	
Total		$1,243,360
Utilities		
Electric use	$3,500,000	
Heat	$100,000	
Sewer Charges	$500,000	
		$4,100,000
By-products		
Wastewater pretreatment	$250,000	
Composting	$300,000	
		$550,000
	Total	$5,893,360

[1.] Includes allowances for overtime and benefits.

This translates into an O&M cost of $58.93 per ton.

Depending on the energy use options, O&M cost may increase slightly. The base case assumes direct use of the biogas at a local source. If the biogas is to be converted to pipeline quality gas, an additional O&M cost for this equipment is estimated to be $80.00/ton. If the biogas is converted to electricity, the O&M cost would be $0.015/kwh. This translates to $7.57/ton in addition to the $58.93 per ton cost..

6.4.3 Summary

O&M costs for AD facilities ranged from $10.00/ton to $100/ton. The O&M costs are dependent on the size of the facility, energy option selected and local conditions for labor and electric power. For the proposed facility, an appropriate O&M rate of $53.00/ton should be used. This rate is based on the assumption that the biogas has a direct use nearby. If the biogas is converted to electricity, the plant O&M cost would increase to $60.00/ton.

6.5 Revenues

6.5.1 Electrical Revenues

Converting biogas to electricity is a mature industry with several vendors available to provide the engine/generator sets and the controls to convert the biogas to electrical power. As previously discussed, the proposed plant could support 4 engine/generator sets that each produce 1.6 MW of electric power. The engine generator sets have a 90% availability, so the total annual electricity produced would be 50,457,600 kWh. Given the current markets for "green power," there is potential the electricity produced could be sold for at least $0.06 per kWh. This would yield revenues of $3,027,456 per year or approximately $30.00 per ton for a 100,000 TPY AD facility

6.5.2 Direct Gas Sales

To sell the biogas to a direct user would also yield revenues. To estimate the revenue, the natural gas spot price of $6.00 to $8.00 per decatherm (1 MMBtu) was used. If the estimated thermal production rate is between 380,000 to 530,000 MMBtu, then the anticipated revenue for selling the biogas to a direct user would be $2.28 million to $4.24 million annually. At 100,000 TPY, this equates to approximately $23 to $42 per ton.

It is important to note, biogas thermal energy may be slightly discounted due to higher maintenance and operating costs issues for the direct gas user. Also, the natural gas market is subject to large fluctuations as a result of supply and demand. In previous years, the cost per MMBtu for natural gas was as high as $13.00. Therefore, the revenue estimates presented should be considered conservative.

6.6 Financing Options

A debt financing estimate was provided for the estimated capital cost of approximately $38.5 million. The annual debt service payments were projected to be approximately $3 million per year for a net debt related cost of $30 per ton for a 100,000 TPY facility.

6.7 Projected Cost Per Ton

The O&M costs were projected to range from $53 to $60 per ton. The debt service estimate was $30 per ton for a total cost per ton of $83 to $90 per ton.

Projected revenues were $30 per ton for electrical generation and $23 to $42 per ton for direct gas sales.

With these estimates, it appears a reasonable estimated net cost per ton would be in the range of $55 to $60 per ton.

6.8 Schedule

The total time required to permit, design and build an AD plant to support SSOM conversion in the eight county metro area is dependent on the length of permitting. The plant design and construction is estimated to take 18 to 24 months. Permitting can take as short at 6 months and as long as 24 months. Therefore, the schedule to develop an AD plant ranges from 24 to 48 months.

7 Conclusion

AD of various organic materials is a proven technology in various European and Asian countries. While the specific compositions of the waste streams in those countries may be different from the waste streams in the eight county metro area, a SSOM AD facility should be technically feasible for the eight county metro area. There do not appear to be any fatal flaws limiting technical feasibility.

There is “work to be done” to develop and provide an adequate supply of source separated organic materials. This will include a combination of public policy and private business cooperation to identify the sources and collect the organic materials.

A site will be required to locate the facility and the environmental permitting process must be followed.

Direct use of the biogas appears to be the most economically feasible approach.

Appendices

Appendix A
Plant Suppliers and Operating Plants from IEA – Biogas

Appendix A-1
AD Plant Suppliers

Appendix A-2
Operating AD Plants

Appendix B
Wayzata's Curbside SSOM Recycling Program: Additional Details

Endnotes

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- Vintage: http://www.vintagewaste.com/vwsorganics.html
- City of Minnetonka : http://www.eminnetonka.com/news.cfm?story_id=OrganicsRecyclingSignUp200809

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