Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant

State of Michigan Biomass Energy Program Grant PLA-06-48

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MEMORANDUM

To: Michigan Biomass Energy Program

Fr: City of Ann Arbor Biomass Energy Grant Review Team

Date: August 31, 2007

Re: Wastewater Treatment Plant Methane Digester Feasibility Analysis
Grant # PLA-06-48

The City of Ann Arbor does not agree that this report supports the conclusions stated in the Executive Summary and in the "Conclusions" section. This report states, "It is technically and economically feasible to construct and implement an integrated Biomass to Energy (BM-E) system at the City of Ann Arbor WWTP." We are inserting this Memorandum into the report because we believe it is important to give a second opinion. Readers without a specific technical background could draw inaccurate conclusions about the feasibility of implementing the system under study at the City of Ann Arbor Wastewater Treatment Plant (WWTP). The most significant deficiencies in the report that we identified during our review are presented in this memorandum.

The "Conclusions" section clearly states that the implementation of the BM-E system at the Ann Arbor WWTP would result in an additional cost of $430,000/yr for 20 years. We do not consider this economically feasible.

There are a number of technical issues that were not considered in the report that need to be addressed before any decision of technical feasibility can be justified. The BM-E system produces recycle flows from the digesters to the existing treatment process, which creates additional treatment demands. There is no analysis of the effects of this on the existing system, which could include diminished effluent quality. It is important to note that the WWTP is subject to fines of $25,000 per day per occurrence for discharge permit violations. Additional items, such as possible increases in odors and noise, new MDEQ Air Quality permit requirements and a thorough risk assessment including safety factors have not been addressed.

An obvious technical problem has to do with space limitations at the Ann Arbor site.

Appendix O of the report contains a site plan that depicts the future layout of the WWTP with the area required for the BM-E superimposed in the corner of the drawing, literally in the river. This drawing is intended to show the necessary footprint for the BM-E system but does not address how such a system could actually fit at our very space limited site. The drawing visually demonstrates the site constraints and lack of available space at the WWTP to accommodate a BM-E system and appears to show that the proposed BM-E system is technically infeasible.

Of great concern to the City Review Team is the statement at the end of the Executive Summary that "It is important to note that if the City were to change direction and abandon the SRMP improvement project and implement a BM-E system, it is conceivable that the City could realize a savings over the existing plan of about $1.3 million in projected 20-year equivalent annual cost." This statement is not addressed or supported anywhere in the body of the report, and no economic analysis of this option is provided in the report. The City's current project, the Residuals Handling Improvement Project (RHIP), has been designed over the past two years at a cost of approximately $3 million, and is the result of a comprehensive plan (the Sewage Residuals Management Plan) that addresses the WWTP's biosolids handling needs for the next 20 years. Technical feasibility concerns, some of which were raised above, have not been adequately addressed for this undeveloped option. Before the City could responsibly consider abandoning the ongoing RHIP, a great deal more research and information on the BM-E system to justify such a decision would be needed..

The City of Ann Arbor is very interested in exploring ways to utilize renewable energy in City operations to reduce reliance on limited fossil fuel supplies and stabilize ever-rising energy costs. We believe that exploring the feasibility of utilizing WWTP biosolids to produce energy and reduce operating costs at the WWTP is worth exploring and appreciate the great amount of time and effort that went into this report. This report does demonstrate that the BM-E process described can significantly lower operating costs at the WWTP. However, the initial cost appears to be a significant barrier and there are many more questions and issues to be addressed before any "go, no-go" decision can be considered.

David Konkle, Energy Coordinator

Earl J. Kenzie, P.E., Wastewater Treatment Services Manager

Executive Summary

It is technically and economically feasible to construct and Implement an Integrated Biomass to Energy (BM-E) system at the City of Ann Arbor WWTP.

Such a facility has the potential to create 5,820,000 kWh of electricity per year and save 2,500 therm/year of natural gas, which in turn will save the City of Ann Arbor $436,500 in reduced energy expenditures.

Additionally it is conceivable that the City of Ann Arbor WWTP could create a reduced volume of Dried Solid Material which can be marketed and sold as an alternative fuel source to numerous energy consumers in the area around Ann Arbor. Major target markets include cement producers and coal fired power plants. These markets are currently undeveloped; however, initial conversations with a cement manufacturer close to Ann Arbor have been encouraging.

Provided that there is adequate space within the grounds of the Ann Arbor WWTP, this process could be implemented into the currently planned improvements under development for the facility, while still maintaining the original scope of the improvements. Implementation of this process into the existing SRMP would add approximately $430,000 per year to the 20-year equivalent annual cost despite a 75% reduction in annual operating costs that would be realized by implementing this system. The increase in cost is primarily due to the increased capital expenditure over and above that which is already planned under the existing SRMP project.

It is important to note that if the City were to change direction and abandon the SRMP improvement project and implement a BM-E system, it is conceivable that the City could realize a savings over the existing plan of about $1.3 million in projected 20-year equivalent annual cost. Moving in this direction would require more consideration, however, as the City would incur significant engineering costs and factors such as flexibility, regulatory issues, operational concerns, environmental impacts, odors, noise, and optimal use of limited space at the WWTP site have not been considered in this report. Consideration of these factors would most certainly reduce the projected savings substantially.

List of Figures & Tables:

1 Introduction

The concept of Renewable Energy has become more and more prevalent in our lexicon in recent years due to a variety of factors. Regardless of where you stand on the issues of what is the major cause of global warming, people are generally finding it desirable to reduce their “carbon footprint” on this earth.

The City of Ann Arbor is no different in this endeavor and feels that driving towards reducing its own carbon footprint on the world is inherently a good thing for society and is endeavoring to be a leader in the world by setting a goal of 30% of the energy consumed by the City of Ann Arbor will be from renewable sources by the year 2010.

One of the first places to look to meet this ambitious goal is at perhaps the single largest municipal consumer of energy within the City – The Wastewater Treatment Plant.

This study examines the feasibility of constructing an Integrated Biomass to Energy System at the City of Ann Arbor WWTP. This report will assess the economic feasibility of implementing such a system and will also explore some peripheral environmental issues that are affected by the implementation of such a system.

In this light it is assumed that the reader is familiar with some of the issues surrounding the generation of municipal biosolids materials, such as the definitions of Class A and Class B Biosolids. If the reader is unfamiliar with these issues and terms, it will be possible to understand this report from an overall economic sense; however the reader may want to gather information from additional resources to fully understand some of the peripheral benefits that are presented.

It should be noted that HESCO Sustainable Energy, LLC. is the primary author of this study and is also the developer of the proprietary process under consideration. It should be further noted that there exists a Solids Residuals Management Plan (SRMP) previously completed by the City of Ann Arbor. This SRMP involved a cross section of stakeholders and evaluated a variety of solids handling options which considered economics, flexibility, regulatory issues, operational concerns, environmental impacts, odors, noise, and optimal use of limited space at the WWTP site. This study also included a public participation component. While HESCO attempted to incorporate the SRMP goals into this evaluation, the scope of this particular study only considers the economic and technical feasibility of implementing a biomass to energy system, and the reader is directed to consider other issues affecting the WWTP prior to determination as to whether this technology is appropriate for the City of Ann Arbor.

1.1 Background

Non-renewable sources supply nearly all of the State of Michigan's energy requirements. Recognizing that the use of biomass energy could be accelerated through applied research and demonstration projects to assist commercialization of proven technology, the Michigan Biomass Energy Program run by the DLEG / Energy Office issued its 2005 Request for Proposals for projects that increase production, production efficiency and / or expand markets for energy and fuel derived from Michigan biomass resources.

HESCO Sustainable Energy, LLC proposed to the City of Ann Arbor Energy Office the concept of using an integrated biomass to energy system at the City of Ann Arbor WWTP, and suggested collaborating on a Grant Application to fund a study that would assess the feasibility and determine the details of deploying HESCO Sustainable Energy's Biomass to Energy System at its WWTP.

It is widely accepted that biosolids from wastewater treatment plants have economic worth based on the energy content and fertilizer value they possess, and may offer promise of using Michigan biomass resources to positively impact markets for electrical energy, solid fuel, as well as Michigan agriculture. The purpose of the feasibility study was then defined to look specifically at the potential impacts of implementing HESCO Sustainable Energy's Biomass to Energy System at the Ann Arbor WWTP given the specific challenges faced at that facility, and use this as a basis for a model approach that could be used for assessing the viability of this Biomass to Energy System at other WWTPs across the state.

The following is a list of the entities involved in this study along with brief descriptions of their roles within this study project.

- Michigan Biomass Energy Program – accepted proposal and issued grant funding for feasibility study.
- City of Ann Arbor Energy Office – study management and oversight, central point for coordination & communication between all involved parties
- City of Ann Arbor Wastewater Treatment Plant – source of technical information on plant assets, operations and planning, technical review of feasibility study
- HESCO Sustainable Energy, LLC – lead design of biomass to energy system using anaerobic digestion and combined heat and power system, performance of feasibility investigation, author of final report.

The City of Ann Arbor's Municipal Budget for energy is $4,000,000 per year. The largest usage of this budget is for street lighting at approximately $1,400,000 per year. The next largest consumer of electricity is The Ann Arbor WWTP. In 2006 the Ann Arbor WWTP spent about $200,000 on natural gas and almost $900,000 on electricity.

The City of Ann Arbor WWTP serves a total population of 114,000. The influent flow rate to the plant averages 19.2 million gallons per day (MGD) or 7,000 MG annually. The liquid load to the plant undergoes numerous treatment processes generally encompassing Screening, Grit Removal, Primary Settling, Aeration, Secondary Clarification, Filtration and finally Ultraviolet Disinfection. The solids removed during screening and grit removal is land filled. The solids generated and removed in the primary and secondary treatment processes are a waste stream that must be also disposed, and are generally termed “biosolids”. Currently, the plant generates approximately 6,500 dry tons per year of biosolids which are either land filled, or applied to agricultural land as fertilizer or soil amendments. Currently, the land applied biosolids produced at the plant are regulated by the State of Michigan and are classified as Class B biosolids. Class B biosolids must meet certain minimum quality standards may only be applied to land within specific restrictions of loading rates, crop use, and timing.

1.2 Objectives

The objective of this study is to evaluate the feasibility and economic viability of using HESCO Sustainable Energy’s Biomass-to-Energy System to efficiently produce electricity and Class A (EQ) biosolids by using anaerobic digestion in conjunction with combined heat and power generation processes at the Ann Arbor WWTP. It is further expected that the results of this study can easily be translated to examine the feasibility of implementation o this process at other facilities throughout the state.

1.3 Outline

This report first presents descriptions of both the anaerobic digestion (AD) and combined heat and power (CHP) processes that comprise HESCO Sustainable Energy’s Biomass-to-Energy system.

The details of deploying such a system at the wastewater treatment plant are then presented in sections that describe the process and component sizing, and the assumptions these are based on that are specific to the Ann Arbor WWTP.

The performance of this system is next presented at various loading conditions to the WWTP from current flows / loading to design conditions (year 2025).

The report then describes nine cases for implementation of the AD_CHP Biomass to Energy system, and presents economic analysis of these scenarios specific to the Ann Arbor WWTP. The nine cases are comprised of three scenarios. Each scenario is analyzed using three different dewatering / drying options.

Other benefits and considerations related to this AD_CHP Biomass to Energy approach, which are not captured in the economic analysis, are discussed.

Finally, the conclusions of the feasibility study are presented.

2 Process Descriptions

2.1 BM-E System Overview

The proposed biomass-to-energy system is comprised of:

- an anaerobic digestion (AD) process which effectively reduces the mass of biosolids by destroying volatile solids and converting them to a biogas consisting primarily of methane
- A combined heat and power (CHP) process, which utilizes the biogas from the AD process to fuel a generator to produce electricity. Waste heat from the generator is returned to the AD process to supply the required process heat to the digesters.

For the purpose of this study, it was assumed that Primary Sludge (PS), and waste activated sludge (WAS) will be combined and fed to gravity thickeners.

The gravity thickened sludge (GTS) is then fed to the AD process. The specific AD process utilized is a two-phase anaerobic digestion process known as 2PAD, which carries EPA Pre-Approval for achieving pathogen destruction and producing Class A biosolids. Further, the separation of the digestion process into two phases increases the volatile solids destruction which in turn produces a greater volume of biogas

The inputs to the 2PAD process are:

- Raw Sludge – in this case GTS consisting of both PS and WAS thickened to a minimum of 3.0% solids.
- Electricity – to run the pumps and equipment associated with the process
- Heat – to keep the digester contents at the required temperature.

The outputs from the 2PAD process are:

- Digested Sludge – volatile solids are destroyed in the process, yielding a significant reduction in the solids mass
- Biogas – volatile solids that are destroyed are converted to biogas consisting of methane, carbon dioxide, hydrogen sulfide and other gases such as hydrogen and nitrogen. The biogas has a heating value of approximately 600 BTU/cf.

From here, the biosolids are fed to the solids handling facility which, depending on the selected dewatering option, consists of a mechanical thickening process and a mechanical dewatering process as well as sludge storage.

The mechanical thickening process (used in Scenario 3 presented later) is gravity belt thickening (GBT) which thickens the 2PAD digested sludge from about 2% solids to approximately 7% solids. This GBT sludge is then stored and/or fed to the dewatering process.

The dewatering process utilizes either centrifuge or belt filter press equipment to further increase the solids content of the sludge from 7% up to approximately 32% or 23% respectively.

Finally, in one case (dewatering Option A) for each scenario, a drying process utilizes heat to remove water from the dewatered sludge. This drying process increases the solids content to approximately 90%, thereby reducing both the volume and weight of the end product that must ultimately be transported off-site.

The combined heat and power system utilizes the bio-gas produced by the 2PAD system, as a fuel.
The inputs to the CHP system are:

- Biogas: Renewable, Sustainable Fuel Source
- Electricity: to run various pumps and motors in the process
- Cooling Water: heat recovery and heat distribution
- Digested Sludge: primary input to the drying system.

The outputs from the CHP system are:

- Electricity: Excess electricity is produced, far beyond the demands of the 2PAD and CHP processes.
- Heat: Recovered from the generator and drying system and used as a heat source for digester heating.

Additionally, in the case of dewatering Option A:

- Dried Solids: Approximately 90% solids by weight

The CHP process first cleans the biogas generated by the 2PAD process, removing contaminants which would otherwise harm the generation equipment, such as hydrogen sulfide (H2S) and siloxanes. The generation equipment then uses the cleaned biogas as fuel to produce electricity. The heat from the generator is captured and used as the heat source for digester heating and, in the case of Option A, the drying process, further reducing the water content of the dewatered sludge. The waste-heat from the drying process is then recovered and utilized to satisfy the heat demands of the 2PAD process. These heat demands include both the heat required to restore ambient heat loss from the digester vessels, and the heat required to bring the raw GTS from ambient temperature (50F) up to the required batch temperature of (131F).

Sections 2.2, 2.3 and 2.4 respectively, describe the anaerobic digestion processes, dewatering processes and CHP processes in further detail.

2.2 Anaerobic Digestion (2PAD)

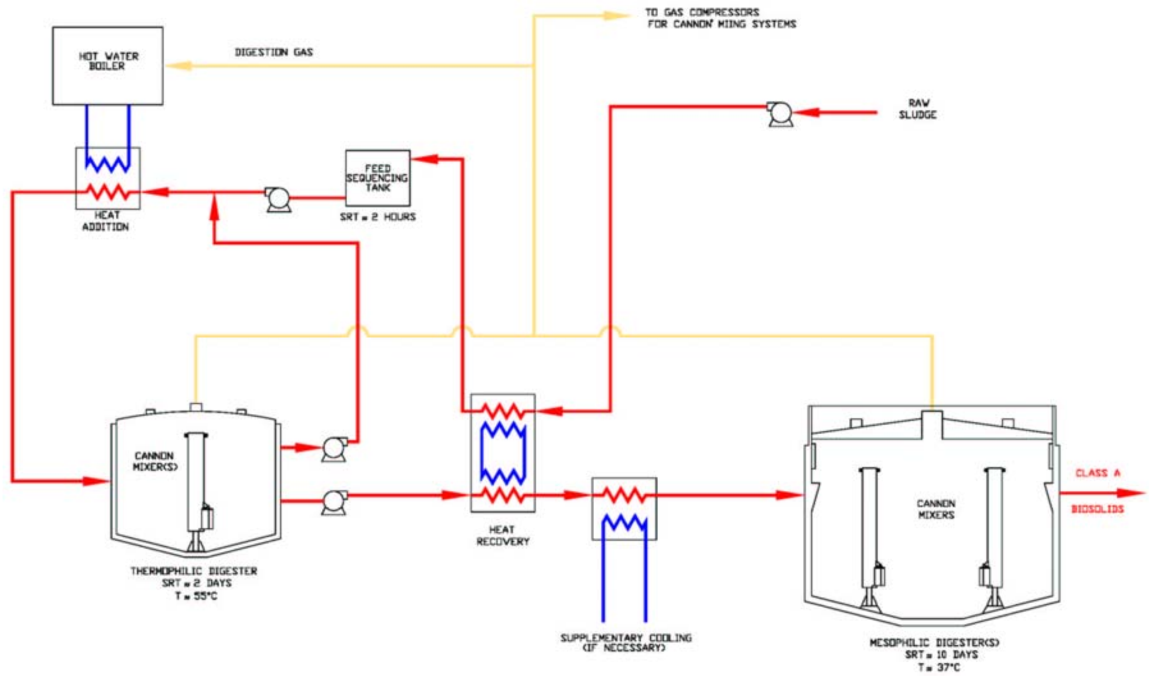
Two-Phase Anaerobic Digestion (2PAD) produces Class A Biosolids, which can be land-applied without restrictions in accordance with EPA's 40 CFR Part 503 Regulations. This unique and innovative process separates the acid-forming and methane forming (acidogenesis and methanogenesis) digestion phases, increasing the efficiency of each. This increased digestion efficiency combined with the high temperature, destroys the pathogens in the biosolids to below detectable limits. This process has been certified by the EPA Pathogen Equivalency Committee to produce Class A Biosolids. The separation and increased efficiency of both phases also greatly reduces the total hydraulic retention time required for digestion meaning the digester size and associated costs are also reduced as compared to both traditional and egg-shaped anaerobic digestion systems.

The anaerobic digestion process does not require large amounts of electricity. Problems commonly associated with operation of anaerobic digesters such as foaming, are virtually eliminated with the 2PAD process because nocardia bacteria, the typical cause of digester foaming, is destroyed in the thermophilic stage.

The 2PAD process consists of the following vessels and major equipment:

- Feed Sequencing Tank
- Transfer Pumps
- Thermophilic Digesters
- Mesophilic Digester
- Heat Exchangers
- Boiler
- Gas Mixing System
- Gas Safety & Handling Equipment

Figure 2.1 - 2PAD Process Flow Diagram



2.2.a SLUDGE FLOW & HEATING SEQUENCE

Raw sludge from the gravity thickeners is fed to the 2PAD process
This sludge is a combination of the primary sludge (PS) and the waste activated sludge (WAS) that has been combined and thickened in the gravity thickeners.

Gravity Thickened Sludge (GTS) is fed to the Feed Sequencing Tank (FST) of the 2PAD process. As the GTS is pumped to the FST it passes through a sludge/sludge heat exchanger. This heat exchanger recovers heat from sludge being transferred from the thermophilic digester at 131F, which must be cooled prior to entering the mesophilic digester at 99F, and transfers this excess heat to the sludge entering the FST.

The 2PAD process is a semi-batch process, partially drawing and filling the thermophilic digester in batches on an on-going basis. The EPA will not allow a continuous feed system for production of Class A biosolids due to the potential for flow to short circuit and allow pathogens to escape without being destroyed. Batching is the only way to prevent short circuiting and assure pathogen destruction. As the thermophilic digester is being drawn down (batch-out), GTS is pumped through the aforementioned sludge/sludge heat exchanger to the FST where it is held until the thermophilic digester is ready for refilling (batch-in). Then, the warmed GTS is pumped from the FST through a series of external heat exchangers to the thermophilic digester.

Next, the thermophilic digester must be heated back to, and then maintained at batch temperature. This is done using the external heat exchangers. Sludge is continuously drawn from the digester, and run through a series of external heat exchanges fed with hot water from dryer and/or generator heat recovery systems (which are backed up by a boiler), and the heated sludge is recirculated to the digester.

Once the thermophilic digester is up to batch temperature, it is held at batch temperature for a minimum of 3 hours to ensure the required pathogen kill is achieved. The thermophilic stage produces organic acids (VFAs). This results in high acid concentrations within the digester that, when combined with the high temperatures of the digester, achieve pathogen destruction.

By separating the thermophilic (acidogenesis) phase from the mesophilic phase, the acid forming bacteria are maintained in an environment with optimal temperature, nutrient and pH conditions. These organic-acid forming heterotrophs utilize the organic substrates (carbohydrates, proteins, fats & oils) in the sludge fed into the digester and produce organic fatty acids called “volatile fatty acids” or VFAs. These are primarily propionic and acetic acid, along with smaller amounts of butyric and valeric acids. These bacteria are relatively fast growing, and can thrive in a fairly wide range of pH.

As mentioned, the sludge from the thermophilic digester is cooled before it enters the mesophilic digester. Once in the mesophilic digester, sludge is maintained at optimal conditions for volatile destruction, and methane formation. The methane producing bacteria in the mesophilic (methanogenesis) phase utilize the VFAs produced in the thermophilic stage as substrate, and produce biogas (methane, carbon dioxide and other gases). This final conversion to gas completes the stabilization of the solids fed to the digestion system. The methane producing microbes grow more slowly than the acid formers, and require a rather narrow pH range.

Although some methane is produced in the thermophilic stage, the bulk of the methane is produced in the mesophilic stage.

2.2.b GAS STORAGE

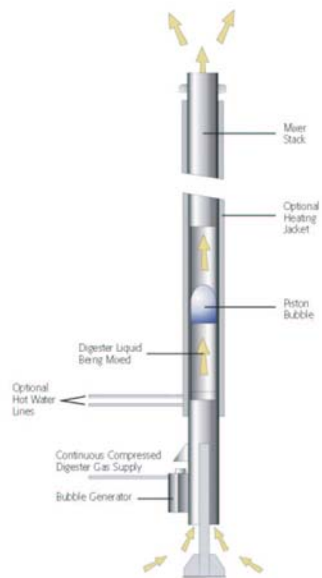
The gas produced in the anaerobic digestion system is contained within the system and prevented from escaping to atmosphere. A certain volume of gas is always held within the system to allow for drawing and filling of the digester tanks without displacing biogas from the system or the need to draw in air. This gas volume is also used for mixing the contents of the digesters using a Cannon gas mixing system. Excess gas, not required for draw/fill displacement or digester mixing, is then available for use as fuel for the generator, or boiler. Since the rates of gas production and gas demand are not always steady, nor identical, a certain volume of gas storage is required. This gas storage is achieved in the mesophilic digesters. The digester covers are floating, and gas can be stored between the liquid level and the underside of the floating cover.

2.2.c MIXING

Figure 2.3 - Cannon Mixer Installation

The Cannon gas mixing system mentioned above operates as follows. Vertical stack pipes open at each end and varying in length according to digester depth, is the central component of the Cannon mixing system. Based on computer modeling, multiple units are strategically arranged to optimize mixing zones across the entire digester and ensure greater than 90% total active volume. A bubble generator is mounted on each of these vertical stack pipes. Recirculated gas is continuously fed to the bubble generator and intermittently discharged to the stack pipe as a large "piston" type bubble the full diameter of the stack pipe. The piston bubble fills the entire cross section of the stack pipe, driving out liquid as it rises and creating a siphon. As one bubble leaves the stack pipe at the top, another enters from the bubble generator for both continuous mixing and prevention of solids settling. The large bubbles burst upon reaching the liquid surface, creating substantial turbulence that prevents scum formation & build-up.

Figure 2.4 - Cannon Mixer Diagram



Recirculated digester gas feeds the bubble generator on the mixer. The continuous mixing that results, maintains the entire digester volume in suspension (guaranteed better than 90% active volume), and requires 50% less energy than conventional mechanical means of mixing. The mixing system has no moving parts located within the digester.

2.2.d HEATING

The thermophilic and mesophilic digester tanks operate at 131F and 99F respectively. These digester tanks and their covers are insulated to minimize ambient heat loss. In order to restore the ambient heat losses, and maintain the desired temperatures, the digesters must be heated continuously.

The thermophilic digester utilizes an external heating loop. This is primarily due to the large heat flux required to bring the digester up to batch temperature in a short period of time, after a new cooler batch has been sequenced in and lowered the digester temperature. This external heating loop performs the “batch heating”. Once the digester is up to batch temperature this heating loop is then used as needed to replace ambient heat losses.

The mesophilic digester utilizes heating jackets on the Cannon Mixers. The mesophilic digester receives relatively warm sludge, partially cooled down from the thermophilic stage, and therefore does not require “batch heating”. The only heating required is to replace ambient heat losses. By circulating hot water through the heating jackets on the Cannon Mixers, they serve as a highly efficient tube-in-tube heat exchangers using re-circulated hot water. This eliminates the needs for external heat exchangers and sludge recirculation equipment. Further, utilizing heating jackets inside the digester at relatively low surface temperatures eliminates thermal shocks and provides even heat disbursement. External heat exchangers and recirculation loops can thermally shock the methane-forming bacteria resulting in a decrease in digester performance. Mounted on and combined with the mixing action of the Cannon Mixers this method of digester heating ensures uniform heating throughout the digester and optimal temperature control, maintaining temperatures within 1F throughout the digester, without thermally shocking the methane-forming bacteria.

2.3 Solids Handling

The liquid sludge from the 2PAD and the reduced mass of stabilized solids contained in this liquid must next be thickened to approximately 7% solids, if it is to be hauled off site as a liquid for land application. If it is to be land filled or land applied as a cake, it must have additional water removed through a dewatering process. Typically, this dewatering step increases the solids content to approximately 32 to 23%, depending on the dewatering process employed (centrifuge vs. belt filter press). This dewatering step is also necessary prior to drying process used in dewatering Option A for each Scenario.

For Scenario 3 (described later in the report), this study utilizes a mechanical means of thickening known as gravity belt thickening currently planned for use at the Ann Arbor WWTP. This process is capable of thickening the sludge from approximately 2% solids up to 7% solids. This type of equipment can typically achieve a 95% solids capture rate. The solids that are not captured on the belt thickener are recycled to the head of the WWTP along with all of the water removed in the thickening process.

This thickened sludge may be hauled off in liquid form for disposal via liquid land application as Class A biosolids, or fed to a dewatering process for further consolidation.

If further dewatering or drying is to follow, the thickened sludge at 7% solids (or unthickened sludge) is then fed to the dewatering process. This study investigates two types of dewatering processes for solids handling – centrifuge or belt filter press. Centrifuges are used for the dewatering step in Option A for each scenario, when subsequent drying is employed. They are also used in Option B, for dewatering alone with no drying. Centrifuges are capable of removing additional water and increasing the solids content to approximately 32% and typically achieve a solids capture of 95%. Belt Filter Presses are capable of removing water from thickened sludge and increasing the solids content to approximately 23% and typically achieve a solids capture of 95%. Belt filter presses are used in Option C for each scenario, again dewatering alone, no drying. The solids that are not captured in the dewatering process are recycled to the head of the WWTP along with all of the water removed.

This dewatered sludge may then be land filled, land applied as Class A biosolids cake, or – in the case of Dewatering Option A - fed to the drying process contained in the CHP.

2.4 CHP

The CHP System uses the biogas produced by the 2PAD system as a fuel to run generation equipment. The electricity generated from this biogas exceeds the electrical demand of the BM-E system and therefore yields a surplus that may be utilized elsewhere in the WWTP facility or sold onto the grid. Sufficient heat from the generator's combustion process is recovered to satisfy the heat demands of the 2PAD digestion process, as well as the drying process.

The CHP system consists of the following processes and major equipment:

- Gas Cleaning
- Gas Blending
- Generation
- Generation Heat Recovery
- Direct Dryer
- Dryer Heat Recovery

Each of these is described in further detail in the following sections.

2.4.a GAS CLEANING

The process starts with gas cleaning. The biogas from the 2PAD process contains constituents that have a detrimental effect on generation equipment if not removed. In addition to moisture and particulates, contaminants of primary concern are hydrogen sulfide (H2S), and siloxanes.

Figure 2.2 – Eroded Valve

Figure 2.3 - Siloxane Deposits in Boiler

- Hydrogen sulfide can create acids in the system which will corrode and permanently damage the materials within the generator.
- Siloxanes are a chemical species introduced relatively recently and now used extensively in industrial products such as lubricants and in personal care products like cosmetics, shampoos and deodorants. Siloxanes are the major cause of damage to equipment such as boilers and generators that use biogas as fuel. When run through a combustion process, siloxanes can create deposits of solid silica (SiO_2) in the generation equipment which increase wear and stresses on close tolerance engine components, and clog valves. The removal of siloxanes is therefore the key to ensuring the successful operational life of such equipment when running on biogas.

The gas cleaning skid first removes particulates in the biogas, as well as moisture. The moisture content of the biogas is reduced sufficiently to protect the compression and combustion equipment from condensate damage. The hydrogen sulfide and organic sulfur are removed using activated carbon filtration. The biogas is then run through a blower to maintain pressure required by the generator. It next flows through a two stage heat exchanger to drop the temperature and further dry the gas, and then increase the gas temperature well above the dew point. Finally, the gas passes through the siloxane removal system after which it is available as fuel.

Figure 2.2 - Gas Cleaning Skid

This Gas Cleaning System consists of:

- Glycol / Gas Heat Exchanger - lowers the dew point of the incoming gas to 70F.
- Scrubber – removes 99% of suspended moisture and particulates greater than 3 micron using a woven poly mesh element
- Gas Blower System – to increase gas pressure to generator feed pressure. Specifically built for biogas, including particulate filter, cooler, reservoir, coalescing filter, and pressure relief system.
- Heat Exchanger – Integrated dryer/recuperator, drops the dew point to 40F, further drying the gas, and then increases the gas temperature.
- Siloxane Removal System – using a combination of polymorphous porous graphite sieves for removal of all siloxane species.
- Integral Control Panel – linked to the AD_CHP Master Control Network
- Continuous On-Line Gas Monitoring System (CH_4, O_2, CO_2 & H_2S)

2.4.b GAS BLENDING

Following gas cleaning, the BM-E system has the ability to blend in natural gas with the biogas to supplement the biogas, and provide consistent fuel quality to the engine. The blending station permits natural gas to be used as the only fuel, if biogas is not available at all, or for supplemental blending with the biogas if the flow or energy content of available biogas is insufficient, or inconsistent. This supplemental blending is achieved by mixing compressed air with the natural gas to match the BTU content of the biogas based on input from the continuous gas monitoring system. In this manner, the fuel quality / content fed to the generation equipment is maintained constant.

2.4.c GENERATION

Next the cleaned (possibly blended) biogas is fed to the generator and used as fuel. Through the life of the facility it is estimated that the biogas production will range from 263,000 to over 425,000 cubic feet per day. The generation system is composed of two (2) reciprocating generators sized to effectively utilize these gas flows on a continuous basis.

The generator system produces approximately 545,000 BTU/hr of heat per 100 kW of output. Approximately 80% of this heat may be recovered and re-used as a supply for other heat demands both in the BM-E system and elsewhere.

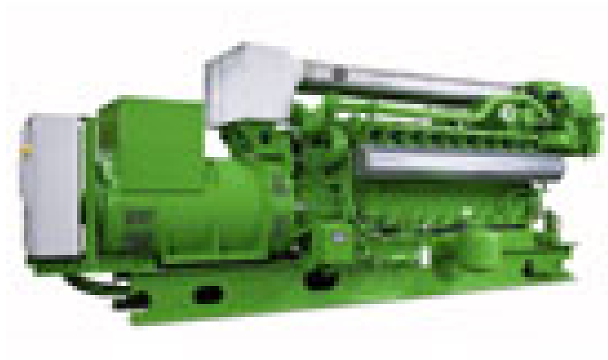


Figure 2.3 – JenbacherEngine Generator

2.4.d GENERATOR HEAT RECOVERY

Heat from the generator is recovered three ways. The first and largest system is the exhaust heat recovery system. This accounts for approximately 59% of the recoverable waste heat from the generator. Second, the generator cooling jacket system captures approximately 37% of the recoverable waste heat from the generator. This cooling jacket system recovers excess heat from the lube oil, engine block, and 1st stage intercooler to maintain them at their required operating temperatures. Finally, a small percentage of heat is recovered in the 2nd stage intercooler.

2.4.e DRYING

Drying is employed and investigated in Option A for each of the three scenarios prepared for this study. The dryer is fed with digested, dewatered biosolids with a solids content of about 32% solids by weight. Concurrently, heat captured from the generator exhaust and & dryer cooling system is fed to the dryer and the solids flowing within it. Water is removed from the solids and transported out of the dryer in the hot dryer exhaust gas. Solids are dried to 90% solids content, reducing the mass of material that must be transported off-site, and providing new options for the use of this end-product.

Figure 2.4 - Direct Dryer

2.4.f DRYER HEAT RECOVERY

Exhaust from the dryer is sent through a condensing boiler capable of recovering over 60% of the dryer heat. This heat is transferred to the main hot water loop of the digester heating, and used to heat make-up air blended with the generator exhaust and fed to the dryer inlet.

This condensing boiler also reduces VOC and other emissions to satisfy emission standards. A provision has been made in the heat recovery system for secondary treatment if necessary.

2.5 Summary

By utilizing the BM-E process, whether the biosolids are dried or not, the end product meets the pathogen destruction requirements of the EPA 503 Regulations for Class A, and can be land applied without restrictions. This “Exceptional Quality” characteristic adds tremendous flexibility to the disposal operations. Producing Class A biosolids also eliminates the dependency on lime stabilization for pathogen destruction currently practiced at the plant, which uses over 1,100 tons/year of lime at $119/ton. This translates to a potential annual savings of at least $166,000, which will only increase in size as plant treatment continues to increase as projected.

Further, the BM-E process destroys over 60% of the volatile solids fed to it, thereby reducing the mass of solids that must ultimately be transported off-site.

At $17/ton for hauling, reducing the mass of solids has a substantial positive effect on transportation (disposal) costs.

Finally, the entire BM-E process consumes only 15 to 37% of the electricity it generates – depending on whether drying is employed and what dewatering equipment is used. The surplus electricity is then available for satisfying on-site electrical demands at the WWTP. This increases the amount of energy Ann Arbor obtains from renewable sources, and achieves substantial progress towards Ann Arbor's renewable energy goal. Although this energy would be used on-site, it is important to note that it could still generate revenue. The green energy credits for this energy can be sold to the utilities as part of their Renewable Portfolio Standards initiative. The revenue from these credits can be used to offset the cost of maintaining the generation equipment. It would also free up grid capacity which can reduce the burden on rate payers for grid infrastructure and capacity improvements. This grid capacity could also be used to attract business and stimulate economic growth in the region.

3 BM-E System Sizing

3.1 Overview

The BM-E System consists of the anaerobic digestions system known as 2PAD, and the combined heat and power (CHP) system.

The sizing of the 2PAD system is based upon the volume and mass of biosolids (sludge) produced by the WWTP. For the purposes of this feasibility study, these values were obtained using the spreadsheet model of the WWTP contained in the “Sewage Residuals Management Plan Reassessment and Update”, dated September 2003 report. This model was modified to account for different solid/liquid recycle rates from the 2PAD system and subsequent thickening and dewatering operations. Appendix A summarizes all of the assumptions used for this report. The model, its inputs, calculations and results are presented in Appendix B.

The 2PAD component of the BM-E system for this study was conservatively sized to effectively operate over a wide range of loading conditions, from current plant conditions to the projected conditions of year 2025.

3.2 Current Conditions

The current conditions were extracted from the average of several years of Monthly Operating Reports. presents these as follows

Table 3.2-1: Current Conditions

		Current
Plant Influent		
Flow	(MGD)	19.20
BOD	(mg/L)	162
TSS	(mg/L)	195
Primary Sludge		
Hydraulic Flow	(gal./day)	94,977
Solids Mass Flow	(lbs/day)	31,684
Volatile Solids	*(lbs/day)*	*22,179*
WAS		
Hydraulic Flow	(gal./day)	169,695
Solids Mass Flow	(lbs/day)	14,458
Volatile Solids	*(lbs/day)*	*9,976*
Gravity Thickener Loading		
Hydraulic Load		
Combined Sludge	(gal./day)	274,125
Solids Load		
Combined Sludge	(lbs/day)	46,142
Combined Sludge	(dt/yr)	8,421
% Volatile	*(%)*	*70%*
Volatile Solids	*(lbs/day)*	*32,155*
Gravity Thickened Combined Sludge		
Hydraulic Flow	(gal./day)	114,849
Solids Mass Flow	(lbs/day)	35,760
% Solids	(%)	3.73%
Volatile Solids	*(lbs/day)*	*24,920*

3.3 Design Conditions (2025)

The 2PAD system was designed with the capacity to treat the loading and flow rates to the plant projected for the year 2025, while maintaining the ability to treat the lower loadings currently experienced.

presents the Design Conditions projected for year 2025 as well as the loading conditions for several intermediate years between now and then.

Table 3.3-3.1 Loading Conditions

		Current	2010	2015	2020	2025
Plant Influent						
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50
BOD	(mg/L)	162	159	156	152	149
TSS	(mg/L)	195	200	205	210	215
Primary Sludge						
Hydraulic Flow	(gal./day)	94,977	109,628	124,704	140,197	156,098
Solids Mass Flow	(lbs/day)	31,684	36,572	41,601	46,770	52,074
Volatile Solids	*(lbs/day)*	*22,179*	*25,600*	*29,121*	*32,739*	*36,452*
WAS						
Hydraulic Flow	(gal./day)	169,695	191,849	213,776	235,448	256,838
Solids Mass Flow	(lbs/day)	14,458	16,345	18,213	20,060	21,882
Volatile Solids	*(lbs/day)*	*9,976*	*11,278*	*12,567*	*13,841*	*15,099*
Gravity Thickener Loading						
Hydraulic Load						
Combined Sludge	(gal./day)	274,125	312,244	350,568	389,060	427,684
Solids Load						
Combined Sludge	(lbs/day)	46,142	52,917	59,815	66,830	73,957
Combined Sludge	(dt/yr)	8,421	9,657	10,916	12,196	13,497
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*
Volatile Solids	*(lbs/day)*	*32,155*	*36,879*	*41,688*	*46,580*	*51,551*
Gravity Thickened Combined Sludge						
Hydraulic Flow	(gal./day)	114,849	131,713	148,881	166,341	184,081
Solids Mass Flow	(lbs/day)	35,760	41,011	46,356	51,793	57,316
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%
Volatile Solids	*(lbs/day)*	*24,920*	*28,581*	*32,308*	*36,100*	*39,952*

3.4 2PAD Component Sizing

The input to the 2PAD system is the liquid and solids contained in the sludge from the Gravity Thickening process. Each component of the 2PAD system is sized based on one or both of the solid mass and liquid hydraulic loading.

3.4.a SLUDGE TRANSFER

Table 3.4-1: Batch Sizes, shows that the hydraulic volume of gravity thickened sludge fed to the 2PAD system will range from 114,849 gallons per day, during current conditions, up to 184,081 gallons per day as projected for year 2025.

Since the 2PAD process is a “batch” process as previously described in Section 2.2.a, sludge must be transferred between the various vessels of the process several times per day. Normally, a small percentage of each thermophilic digester volume will be batched in/out three times per day. Two parallel trains each consisting of one thermophilic and one mesophilic digester will be used. Each train of thermo/meso digesters will be batched approximately three times per day, therefore the incoming flow will be divided into approximately six batches per day – three batches to each thermo/meso train.

Table 3.4-1: Batch Sizes

Current Conditions:	114,849	(gpd)	/	6	batches / day	=	19,142	(gallons / batch)
Year 2010:	131,713	(gpd)	/	6	batches / day	=	21,952	(gallons / batch)
Year 2015:	148,881	(gpd)	/	6	batches / day	=	24,813	(gallons / batch)
Year 2020:	166,341	(gpd)	/	6	batches / day	=	27,724	(gallons / batch)
Design (2025):	184,081	(gpd)	/	6	batches / day	=	30,680	(gallons / batch)

This table also shows the batch size for various conditions. The batch size will range from 19,000 gallons under current loading conditions, up to 31,000 gallons at design conditions in the year 2025.

Batches are normally transferred within 1.5 hours. Given this, and the range of batch sizes listed above, the sludge transfer pumping systems must be sized to handle a flow range from 196 gpm to 389 gpm.

Within the BM-E System proposed for this facility, sludge feed and transfer pumping applications use a duplex alternating set of 10HP pumps sized for 354 gpm at 55 feet TDH each with VFD speed control. These pumps are preceded by a 5HP grinder.

The pump and grinder equipment and valve manifold will have a footprint of approximately 800 sf including access area for maintenance.

This pumping and grinding equipment is included in the cost of the 2PAD system presented in the opinions of probable construction cost.

3.4.b FEED SEQUENCING TANK

The Feed Sequencing Tank (FST) must be of sufficient volume to handle the range of batch volumes. Table 3.4-1: Batch Sizes above, provides the range of batch sizes for the given range of loading conditions.

Applying the peaking factor of 1.20 for maximum month conditions, to the maximum batch volume of 30,680 gallons, results in the required FST volume of 37,000 gallons.

The FST will be an enclosed tank 20 feet in diameter by with a side water depth of 16 feet, and 3 feet of freeboard, and an available volume of 37,600 gallons.

The opinion of cost for the FST including insulation and appurtenances is estimated to be $ 168,000 .

3.4.c THERMOPHILIC DIGESTERS

The Thermophilic Digester (TD) is sized to provide a Hydraulic Retention Time (HRT) of approximately 2 days. A total of two TDs will be utilized. Initially when loading volumes are relatively low, the level in the TD will be adjusted to near its minimum to maintain the proper HRT. As loading volumes continue to increase until Design Conditions are reached in 2025, the side water depth in the TD will be increased accordingly, and the HRT will be adjusted to ensure proper batch conditions are maintained.

Each TD will be an enclosed tank with a fixed cover 40 feet in diameter, with a side water depth of approximately 22.5 feet, with a net volume of 30,371 cf (or 227,000 gal.).

The tanks will be insulated with two inches of foam to achieve a heat transfer coefficient of 0.065 BTU/(ft^2*F*hr).

The opinion of cost per TD including insulation and appurtenances is estimated to be $ 500,000 .

The TDs are equipped with a sludge recirculation pumping system, to circulate sludge through the TD external heat exchangers back into the TD being heated. The sludge recirculation system is a triplex alternating set of 15HP pumps sized for 650 gpm at 50 feet TDH each with VFD speed control. The pumping equipment and valve manifold will have a footprint of approximately 450 sf including access area for maintenance.

This pumping equipment is included in the cost of the 2PAD system presented in the opinions of probable construction cost.

3.4.d MESOPHILIC DIGESTERS / COVERS

The Mesophilic Digester (MD) is sized to provide a Hydraulic Retention Time (HRT) of approximately 10 days. A total of two MDs will be utilized for this design. The MD and its mixing system are sized to allow for varying the side water depths within the digester. Initially when loading volumes are relatively low the side water depth in the MD will be low. As loading volumes increase, the side water depth will be increased and to ensure the HRT remains within an acceptable range.

Each MD will be an enclosed tank with a floating cover 85 feet in diameter, with a maximum side water depth of 29.0 feet, with a net liquid volume of 185,379 cf (or 1,387,000 gal.).

The floating cover and tank will provide 35,000 cf of gas storage per digester. Normally, the generators will demand a fairly constant flow of biogas for fuel. During these periods, gas storage needs to be sufficient to account for fluctuations in gas production and ensure there is always sufficient gas on hand to feed the generators at consistent rates.

If neither generator was operating, gas would be routed to the boiler to furnish the heat for the digesters. Under these conditions gas storage would be utilized to balance the varying gas demand of the boiler per batch, as well as provide for storage until the generator(s) are running again. Excess gas would be fed to the dryer's burner, used by other gas fueled systems at the plant, or flared.

The tanks will be insulated with two inches of foam to achieve a heat transfer coefficient of 0.065 BTU/(ft^2*F*hr).

The opinion of cost per MD including insulation and appurtenances is estimated to be $500,000. The additional cost of the floating cover and its appurtenances are included in the cost of the 2PAD system.

3.4.e MIXING EQUIPMENT

The TD and MDs will be mixed using the Cannon gas mixing system as described in Section 2.2.c MIXING.

The TDs will each have three (3) 24-inch mixers and each MD will have eight (8) 30-inch Cannon Mixers installed within the digester. Each 24-inch mixer generates approximately 3,500 gpm of pumping and each 30-inch mixer generates approximately 5,500 gpm of pumping, transferring sludge from the bottom of the tank and disbursing it across the top, creating a complete and continuous vertical circulation of flow across the entire digester.

Each Cannon mixer is a vertical stack pipe equipped with a bubble generator.

Each bubble generator on the 24-inch and 30-inch mixers requires a gas flow of 24 scfm and 31 scfm respectively, to create the pumping within the stack pipe.

A quantity of six gas compressors will be used to furnish the mixers with the required gas flow at the required pressure. Gas balancing systems will be utilized at each digester to ensure gas flow is evenly distributed among the mixers in the digester.

The TDs will each be equipped with compressors capable of supplying 72 scfm of biogas at the required pressure.

The MDs will each be equipped with compressors capable of supplying 248 scfm of biogas at the required pressure.

The compressors, their gas conditioning appurtenances and gas balancing system will utilize approximately 600 sf of floor space for the equipment footprint and suitable access area around it.

The mixing equipment is contained in the cost of the 2PAD system listed in the opinion of probable construction cost.

3.4.f Pumps / Compressors

The boiler hot water recirculation system uses a duplex alternating set of 10HP horizontal centrifugal pumps sized at 1,120 gpm at 20 feet TDH each with VFD speed control.

The MD heating jacket system uses a triplex alternating set of 3HP horizontal centrifugal pumps for recirculation water sized at 160 gpm at 40 feet TDH each with VFD speed control. This provides 20 gpm of firm capacity to each of the eight heating jackets in each digester.

These pumps and their appurtenances will utilize approximately 800 sf of floor space for the equipment footprint and suitable access area around it.
The cost of these pumps is contained in the cost of the 2PAD system.

3.4.g Boiler

Although the CHP system is capable of supplying all of the heat required for digester heating, a boiler will also be furnished. The boiler will be sized with a capacity of 5,383,822 BTU/hr, and will utilize 190 scfm of biogas at 600 BTU/cf to achieve that capacity.

This capacity exceeds the peak heat demand required during winter when furnishing heat for ambient digester loss, as well as the high demand of heating the TD to batch temperature.

This boiler is furnished with two gas fuel trains to run on either biogas, or on natural gas.

There is more than enough biogas production to fuel the boiler and furnish all of the digester heating requirements.

However, during initial start-up or any start-ups following major maintenance disruption, there may not be sufficient biogas production to satisfy the heating demands. During those periods, natural gas can be used as the fuel source until the biogas production has sufficiently increased.

The boiler and its appurtenances will utilize approximately 350 sf of floor space for the equipment footprint and adjacent area required for proper access and maintenance.

The cost of this boiler is included in the cost of the 2PAD system presented in the opinion of probable construction costs for each Scenario in Appendices C through K.

3.4.h Heat Exchangers

There are a total of four heat exchanger systems within the 2PAD system.

The first is the Heat Recovery System. This system is a sludge to sludge heat exchanger that recovers heat from the sludge batching out of the TD at 131F and cools it to 99F prior to entry into the MD. The other sludge stream on this sludge-to-sludge heat exchange system is the sludge that is batching into the FST. The heat recovered from the sludge batching out of the TD is transferred to the raw sludge entering the FST. This heat recovery system heats the raw sludge from temperatures as low as 50F up to approximately 78F.

This system is capable of transferring approximately 5,857,000 BTU/hr under worst case conditions.

This sludge-to-sludge heat exchanger system actually consists of two water-sludge heat exchangers.

The heat recovery heat exchange system uses a duplex alternating set of 10HP horizontal centrifugal pumps for recirculation water sized at 250 gpm at 70 feet TDH each with VFD speed control.

The Heat Recovery System including the heat exchangers, water pumps and appurtenances will utilize approximately 600 sf of floor space including the adjacent area required for safe access and proper maintenance.

The second heat exchanger system is the Supplemental Cooling System which is used to further cool the sludge batching out of the TD in case the Heat Recovery system does not sufficiently cool this sludge.

This system is fed with PEW, which is simply wasted. The design of the 2PAD does not rely upon this system for routine operation. This system is a back-up / fail-safe cooling system only. As such, wasting rates were not accounted for in operating costs or plant loading calculations. This system has a heat transfer capacity of 1,912,000 BTU/hr using an 80F water supply to ensure the sludge is cooled to 99F before it enters the MDs.

The Supplemental Cooling heat exchange system uses a duplex alternating set of 3HP horizontal centrifugal pumps for recirculation water sized at 300 gpm at 30 feet TDH each with VFD speed control.

The Supplemental Cooling System including the heat exchangers, PEW flow control system and appurtenances will utilize approximately 350 sf of floor space including the adjacent area required for safe access and proper maintenance.

The third heat exchanger system is the TD Recirculation System. There are two (2) TD Recirculation heat exchangers. Each is sufficiently sized to provide the heat necessary to bring the largest batch up to batch temperature within 3 hours. These units are used to heat the sludge in the TD to bring its contents back to batch temperature after the filling (batch-in) step, or maintain temperature against ambient heat loss. They are also used to heat the sludge as it is batching into the TD from the FST.

These heat exchangers each have a capacity of 3,767,718 BTU/hr. They are fed by a triplex arrangement of 7.5HP horizontal centrifugal pumps for recirculation water sized at 400 gpm at 40 feet TDH, and a triplex arrangement of 15HP sludge pumps sized at 650 gpm at 50 feet TDH, each with VFD speed control, to provide firm sludge and water pumping capacity to each heat exchanger system.

The sludge pumps, hot water pumps, heat exchangers and appurtenances will utilize approximately 1,000 sf of floor space including the adjacent area required for safe access and proper maintenance.

The fourth digester heat exchanger system is the MD Heating Jackets. The heating jackets mounted on the Cannon Mixers in the MDs will be used to maintain the MD temperature at 99F against ambient heat losses. Since the sludge from the TD already comes in at temperature, no additional heating is required in the MD beyond ambient heat loss.

These heating jackets are each fed with a supply of 155F water at up to 20 gpm using two of three (3) 3 HP pumps rated for 160 gpm at 40 ft of head. Each jacket is capable of furnishing 200,000 BTU/hr of heat. There are eight (8) heating jackets in each MD. Therefore the heating capacity in each MD is 1,600,000 BTU/hr. Heat loss calculations in Appendices C-K for each Scenario, show worst case ambient heat loss of MDs to be approximately 157,000 BTU/hr per digester. The apparent extreme discrepancy between the heating demand and capacity is in engineered in place to cover the worst-case scenario in which the thermo digesters are by-passed and raw sludge is fed directly to the MDs. In this case, the heat required to bring raw sludge up to temperature would be 1,800,000 BTU/hr.

The cost of all this heat exchange equipment is included in the cost of the 2PAD system presented in the opinion of probable construction costs in Appendices C-K.

3.5 Solids Handling Requirements

For the purpose of this feasibility study, several scenarios have been prepared. Each Scenario is further worked up with three different dewatering options. These scenarios and dewatering options are detailed in Section 6 Implementation, of this report.

Table 3.5-1: 2PAD Sludge Output presents the amount of sludge produced by 2PAD for various future operating conditions.

Table 3.5-1: 2PAD Sludge Output

Year	Hydraulic Flow (gal./day)	Solids Mass Flow (lbs/day)
Current	114,849	20,808
2010	131,713	23,862
2015	148,881	26,971
2020	166,341	30,133
2025	184,081	33,345

The following table also calculates the amount of storage in terms of days available using the existing gravity thickeners for digested sludge storage.

Table 3.5-2: Sludge Storage - Existing Thickeners

	Number of Tanks		Tank Size					
Year	Total	Operating	Diameter (ft)	Water Depth (ft)	Operating Surface Area (sf)	Operating Volume (cf)	Sludge Flow (MGD)	Available Holding Time (hours)
Current	2	1	70	12	3,848	46,182	114,849	72
2010	2	1	70	12	3,848	46,182	131,713	63
2015	2	2	70	12	3,848	46,182	148,881	111
2020	2	2	70	12	3,848	46,182	166,341	100
2025	2	2	70	12	3,848	46,182	184,081	90

Thickening Equipment

Dewatering Option A for each Scenario incorporates a Gravity Belt Thickener process to thicken the sludge from approximately 2.2% coming from the 2PAD process to 7.0 % solids prior to the dewatering step.

Two Gravity Belt Thickeners with belts 2 meters in width will be provided. One for duty and one as a spare. These are sized for over 400 gpm.

Thickened Sludge Storage Volume available

The gravity belt thickened sludge will be stored in four storage vessels planned under the SRMP each with a 140,000 gallon capacity. At the Year 2025 Design loading rates, this will accommodate over 10 days for storage for sludge thickened to 7% solids.

Dewatering Equipment
Depending on the dewatering option utilized, either a centrifuge, or a belt filter press will be utilized. In the case of Dewatering Option A, the centrifuge is preceded by the Gravity Belt Thickener, and therefore fed with 7% solids. In Dewatering Options B & C the dewatering equipment, centrifuge and belt filter press respectively, will be fed with sludge ranging from 3-5% from the sludge storage tanks.

Table 3.5-3: Dewatering Equipment by Scenario

Scenario	Dewatering Equipment	Qty	HP	Flow Capacity (gpm)	Solids Capacity (lbs/hr)
1A	Centrifuge	2	100	200	2,000
1B	Centrifuge	3	100	200	2,000
1C	Belt Filter Press	4	15	140	1,400
2A	Centrifuge	2	100	200	2,000
2B	Centrifuge	3	100	200	2,000
2C	Belt Filter Press	4	15	140	1,400
3A	Centrifuge	2	250	250	5,000
3B	Centrifuge	3	250	250	5,000
3C	Belt Filter Press	4	15	140	1,400

Following dewatering, sludge will be stored in eight hoppers, each with a volume of 52 cubic yards and a capacity of 40 wet tons. At Year 2025 Design loading conditions this array of hoppers will provide 7 days of dewatered sludge storage volume.

The storage vessel costs are contained in the Opinions of Capital Cost for each Scenario in Appendices C through K.

3.6 CHP Component Sizing

The inputs to the CHP system include biogas from the digestion process, solid fed to the drying process, and heat recovered from the generator and or dryer system. Components are sized on the gas flow, fuel value of the gas, amount of water to be removed from the solids during drying.

3.6.a Gas Cleaning & Gas Blending Systems Skid

The gas cleaning system is capable of treating 500,000 cubic feet per day of biogas on a continuous basis, removing particulates, moisture, H2S and siloxanes to the following levels.

- Moisture: remove to 40F dew point and re-heat to 20F cushion
- Hydrogen Sulfide: 200 ppm or less
- Siloxanes: 24 ppbv

This skid mounted system uses approximately 35 HP on a continuous basis, and has a footprint of approximately 280 sf including sufficient access area for safe operations and maintenance.

The gas blending system is capable of feeding 400 scfm of a 0-100% blend of natural gas to generation system, depending on the content and quantity of available biogas. The horsepower and footprint are included in the 280 sf and 35 HP provided above. An additional 120 SF of area is required for the siloxanes scrubber vessels which are not mounted on the skid.

3.6.b Generation System

The generation system consists of two reciprocating engine generators. One rated at 848 kW, the other rated at 335 kW. This system is sized to handle the full range of gas flows from current condition to the design conditions of 2025. At design loading conditions the digesters will provide about 17,000 cf/hr of biogas to the generation system. This equates to fuel value of approximately 10,000,000 BTU/hr. Combined the generation system has footprint of approximately 1,000 sf including sufficient access area for safe operations and maintenance.

3.6.c Heat Recovery System

Integral to the Generation System is its own heat recovery system capturing heat from the generator's lube oil, engine cooling water, and intercooler. At 848 kW the recoverable heat from these systems is 1,717,000 BTU/hr. The water flow rate through this system is approximately 185 gpm. An additional 1,924,000 BTU/hr is recoverable from the exhaust. Finally, there is a second stage intercooler which captures an additional 160,000 BTU/hr with a water flow of about 65 gpm.

3.6.d Drying System

The drying system has a footprint of approximately 1,000 sf including sufficient access area for safe operations and maintenance. The unit is sized for a feed rate of 4,700 lbs. per hour of solids at 68% moisture content, and sufficient drying capacity to decrease the moisture content down to 10% resulting in a 1,700 lb. per hour solids out-feed rate.

3.6.e Dryer Heat Recovery System

Heat from the dryer exhaust is captured with a condensing boiler. This system includes a 125 HP variable speed fan sized to handle 25,000 lbs / hr of air flow, at a 300F temperature. Ultimately this system is capable of recovering over 2,200,000 BTU/hr from the dryer exhaust.

3.7 System Space Requirements

The BM-E system footprint would require approximately 23,000 SF of area. This consists of:

Feed Sequencing Tank (FST)	Qty (1) @ 20 ft. dia.	314 SF
Thermo Digesters (TD)	Qty (2) @ 40 ft. dia.	1,257 SF
Meso Digesters (MD)	Qty (2) @ 85 ft. Dia.	11,350 SF
BM-E Facility Building		
2PAD Systems		4,050 SF
Gas & Generator Systems		1,300 SF
Thickening, Dewatering & Conveyance Systems		2,600 SF
Drying Systems		650 SF

Appendix O presents a site plan of the Ann Arbor WWTP along with the footprint of the proposed BM-E system for Scenario 3A.

For the purposes of cost estimates, the footprint for the BM-E facility building was inflated substantially to account for miscellaneous building related systems and space requirements.

4 Biomass to Energy System Performance

This section presents the BM-E System performance projected by the calculations contained in Appendices C through K for each Scenario and Dewatering Option.

4.1 2PAD Performance

The following sections summarize the projected performance of the 2PAD portion of the BM-E system.

Based on the loading conditions presented in , the performance of the 2PAD system can be estimated using the following conservative assumptions.

- Minimum Volatile Solids Destruction: 60%. This minimum value is based the manufacturer's research & full scale experience at a plant in Chattanooga, TN. Separation of the acid and methane forming phases has a very positive effect on the volatile solids destruction. [Typical performance ranges from 70-75%]
- Biogas Production: 17 standard cubic feet per pound of volatile solids destroyed. [Typical Range: 17-19 cf/VSSd]
- Heat Value of Biogas: 600 BTU per standard cubic foot.

Table 4.1-1 summarizes the 2PAD performance, at several loading conditions ranging from current loading to Design Loading for year 2025. This performance is provided as stabilized sludge output in terms of hydraulic flow volume, stabilized solids mass flow and solids content of the liquid output.

Table 4.1-1: 2PAD Solids Performance

Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%
Hydraulic Flow	(gal./day)	114,849	131,713	148,881	166,341	184,081
Solids Mass Flow	(lbs/day)	20,808	23,862	26,971	30,133	33,345
Solids Mass Flow	(dt/yr)	3,797	4,355	4,922	5,499	6,086
% Solids	(%)	2.2%	2.2%	2.2%	2.2%	2.2%
VS Destroyed	(lbs/day)	14,952	17,149	19,385	21,660	23,971

At design loading conditions the Volatile Solids Destruction (VSd) capabilities of the 2PAD system will be reducing the mass of solids that must be transported off-site by 12 tons per day, and converting this solid mass to valuable biogas.

Table 4.1-2 presents the biogas production of the 2PAD. This is given in both volumetric gas flow, as well as heat value. The final line of the table shows the available heat from a boiler assumed to be 80% efficient. These values for heat available from a boiler can be compared to the digester heat losses and sludge heating requirements contained in the next section. (The values for biogas production in cubic feet per day were used for sizing the generation equipment.)

Table 4.1-2: 2PAD Biogas Performance

Biogas / VSd	cf/lbs VSd	17	17	17	17	17
Biogas Daily Production	cf/day	254,185	291,525	329,545	368,216	407,509
Biogas Flow Rate	cf/hr	10,591	12,147	13,731	15,342	16,980
Energy Value of Biogas	BTU/cf	600	600	600	600	600
Gas Flow Energy	BTU/hr	6,354,618	7,288,126	8,238,618	9,205,388	10,187,731
Energy Output	BTU/day	152,510,843	174,915,023	197,726,828	220,929,309	244,505,541
Heat Availble from Boiler	BTU/hr	5,083,695	5,830,501	6,590,894	7,364,310	8,150,185

The above mentioned reduction in mass, when combined with the Class A quality of the stabilized sludge, results in the elimination of lime addition for stabilization.

Currently, the WWTP uses over 1400 tons / year of lime *(3.82tpd*240days+15.4tpd*80days = 2,149 tpy)* at a cost of $119 per ton, which accounts for $166,000 per year of lime that must be purchased.

This same mass of lime is then disposed of either via landfill at $17 per ton or land applied at $0.028 per gallon, accounting for approximately $24,000 of the annual disposal costs. The economic burden of lime purchase and disposal is therefore approximately $190,000 per year under current operating conditions. This does not account for the capital cost or the operating and maintenance costs of the lime storage, handling and feeding equipment. Implementation of the BM-E system would therefore eliminate over $190,000 per year in annual operating costs.

4.1.a Heat Requirements

Ambient heat losses from the digester vessels are fairly constant. However, sludge heating requirements can be quite variable depending on the mode of heating operation used.

During worst case winter conditions the digester ambient heat losses are calculated to be 60,788 BTU/hr for the thermophilic digesters and 156,448 BTU/hour for the mesophilic digesters. If all heating were stopped this would account for a drop in digester temperature of less than 1F/day due to ambient losses.

Summer digester heat loss is calculated to be 22,719 and 22,734 BTU/hr respectively.

Table 4.1-3 shows the heat demand due to ambient digester heat loss during worst case winter conditions.

Table 4.1-3: 2PAD Heat Demand

Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576
Thermo Batch Heating	BTU/batch	5,325,182	6,607,871	7,913,683	9,241,704	10,591,023
Thermo Batch Heating	hrs/batch	3	3	3	3	3
Thermo Batch Heating	Batch BTU/hr	1,775,061	2,202,624	2,637,894	3,080,568	3,530,341
Worst Case Demand	BTU/hr	2,209,533	2,637,096	3,072,366	3,515,040	3,964,813

For the purpose of calculating the sizing for the boiler capacity and the TD sludge recirculation heating loops, the standard 2PAD heating operation was used. This mode transfers the entire sludge batch from the FST to the TD, which has just previously batched out an equivalent volume. The raw sludge in the FST has been heated somewhat by the Heat Recovery System as the TD is batched down over a 1.5 hour period. However, the raw sludge is still considerably cool when it is pumped from the FST into the TD. It therefore lowers the temperature of the entire contents of continuously mixed TD to around 120F. The entire contents of the TD must then be heated to 132F in a limited amount of time. This heating occurs during the 1.5 hours it takes to transfer the sludge into the digester, and for an additional 1.5 hours after the transfer is complete. During these 3 hours, approximately 3.7 mmBTU per hour of heat must be transferred to the TD (worst case loading and raw sludge temperature conditions). This leaves more than the required 3 hours for the entire contents of the digester to remain at batch temperature. After which a new 8-hour batch cycle is started. Appendix M provides an illustration of the feed cycles and heating sequence described above.

Table 4.1-3 also presents the Batch Sludge Heating Requirements assuming this traditional 2PAD mode of batch heating operation is utilized. This is presented as Batch BTU per hour. The configuration of two parallel trains of thermo/meso digesters spreads the heat demand evenly over the day between the two trains and the Average BTU per hour becomes a very manageable demand for the steady heat supply of the CHP.

Depending on the loading conditions, the heat demand ranges from as little as 1,946,781 BTU per hour to as high as 3,767,718 BTU/hour, during the three hours of batch heating. These three hours consists of 1.5 hours as the batch is filling the TD, and 1.5 hours of heating the TD contents after it has been filled.

Regardless of the loading conditions, the thermophilic digester heat loss is relatively low in comparison, never exceeding 61,000 BTU/hr even under worst case (winter) temperature conditions.

By using a FST along with the sludge recirculation heating system fed by either the dryer heat, generator heat or boiler heat, along with the ability to route heat to any of the FST or TD vessels, the system is capable of distributing the heat demand more consistently across the batches and across the day to better match the steady available heat supply.

4.1.b Energy Requirements

The connected horsepower of the various components of the BM-E system are as follows:

2PAD *(Refer to Appendix N)*	approximately 212 HP
Thickening	
Gravity Belt Thickener	5 HP
Dewatering System	
Centrifuge	250 HP
Belt Filter Press (3 units operating @ 15 HP ea.)	45 HP
Generation / Gas Cleaning / Gas Blending	35 HP
Drying	275HP

These loads are not all run continuously, or concurrently.

In terms of annual energy consumption the Operating & Maintenance costs sheets contained in Appendix C-K presents the projected energy requirements of each component and the total energy requirement of the overall BM-E system for each Scenario.

4.1.c Performance Summary

At year 2025 Design Loading Conditions, fed 57,300 dry lbs / day of combined primary and WAS, the 2PAD portion of the BM-E system will reduce this mass by 58% to 33,300 dry lbs / day of digested liquid sludge, and generate 244,505,500 BTU/day of biogas. The electrical demand of this process (including the dryer electrical load) is 7,552 kW*hr / day, which is only 31% of the 24,000 kW*hr / day that can be generated from the biogas produced.

Energy Consumed:	$250,641
Energy Produced:	($660,298)
Chemical:	$5,833
Labor & Generator Maintenance:	$688,040
Disposal:	$197,561
TOTAL ANNUAL O&M COSTS:	$481,000

When energy consupmption of transfer pumping, mechanical thickening, and dewatering systems furnished under the SRMP are included, the total system electrical use increases to 9,155 kW/hr/day, which is 38% of the total electrical energy produced by the BM-E systems.

4.2 CHP Performance

4.2.a Gas Cleaning / Blending

The gas cleaning system is sized to satisfy a performance guarantee to provide gas at the minimum specifications required by the generation system, as previously described in 3.6.a.

4.2.b Gas Consumption

The generation system is sized to ensure the full range of gas production projected from current conditions to future conditions in year 2025 can be completely utilized by the generators, without compromising their efficiency.

4.2.c Energy Production

The electrical efficiency of the generators sized for this project ranges from 36% at full load, to 32% at half load. Table 4.2-1presents the electrical output of the generation system at various future loading conditions with 95% uptime.

Table 4.2-1: Energy Output

Year	Generator Output (kW)	Electrical Production (kW*hr/yr)
Current	660	5,491,499
2010	757	6,298,212
2015	856	7,119,603
2020	956	7,955,061
2025	1,058	8,803,977

4.2.d Heat Production & Recovery

The generation system produces recoverable heat of approximately 5,250 BTU per kW of output. The cooling water jacket captures 40% of this heat, and directs it to the digestion heating system. The remaining 60% of the recoverable generator heat production is contained in the exhaust. This exhaust heat is fed to the dryer inlet.

4.2.e Dryer - Heat Consumption & Heat Recovery

The dryer consumes approximately 1,475 BTU / lb of water that must be evaporated from the solids. Evaporation of this water also requires approximately 9 lbs of air per pound of water evaporated. Much of this heat and air flow is directly provided by the generator exhaust. The remaining air flow, and heat is furnished by a heat recovery system on the dryer exhaust used to pre-heat make-up air that is blended with the generator exhaust and fed to the inlet of the dryer.

The dryer exhaust is fed to a heat recovery step consisting of a condensing boiler. Conservatively, 60% of the dryer exhaust heat is recovered in this step.

Approximately 17% of this recovered heat is used to pre-heat the additional dryer inlet air blended with the generator exhaust. The remainder of this heat is input to the digester heating system.

4.2.f Performance Summary

Table 4.2-2: Performance Summary summarizes the performance of the BM-E system (for Scenario 3A) in terms of gas consumption, electrical output, heat output, of the generation system, electrical and heat demand of the digestion and drying process, and heat recovered from the generation and dryer systems.

This is based on the conservative projections of gas production from the digestion process, as well as dewatering the digested sludge to 32% and then drying it to 90% solids.

The table illustrates that the BM-E system, while operating at conservative levels of performance, is sufficiently capable of producing all of the heat, and electricity required to operate the digestion system, and dewatering equipment, as well as dry the end product to 90% solids.

Table 4.2-2: Performance Summary

	Year:	Current Conditions	Year 2010	Year 2015	Year 2020	Design Conditions (2025)
2PAD Performance						
Solids In	(dry lbs/day)	35,800	41,000	46,400	51,800	57,300
Solids Out	(dry lbs/day)	20,800	23,900	27,000	30,100	33,300
Biogas Production	(BTU/day)	152,510,800	174,915,000	197,726,800	220,929,300	244,505,500
Heat Demand	(BTU/hr)	2,209,500	2,637,100	3,072,400	3,515,000	3,964,800
Electrical Demand	(kW*hr/yr)	866,700	866,700	866,700	866,700	866,700
Generation Systems						
Generator Output	(kW)	660	757	856	956	1,058
Electricity Production	(kW*hr/yr)	5,491,500	6,298,200	7,119,600	7,955,100	8,804,000
Electrical Demand	(kW*hr/yr)	228,700	228,700	228,700	228,700	228,700
Recoverable Heat	(BTU/hr)	3,589,300	4,116,500	4,653,400	5,199,400	5,754,200
Dryer Performance						
Solids In	(wet tons/yr)	10,800	12,400	14,000	15,600	17,300
Solids Out	(wet tons/yr)	3,800	4,400	5,000	5,600	6,200
Heat Demand	(BTU/hr)	2,343,300	2,687,200	3,037,400	3,393,400	3,755,200
Electrical Demand	(kW*hr/yr)	1,036,600	1,188,700	1,343,600	1,501,100	1,661,100
Recoverable Heat	(BTU/hr)	1,406,000	1,612,300	1,822,400	2,036,100	2,253,100
NET SOLIDS DESTRUCTION	(dt / year)	2,738	6,241,500	7,081,000	7,920,500	8,760,000
NET HEAT SURPLUS	(BTU/hr)	442,500	404,500	366,000	327,100	287,300
NET ELECTRICAL SURPLUS	(kW*hr/yr)	3,130,800	3,785,400	4,451,900	5,129,900	5,818,800

5 Biosolids Fate – Traditional Disposal Practices and Added Opportunities Created by BM-E System

5.1 Disposal vs. Marketable Product

5.1.a Pay to Have it Hauled / Spread / Land filled

Currently, the disposal practices employed at the WWTP are land filling, land application of liquid Class B biosolids or land application of caked sludge. In all cases, there is a substantial cost to the operating budget to pay for the hauling, land application or tipping fee at the landfill.

While some methane is produced by these biosolids when placed in a landfill, the percent capture is relatively low. Additionally, any methane that does escape to the atmosphere is substantially more harmful as a greenhouse gas than CO_2.

Finally, and most importantly, in our opinion, placing the biosolids in a landfill is not a sustainable practice. It effectively takes these solids out of the renewable cycle, without capturing their potential, and compromises the ability of future generations to meet their own needs.

Land application is a beneficial re-use, and sustainable practice. More opportunities related and or similar to this practice should be pursued vigorously. The proposed BM-E system with Class A (EQ) liquid and cake end-products, and the ability to cost effectively dry the end product offers huge potential in this regard. Further, these opportunities should be cultivated so the practice of paying to dispose of the solids is eventually reversed into receiving revenue for a valuable product.

For the purposes of the following sections, the report widens the scope of land application to include soil amendments and fertilizer not only for agriculture but potentially horticulture, forestry landscaping and recreation.

5.1.b Soil Amendment

The proposed biomass to energy approach produces a highly stable end product, rich in essential nutrients and therefore high in value. The Class A characteristic of its solids end-product opens new opportunities for sustainable practices that would increase beneficial re-use and perhaps lead to a commercialized product capable of generating a revenue stream.

Through the creation of a commercialized product line that appreciates the underlying values of its customers, additional markets for biosolids can be developed, and grown in concert with the traditional land application fate of biosolids thus providing multiple avenues and markets for a biosolids program that is both sustainable, and flexible in the face of ever-changing regulations economics and social policies.

5.1.c Fertilizer

Biosolids have a high value as fertilizer due to their rich content of key nutrients Nitrogen (N), Phosphorus (P), and Potassium (K) as well as other micronutrients.

In fertilizer form the approximate economic values of N, P, & K are as follows:

Nitrogen (N)	$0.40/ lb.
Phosphorus (P)	$0.38 / lb.
Potassium (K)	$0.22 / lb.

The agronomic rate of each of these nutrients is approximately:

Nitrogen (N)	130 lbs / acre
Phosphorus (P)	120 lbs / acre
Potassium (K)	30 lbs / acre

Therefore, the approximate cost to fertilize an acre of land to agronomic rates would be:

Nitrogen (N)	$52.00 / acre
Phosphorus (P)	$45.60 / acre
Potassium (K)	$6.60 / acre

Biosolids contain the following approximate concentrations of these nutrients:

Nitrogen (N)	37,000 mg/kg
Phosphorus (P)	13,000 mg/kg
Potassium (K)	3,640 mg/kg

One ton of biosolids dried to a solids content of 90% has the following mass of nutrients:

Nitrogen (N)	66.6 lbs / wet-ton
Phosphorus (P)	23.4 lbs / wet-ton
Potassium (K)	6.55 lbs / wet-ton

In order to fertilize a piece of land the above listed agronomic rates, these biosolids (90% solids content) would be applied at the following rates:

Nitrogen (N)	1.95 wet-tons sludge / acre
Phosphorus (P)	5.12 wet-tons sludge / acre
Potassium (K)	4.58 wet-tons sludge / acre

The agronomic value of these biosolids (90% solids) can therefore be estimated as:

Nitrogen (N)	$26.70 / wet-ton
Phosphorus (P)	$8.89 / wet-ton
Potassium (K)	$1.44 / wet-ton

Taken together, when based only on the nutrient value of N, P & K, the economic value of biosolids is $37.03 / wet-ton [equivalent to $41.14 / dry-ton]. (When the value of electricity produced from the biogas is factored in, the economic value of the dried biosolids increases to over $150 / dry-ton.)

With a density of 30.4 pounds per cubic foot, the biosolids (90% solids content), applied at 5.12 tons / acre would be equivalent to less than one-tenth of an inch of biosolids.

Dried Class A biosolids are easier, and less costly, to incorporate into top 6 to 9 inches of soil for optimal agronomic utilization by the crop root systems, than injecting Class B liquid, or applying Class B cake. At a minimum, this has a positive effect on disposal costs by reducing the cost per ton and the cost per acre to land apply the biosolids.

Michigan's economy imports virtually all of the commercial fertilizer used for agriculture. This amounts to significant amounts of capital leaving the state economy every year. Based on the above information, biosolids with these characteristics should be able to easily compete within the fertilizer market. Any success in this area helps keep these dollars in the Michigan economy, and can be categorized as a Pro-Michigan Practice. As a general estimate, every dollar kept in the Michigan economy has a 3:1 benefit to the economy as compared to dollars that leave Michigan.

5.1.d Fuel

Dried Biosolids have another attractive characteristic that may be desirable; they can be used as an alternative fuel source. While Dried Biosolids have a lower BTU content than coal, they are still a viable source of fuel for many processes. The heating value of dried biosolids is approximately 6,000 btu/lb. Coal typically ranges from 9,000 to 12,500 BTU/lb. The inert ash content of biosolids is relatively high in comparison to coal. However, certain industrial fuel consumers such as cement kilns can re-use this ash since it contains abundant amounts of constituents of value in the make-up of cement. Therefore, even the ash can be beneficially utilized.

Offsetting fossil fuel consumption by utilizing dried biosolids as renewable fuel has a dramatic and positive impact on the carbon footprint of the fuel user's products and processes. Biosolids have a much shorter carbon cycle than fossil fuels. In the case of biosolids, atmospheric carbon is cycled into useable solid and liquid organic forms, in a matter of years to decades. Fossil fuels, with a cycle on the order of millennium, are not carbon neutral in any relevant time frame. Fossil fuels introduce over-abundant amounts of CO_2 into the carbon cycle not only through their combustion but also through their production, and distribution, which imposes a massive unbalancing affect on the carbon cycle.

Aside from the economic benefits from the revenue generated, selling dried biosolids as fuel, or setting up contracts which allow for this option, would add tremendous flexibility to the operations at the WWTP. This path would prove extremely useful for the following scenarios:

- Land not available for land application
  - Due to soil conditions
  - Due to weather
  - Due to time of year
  - Due to lost land contracts
- Landfill not viable
  - Due to unforeseen closure
  - Due to increase in hauling / tipping costs

Coal is another product completely imported into the Michigan economy. A large portion of Michigan's gas consumption is also imported. As a result, over $19 billion a year leave Michigan to purchase coal and gas for power and industry in Michigan.

6 Implementation

For the purpose this report, three different implementation scenarios were developed for the proposed BM-E process. These are:

1. BM-E onto a Green Field
2. Stand Alone BM-E at Ann Arbor WWTP
3. BM-E Integration into Ann Arbor SRMP

6.1 Scenario 1

The first Scenario is implementation of the BM-E system onto a “green field” - in other words, a site with no existing restrictions. This assumes there are no site specific conditions or processes that would impose additional requirements on the most cost-effective implementation of the system.

This Scenario serves two purposes within this feasibility study

1. Identification of Cost Drivers: Using Scenario 1 as a basis for comparison to the other two Scenarios aids in distinguishing the cost impacts created by:
   a. the limitations of the available land at Ann Arbor WWTP
   b. integrating the BM-E system with the existing processes and planned improvements.
2. Basis for Transferability: This Scenario is more generic and therefore transferable to other facilities, than are Scenarios B & C which incorporate conditions unique and specific to the Ann Arbor WWTP. By using this scenario as the baseline, other facilities considering this BM-E system can easily identify, define and add modifications to this baseline scenario that may be required by their own site specific conditions and restrictions.

6.2 Scenario 2

The second Scenario is implementation of a “stand-alone” BM-E system at the Ann Arbor WWTP, with consideration of the limited available space only. This Scenario is based on using only the proposed BM-E system as the only biosolids treatment process at the Ann Arbor WWTP. It does not include consideration of or integration with, any of the site and process modifications currently proposed and/or planned as part of the Sewage Residuals Management Plan (SRMP).

6.3 Scenario 3

The third and final Scenario is “integration” of the BM-E System into the planned SRMP site and process improvements, while taking into consideration the physical space limitations of the Ann Arbor WWTP site, and targeting the goals and objectives identified in the SRMP.

This Scenario provides a look at the cost of implementing and operating this BM-E system within the planned SRMP improvements, and illustrates the benefits and value of adding BM-E system to the currently planed SRMP improvements. This value is in the form of:

- further increases to the operational flexibility in the face of
    - changing regulations
    - fluctuating costs (fuel, electricity, landfill, chemicals, labor)
    - plant operations / upsets
    - social / political / public drivers
- increased beneficial re-use
- operational cost savings
    - production of energy
    - re-use of heat
    - lower mass required to transport

6.4 Dewatering Options

All three Scenarios share two key components of the BM-E System with little to no difference. Specifically, these common components are:

- high rate two-phase anaerobic digestion process to destroy volatile solids, reduce mass, and generate biogas
- combined heat and power process to re-use biogas, to create surplus electricity and useable heat for the biosolids treatment processes

Dewatering is also a key component of biosolids handling and processing. Because there are numerous dewatering processes available, and so many factors affecting the selection of a specific dewatering process, three Dewatering Options were developed for each of the Scenarios.

- Dewatering Option A includes the ability to gravity belt thicken the digested sludge if necessary, followed by centrifuge dewatering, and ultimately a drying step that is incorporated as part of the CHP system.
- Dewatering Option B eliminates drying. Centrifuge dewatering is the final processing of the digested sludge.
- Dewatering Option C uses Belt Filter Press equipment for dewatering as the final processing step of the digested sludge.

Together, the three Scenarios, each with three Dewatering Options provide a matrix of nine distinct cases. These nine cases cover a fairly broad spectrum of the available implementation possibilities and their associated capital and operation and maintenance costs.

Appendix C through Appendix K each present detailed information for each of the nine cases. Each appendix contains a brief introduction describing the Scenario and Dewatering Option, and any notable details of its implementation. This is followed by four sets of spreadsheets.

1. Disposal Costs – calculations used as input for O&M Costs
2. Operation & Maintenance Cost – detailing the following:

    a. Energy Consumption
    b. Chemical Consumption
    c. Labor – Operations & Maintenance
    d. Generator Maintenance Contract Costs
    e. Ultimate Disposal
    f. Energy Production
3. Capital Cost Summary – the summary is followed by detailed sheets presenting the Opinion of Probable Construction Cost for each of the following:
    i. Digestion System
    ii. Gas & Generation System
    iii. Sludge Storage & Liquid Reduction Systems
    iv. Structural Additions & Building Renovation Costs
4. BM-E Process Calculations – solids & hydraulic loading of digestion system, gas production, BTU content, dewatering loading & performance, generation, sludge storage, drying.

Appendix B contains the Mass Balance Model used to produce the mass and hydraulic loading inputs for these BM-E Calculations.

7 Economic Analysis

Table 7.1-1 presents the a summary of the capital costs, O&M costs and annualized total cost for all nine cases developed.

Table 7.1-1 Cost Summary

		Dewatering Option:	A BM-E Centrifuge Drying	B BM-E Centrifuge Dewatering	C BM-E BFP Dewatering
Scenario 1	Capital Cost		$ 26,190,288	$ 25,353,288	$ 25,188,988
"Green Field"	Annualized Capital Cost[1]		$ (2,209,804)	$ (2,139,183)	$ (2,125,320)
		Electrical Demand	$ (244,691)	$ (121,968)	$ (94,256)
		Chemical	$ (2,535)	$ (2,535)	$ (2,535)
		O&M Labor	$ (600,000)	$ (686,066)	$ (686,066)
		Disposal	$ (170,980)	$ (326,334)	$ (444,248)
		Electrical Production	$ 645,493	$ 645,493	$ 645,493
	Annual O&M (Year 2025)		$ (458,778)	$ (491,410)	$ (581,611)
		Annual Total:	$ (2,668,582)	$ (2,630,592)	$ (2,706,931)
Scenario 2	Capital Cost		$ 31,277,233	$ 30,310,033	$ 28,779,098
BM-E Only	Annualized Capital Cost[1]		$ (2,639,015)	$ (2,557,408)	$ (2,428,235)
		Electrical Demand	$ (232,516)	$ (104,892)	$ (94,256)
		Chemical	$ (2,535)	$ (2,535)	$ (2,534)
		O&M Labor	$ (686,066)	$ (686,066)	$ (653,305)
		Disposal	$ (170,980)	$ (326,334)	$ (444,242)
		Electrical Production	$ 645,493	$ 645,493	$ 645,485
	Annual O&M (Year 2025)		$ (446,602)	$ (474,333)	$ (548,853)
		Annual Total:	$ (3,085,617)	$ (3,031,741)	$ (2,977,088)
Scenario 3	Capital Cost		$ 22,500,104	$ 19,899,148	$ 19,982,848
BM-E Integrated with SRMP	Annualized Capital Cost[1]		$ (1,898,445)	$ (1,678,990)	$ (1,686,052)
		Electrical Demand	$ (250,641)	$ (126,058)	$ (95,073)
		Chemical	$ (5,833)	$ (5,833)	$ (5,833)
		O&M Labor	$ (688,040)	$ (655,280)	$ (655,279)
		Disposal	$ (197,561)	$ (349,214)	$ (458,557)
		Electrical Production	$ 660,298	$ 660,298	$ 660,290
	Annual O&M (Year 2025)		$ (481,777)	$ (476,087)	$ (554,452)
		Annual Total:	$ (2,380,223)	$ (2,155,077)	$ (2,240,504)
Baseline	Capital Cost		$ 28,000,000		
Baseline GBT / CFG	Annualized Capital Cost[1]		$ (2,362,499)		
		Energy Consumption	$ (205,289)		
		Chemical	$ (5,833)		
		O&M Labor	$ (600,000)		
		Disposal	$ (1,139,590)		
		Electrical Production	$ -		
	Annual O&M (Year 2025)		$ (1,950,713)		
		Annual Total:	$ (4,313,212)		

[1] 20 Years @ 5.6%

The following is a summary of the information contained in Table 7.1-1:

This table includes a “Baseline” condition based on the proposed process and site modifications currently being implemented through the existing SRMP. These figures were deduced from the information contained in the SRMP report.

The capital cost includes equipment and construction costs, as well as contingency and contractor's overhead and profit. The Annualized Capital Cost presented in this table is the Capital Cost annualized over a 20 year period at 5.6% interest.

Operating Costs shown on Table 7.1-1 include electrical demand, labor, chemicals, disposal, as well as a credit for electricity produced. These are totaled for each case and presented as Annual Operating Cost.

For labor requirements, the BM-E System Scenarios conservatively calculate approximately five full-time-equivalents (FTE). The demand for this labor breaks down roughly as 3.75 FTE for Operations tasks and 1.25 FTE for Maintenance tasks. It is important to note that Scenario 3 cases include labor for operation and maintenance of equipment already contained in the SRMP.

The sum of the Annualized Capital Cost and the Annual Operating Cost is the Total Annualized Cost.

The annualized cost of capital and O&M combined, for the BM-E cases ranges from $2,380,000 to $3,080,000. The annualized cost for the Baseline SRMP is $4,300,000.   Over $1,900,000 per year of this is O&M cost alone.

Despite a higher capital first cost and a higher parasitic electrical load, there is little economic deterrent to include a drying system in a project such as this. These increased costs are greatly offset by a reduction in disposal and transportation costs which are largely attributable to the reduction in the volume of solids to be handled. The dried end product will also lead to greater flexibility in the disposal of this product and will also be more attractive as a marketable product.

Table 7.1-2 Unitized Costs

	Total Capital Cost	Annual O&M Cost	Total Annualized Cost	Cost / Dry Ton Fed	Cost / MG Treated
Scenario 1 - Green Field					
Option A - Drying	$ 26,190,288	$ (458,778)	$ (2,668,582)	$ (261)	$ (248)
Option B - Centrifuge Dewatering	$ 25,353,288	$ (491,410)	$ (2,630,592)	$ (257)	$ (244)
Option C - BFP Dewatering	$ 25,188,988	$ (581,611)	$ (2,706,931)	$ (265)	$ (251)
Scenario 2 - Stand Alone BM-E System					
Option A - Drying	$ 31,277,233	$ (446,602)	$ (3,085,617)	$ (302)	$ (287)
Option B - Centrifuge Dewatering	$ 30,310,033	$ (474,333)	$ (3,031,741)	$ (296)	$ (282)
Option C - BFP Dewatering	$ 28,779,098	$ (548,853)	$ (2,977,088)	$ (291)	$ (276)
Scenario 3 - BM-E Integrated with SRMP					
Option A - Drying	$ 22,500,104	$ (481,777)	$ (2,380,223)	$ (228)	$ (221)
Option B - Centrifuge Dewatering	$ 19,899,148	$ (476,087)	$ (2,155,077)	$ (206)	$ (200)
Option C - BFP Dewatering	$ 19,982,848	$ (554,452)	$ (2,240,504)	$ (214)	$ (208)
Baseline	$ 28,000,000	$ (1,950,713)	$ (4,313,212)	$ (381)	$ (401)

Table 7.1-2 presents a comparison of the annualized capital and O&M costs unitized on two different parameters: dry tons fed to the process, and per million gallons treated. Comparing these scenarios on a basis of these inputs into the system is a more accurate basis of comparison due to the fact that the BM-E system reduces the mass of total solids through the digestion process resulting in a reduced output of solids. If the costs were unitized based upon outputs the

BM-E systems costs would look artificially higher compared to the baseline because the solids reduction due to the digestion process is not considered.

In all cases, the BM-E system scenarios have lower unit costs than the baseline. This is primarily due to:

- the solids reduction achieved within the 2-Phase Anaerobic digestion resulting in lower transportation costs (Solids Volume Minimization)
- the beneficial re-use of digester gas to generate electricity above the demand of the BM-E system (Resource Recovery)
- the efficiency of the BM-E system that results from re-use of heat from the generation system. (Energy Conservation)

Looking at this in terms of mass of solids fed to the biosolids processing facility of the BM-E versus Baseline SRMP, the savings ranges between $79 to $175 per ton on the basis of dry tons fed to the BM-E, or $114 to $194 per MG on the basis of MG treated by the plant.

At these rates of savings, and taking into account that the City of Ann Arbor was prepared to undertake a projected $28 million dollar capital improvement project, the additional $3 million dollars that it would take to build a stand alone BM-E system would be paid back in 2 years. After that payback period, the City would continue to realize a savings of about $1.5 million dollars per year in reduced operating costs over that which would otherwise be incurred under the currently planned project.

The Capital Costs on the above tables are based on the Opinions of Probable Construction Cost contained in Appendices C through K. These Appendices further detail the basis for the O&M costs.

8 Other Benefits & Considerations

The Economic Analysis presented in Section 7 is solely framed within the context of the plant operations. There are many substantial economic impacts outside of this framework that cannot be illustrated by, or even introduced in such an analysis. The act of displacing a major energy net consumer with a net energy producer on the scale of a WWTP, which is typically a municipal government's biggest energy demand, can create far reaching and significant positive impacts on both the local and state economy.

Beyond economics, there a many additional social, political, and environmental benefits, that must be considered and examined as well.

This section and it contents introduce some of these factors
:

- impacts on the local and state economy
- the need for and trend towards decentralized power
- the potential for using biosolids as an alternative fuel for industry
- global energy issues
- Michigan landfill politics
- alternative financing solutions available to renewable energy class projects
- Class A biosolids and pathogen reactivation
- Site constrains and lack of available land – specific to the Ann Arbor WWTP

8.1 Impacts on Local and State Economy

8.1.a Economic Impacts (State & Local)

The net effect of reducing the amount of energy Ann Arbor purchases from traditional non-renewable sources would serve to not only to buffer the local municipal WWTP budget from increasing prices, but would have an effect on the overall economy of the State. This rings true when you consider the fact that almost all of our fuel sources for the energy we consume come from outside of the state and represent dollars leaving our local economy. By generating energy from a local renewable resource, these dollars remain in our economy and can be put to use to increase the economic vitality of the region.

8.1.b Marketable Product

As described in Section 5, the BM-E system end-product has tremendous potential as a marketable product. A growing number of cities are pioneering this avenue with Class A biosolids. This potential is further enhanced when the BM-E system is couple with the drying option which reduces transport costs and opens up avenues for fuel use. The marketable characteristic of the BM-E end products will aid in stimulation of the local and state economies.

8.2 Need for a Trend Towards Distributed Power Generation

The State of Michigan is approaching an energy crisis. As the price for fuel and the demand for it continue to rise, Michigan is in the ill-fated position of importing nearly all of its fuel. Michigan imports 100% of its petroleum, 100% of its coal used for electricity generation, and 75% of the natural gas consumed within the state. Fuel prices have been steadily increasing over time, even before recent natural disasters devastated our nation's natural gas, and petroleum refining infrastructure. In September 2005, natural gas had reached beyond $12 per million cubic feet. A prediction of this was inconceivable only a year earlier.

The State of Michigan's ongoing Capacity Need Forum investigation has preliminarily reported that electricity demand in the state will likely increase more than 30% by 2025 over 2005 levels, if significant emphasis on energy efficiency and renewable energy projects are not implemented.

There are no centralized power plants currently planned for implementation, which would quench this increase in demand. Further, the electrical transmission infrastructure would require massive expansion in order to effectively distribute power from such a centralized facility.

This projected increase in electrical demand, without a substantial increase in production or transmission capacity, dramatically decreases Michigan's energy security. Michigan, like all of the United States is vulnerable to fuel and electricity interruptions based on political conflicts in the Middle East, natural disasters such as hurricanes in the Gulf of Mexico, and broad failures of the electrical distribution infrastructure such as the blackout in 2003.

One means of increasing production as well as increasing the security of Michigan's electrical distribution is through the use of decentralized power facilities. These facilities produce energy for use on a more local level. Because their power is used locally, decentralized power facilities actually free up transmission system capacity.

The power facility proposed as part of the BM-E system would essentially act as a decentralized power facility.

However, decentralized generators face many obstacles to fair competition on the open energy market (grid), and usually get much lower subsidies than centralized coal-fired or nuclear plants. BM-E at WWTPs avoids some of the pains of market competition because of the existing on-site high energy demands at WWTPs. Further, BM-E has the advantage provided by the on-site fuel source of renewable/sustainable biomass.

8.3 Global Energy Issues

Most of the waste heat discarded at US power stations – which amounts to 20% more energy than Japan uses in total – could be lucratively recycled. Recognizing this, the proposed BM-E system captures the waste heat from its generation system, and beneficially uses it to dry solids, which leads to lower disposal costs. This heat is also used to maintain the digestion system at the proper temperature.

Natural disaster, war, and an ever increasing energy demand across the globe are each factors that have tremendous impact on the availability and cost of energy. There are countless arguments in favor of investing in, and committing to a future that utilizes a wide array of renewable energy sources. The proposed BM-E system is an important step in this direction.

8.4 Michigan Landfill Market & Politics

Currently, Michigan allows its landfills to accept solid waste from out of state sources. Canada exports massive amounts of solid waste to Michigan landfills. This has become a contentious issue within the state, and is generally unwanted by the Michigan public.

Due to the North American Free Trade Agreement (NAFTA), it has been difficult for the State to do anything to curtail this practice.

At the time this feasibility study was conducted, Ann Arbor's contract to dispose of biosolids at a local landfill was $17/ wet ton.

During this same time, the State House of Representatives passed a bill which imposes a $7.50 / wet ton fee on all solid waste disposed of in Michigan landfills. (This fee had not yet passed the State Senate, and is not included in the operating cost calculations or economic analyses contained in this report.)

Should this pass, it will amount to a 44% increase in the landfill disposal costs.

This example highlights the volatile nature of landfill disposal and the need for flexibility in any biosolids management plan in the form of a wide array of available paths for the ultimate fate of biosolids. It also underscores the importance of solids volume minimization through anaerobic digestion and conversion to biogas, as well as optimizing dewatering, and utilizing drying processes.

8.5 Financing Alternatives

There are currently many initiatives in place through a variety of sources that may create some innovative methods to finance a project including the BM-E system. Various low interest financing sources and even grants could be available to finance portions or this entire project.

8.6 *Class A Biosolids*

There are many benefits associated with producing Class A (EQ) biosolids in lieu of Class B which is more common level of treatment in the industry. These have been identified and expanded upon in other sections of this report.

The major factor in achieving a Class A biosolids classification is pathogen destruction. The Class A biosolids classification along with processes for producing them are all relatively new. As such, engineering, science and operations are continuously making discoveries and enhancements. Occasionally these discoveries identify new concerns. One of these concerns is Pathogen Reactivation.

8.6.a Pathogen Reactivation

Recently, the Water Environment Research Foundation (WERF) has identified several cases in which pathogens contained in biosolids that have been destroyed to Class A levels, have "reactivated" after the dewatering process. Upon reactivation, the biosolids no longer meet Class A requirements.

In response, WERF set upon a plan to study and further define the problem as well as identify potential solutions.

The first phase of this plan was a study designed to identify and define the problem.

The first phase study looked at conventional mesophilic digestion systems as well as two-phase digestion systems. The mesophilic systems using centrifuge dewatering did exhibit higher pathogen counts following dewatering. The two phase systems were all of the TPAD type, which is fundamentally different from the 2PAD. The original TPAD designs use a continuous flow through the thermophilic and mesophilic digesters connected in series, and are strictly temperature phased. There is a potential for short circuiting. The 2PAD process is significantly different in that it is a semi-batch process and it does separate the acid and methane forming phases. Studies on the 2PAD process have shown that it reduces the fecal coliform MPN (Most Probable Number) to less than 10 per gram of total solids. The requirement for Class A is less than 1,000 per gram of total solids. So, the 2PAD process has a 2-log buffer below the requirement.

The current EPA analytical method (standard culturing) may not have been able to distinguish dormant pathogens. Another analytical method, PCR, which measures number of copies of DNA) does apparently measure dormant pathogens in the digester discharge.

In contrast to the TPAD studied, the 2PAD system uses "semi-batch" processing and complete mixing (>90% active volume) to eliminate the potential for pathogens to "short circuit" and reduce their exposure to the entire destruction process. Four types of TPAD systems were tested for the original WERF research project. Two of these exhibited reactivation, two did not. The Biopasturization process was also tested, and exhibited reactivation.

To date, reactivation has only occurred with processes using high rate centrifuges for dewatering. Further, reactivation has not occurred in all cases of dewatering Class A biosolids with centrifuges. No instances of reactivation have been identified on processes using belt filter presses for dewatering.

This 1st Study Phase of the WERF investigation identified the problem. It did not identify the cause, or determine whether it is related to either the type of digestion process used to achieve destruction, the mechanics and shear forces imparted on a cellular level in the dewatering equipment, or the analytical methods used to detect, identify, and quantify pathogens.

WERF is proceeding with a 2nd Phase Study as part of this investigation. This phase is focused on obtaining more information to answer questions raised about digestion process destruction, centrifuge equipment, and analytical methods.

As to how the pathogen reactivation issue relates to the proposed BM-E system, the current information seems to indicate pathogen reactivation could be a problem for the BM-E system if centrifuges are used for dewatering (Dewatering Option B for each Scenario). If belt filter presses are used for dewatering (Option C), the current information appears to indicate that pathogen reactivation will not occur. For Dewatering Option A, centrifuge dewatering followed by drying, pathogen reactivation would not be a concern due to the thermal pathogen destruction achieved in the drying process.

Further, the 2PAD process used in the BM-E system is a completely mixed, semi-batched process, specifically for the purpose of eliminating potential for pathogen short circuiting, and ensuring sufficient exposure of pathogens to acid and temperature conditions required for maximum destruction. This is fundamentally different than the two-phase processes tested in WERFs 1st Phase Study, which may be forcing some pathogens to a dormant state, short of complete destruction.

8.7 Available Space

Scenario 1 assumes an ideal site with no restrictions on available land or constructability. Scenarios 2 & 3 are targeted specifically for the Ann Arbor WWTP, which is severely landlocked with almost no open area for new facilities. This has a dramatic impact on the constructability of any new project on the site.

It is outside the scope of this report to size primary and secondary treatment process improvements, however, the use of high rate clarifiers for primary treatment and advanced space saving technologies for secondary treatment should be considered.

High rate clarification equipment capable of achieving 4 gpm/sf loading rates, 85% TSS removal and 50% BOD removal is readily available in the marketplace. Utilizing this style of clarification makes sense when on-site available space is at such a premium. Two such units sized for a hydraulic load of 20 MGD would require only 4,000 square feet of area. In comparison existing clarifiers at the WWTP are typically loaded at 400 to 700 gpd /sf. In order to treat a 20 MGD hydraulic load, this type of traditional clarifier would require 28,000 sf for primary treatment.

For secondary treatment, a moving bed bio-reactor (MBBR) process could be sized for approximately 1.6 hour HRT (hydraulic retention time), and produce an effluent with BOD & TSS concentrations <15 mg/L. For a 20 MGD hydraulic load, this would translate to approximately 1,300,000 gallons (or 180,000 cubic feet) of secondary treatment volume. The plant currently has 10 MG of aeration tank operating volume. Retrofitting this 10 MG of volume to MBBR with a 2.0 HRT would result in a secondary capacity of 120 MGD.

Therefore, again due to the premium of on-site space, any expansion of secondary treatment should consider low footprint treatment technology such as the MBBR or others. In addition, in lieu of new MBBR tanks, retrofitting existing aeration tanks to MBBR merits consideration.

9 Conclusions

Based on the sizing and economic calculations, the following general conclusions are made:

1.) It is feasible to implement a BM-E system at the Ann Arbor WWTP that would create a surplus of energy (both electrical and heat) significantly reducing the amount of energy that the City of Ann Arbor would have to purchase from non-renewable sources.
2.) The BM-E would have a significant effect in reducing the operational, costs associated with handling the biosolids produced at the plant. This saving is primarily the result of a reduction in the amount of material that must be removed from the site.
3.) On a site without the spatial limitations and challenges of Ann Arbor WWTP, but within the same size range (20 MGD), it is feasible to design, construct, operate and maintain the proposed Biomass-to-Energy system in a manner that is economically attractive, and both environmentally and socially friendly. Scenario 1 demonstrates this, and projects that in this size range, the annualized cost would be $260 / dry ton of solids or $245 / MG treated. When compared to the Baseline this equates to a benefit of $381 / dry ton or $401 / MG over existing conditions.
4.) The drying component of this system is not a necessary component to make the BM-E system feasible or economically attractive. However, the economic analysis does indicate that drying is an attractive enhancement despite the fact that it adds to the initial capital cost of the system.

When ranked by Total Annualized Cost, Scenario 3B is the most economically attractive case at an annual cost of $2,155,077. Scenario 3A, at $2,380,223, is about 10% higher in cost. All of the scenarios that did not consider integration with the existing SRMP were higher in cost, largely due to the inclusion of process equipment in the capital cost that was already planned for installation by the SRMP.

Through extensive administrative, engineering, operations, maintenance, and public consideration, the SRMP identified additional criteria and objectives beyond economic measures that are to be seriously considered in determining the best course of action for the Ann Arbor WWTP. These include operational flexibility, as well as utility of the end-product, potential for beneficial re-use of the end-product, vehicular traffic, public acceptance etc.

Taking these additional criteria into consideration, and despite the higher capital cost, Scenario 3A appears to be the most attractive Scenario for the Ann Arbor WWTP, because it meets and enhances the SRMP stated goals while being sensitive to the challenges of limited on-site available space. Integrating BM-E system with the current SRMP under this scenario enhances the available flexibility of operations, produces a marketable Class A end-product, substantially increases the extent beneficial re-use is practiced at the plant, and dramatically reduces vehicular traffic.

Integrating the BM-E system into the existing SRMP project the City of Ann Arbor would be increase the capital cost of this project from an estimated $28 million dollar project to a $50 million dollar project. On the surface this seems to be an insurmountable dollar figure to justify. When factoring in the reduced operational costs and break the figures down to an equivalent annual cost, the following figures are derived:

Integration of BM-E into SRMP Project 20-year equivalent annual cost:	$4,742,721
Currently planned SRMP project 20-year equivalent annual cost:	$4,313,212

The figures suggest that for by spending 10% more than was originally planned over the next 20 years, the City of Ann Arbor could implement the BM-E system into the currently planned project. Further the City of Ann Arbor would benefit by achieving a more environmentally sustainable means of biosolids disposal, and moving forward in its goal to obtain energy from renewable sources.

Appendix A

Summary of Assumptions

Ann Arbor CHP - Feasibility Study
Solids Mass Balance

Assumptions & Inputs
SCENARIO 3A: BM-E System - Drying

1.) Raw Wastewater Flow & Characteristics					
Influent BOD					
Concentration (mg/L)	INPUT	145	(mg/L)	2003 G&H Report	
Influent TSS					
Concentration (mg/L)	INPUT	200	(mg/L)	2003 G&H Report	
2.) Primary Clarifiers					
Size of Primary Clarifiers					
Operating Surface Area (sf)	INPUT	43,142	(sf)	2003 G&H Report	
Operating Volume (cf)	INPUT	462,836	(cf)	2003 G&H Report	
Removal Efficiency (%)					
BOD		52.0%		SOURCE OF FORMULA is	2003 Trendline
TSS		73.0%		SOURCE OF FORMULA is	2003 Trendline
Primary Sludge					
Solids Concentration (%)	INPUT	4.0%		2003 G&H Report	
%Volatile Organics		70.0%		Assumed	
4.) Aeration Tanks					
Effluent Concentration (mg/L)					
BOD Removal Efficiency	EST	90%	(mg/L)	Assumed Removal Efficiency Based on 1998 & 2003 Reports	
TSS Removal Efficiency	EST	89%	(mg/L)	Assumed Removal Efficiency Based on 1998 & 2003 Reports	
Aeration Tank Operating Volume (MG)	INPUT	10.0	(Mgal)	2003 G&H Report	
Solids Production					
WAS Yield (mg TSS / mg BOD removed)	INPUT	0.976		ASSUMED (See A2 & Greeley Hansen Comments)	
Mixed Liquor Suspended Solids					
MLSS [Xa=srt*Xtss*Q/Va] (mg/L)	INPUT	2,108	(mg/L)	2003 G&H Report	
Volatile Ratio	INPUT	69%		2003 G&H Report	
RAS Ratio	INPUT	0.26		2003 G&H Report	
Ferric Chloride Added [BioP Removal] lbs/day	EST	107	lb/MG	2145 #/d / 19.98 MGD	Assumed Ratio of lbs/MG
5.) Secondary Clarifiers					
Number of Clarifiers					
Total	INPUT	9		2003 G&H Report	
Operating	INPUT	8		2003 G&H Report	
Size of Clarifiers					
Inside Diameter (ft.)	INPUT	92.20	(ft.)	2003 G&H Report	
Water Depth (ft.)	INPUT	11.00	(ft.)	2003 G&H Report	
6.) Gravity Thickeners					
Number of Tanks					
Total	INPUT	3.00		2003 G&H Report	
Operating	INPUT	1.00		Assume 1 Operating 1 Back-up 1 Other Use	
Size of Thickeners					
Diameter (ft)	INPUT	70.00		2003 G&H Report	
Water Depth (ft)	INPUT	12.00		2003 G&H Report	
Sludge to Thickeners					
Dilution Water (MGD)	EST	0.04	(MGD)	0.01 MG/0.28MG	Assumed Ratio of MG Dilution/MG Sludge Flo
Thickened Sludge					
Solids Capture (%)	INPUT	77.5%		2003 G&H Report	
Sludge Concentration (mg/L)	INPUT	37,334	(mg/L)	2003 G&H Report	!ASSUMED 3.73% SOLIDS!
6A.) 2PAD Process					
Volatile Solids Destruction	EST	60%			Normal Range 60-75%
Biogas Production (cf/lb VS destroyed)	EST	17.00			
Biogas Energy (BTU/cf)	EST	600			
7.) Sludge Chemical Conditioning					
Conditioning Chemicals (lbs/day)					
[assumed 80% retained in sludge mass]					
Ferric Chloride	EST	-	3328 # / 0.12 MG		Assumed Dose lbs FeCl / MG Sludge
Lime	EST	-	9073 # / 0.12 MG		Assumed Dose lbs Lime / MG Sludge
GBT Polymer	EST	9.20			Assumed Dose lbs active / dry ton sludge
CFG Polymer	EST	7.10			Assumed Dose lbs active / dry ton sludge
8.) Gravity Belt Thickening (GBT)					
GBT Sludge					
Solids Capture (%)	INPUT	95%		2003 G&H Report	
GBT Sludge Solids Content (%)	INPUT	4.2%		2003 G&H Report	
9.) Dewatering					
Dewatered Sludge					
Solids Capture (%)	INPUT	95%		2003 G&H Report	
Dewatered Sludge Solids Content (%)	INPUT	32.0%		2003 G&H Report	
10.) Filter Backwash Water					
Flow Rate (MGD)	EST	3.0%	(MGD)		Assumed 3.0% of Secondary Effluent Flow
TSS Concentration (mg/L)	INPUT	100	(mg/L)	2003 G&H Report	
11.) Recycle Stream					
Gravity Thickener BOD / TSS Ratio	INPUT	26%		2003 G&H Report	
GBT & Dewatering Filtrate BOD / TSS Ratio	INPUT	26%		2003 G&H Report	
Filter Backwash BOD / TSS Ratio	INPUT	50%		2003 G&H Report	
12.) Electricity					
Price ($/(kW*hr))	$	0.075			

Appendix B

Solids Mass Balance Projections

Ann Arbor CHP - Feasibility Study
Solids Mass Balance

SCENARIO 3A: BM-E System - Drying

1.) Raw Wastewater Flow & Characteristics								
Influent Flow (MGD)	(MGD)	INPUT	19.20	21.78	24.35	26.93	29.50	(MGD)
Influent BOD								
Concentration (mg/L)	(mg/L)	INPUT	162	159	156	152	149	(mg/L)
Mass Loading (lbs/day)	(lbs/day)		25,941	28,830	31,579	34,188	36,658	(lbs/day)
Influent TSS								
Concentration (mg/L)	(mg/L)	INPUT	195	200	205	210	215	(mg/L)
Mass Loading (lbs/day)	(lbs/day)		31,225	36,321	41,631	47,156	52,896	(lbs/day)
2.) Primary Clarifiers								
Flow Rate (MGD)								
Raw Wastewater	(MGD)		19.20	21.78	24.35	26.93	29.50	(MGD)
Recycle	(MGD)		0.86	0.98	1.10	1.21	1.33	(MGD)
Total	(MGD)		20.06	22.76	25.45	28.14	30.83	(MGD)
BOD Loading (lbs/day)								
Raw Wastewater	(lbs/day)		25,941	28,830	31,579	34,188	36,658	(lbs/day)
Recycle	(lbs/day)		3,459	3,964	4,478	4,999	5,528	(lbs/day)
Combined	(lbs/day)		29,400	32,794	36,056	39,187	42,187	(lbs/day)
TSS Loading (lbs/day)								
Raw Wastewater	(lbs/day)		31,225	36,321	41,631	47,156	52,896	(lbs/day)
Recycle	(lbs/day)		12,848	14,729	16,642	18,586	20,560	(lbs/day)
Combined	(lbs/day)		44,073	51,049	58,273	65,742	73,457	(lbs/day)
Influent Concentrations								
BOD (mg/L)	(mg/L)		176	173	170	167	164	(mg/L)
TSS (mg/L)	(mg/L)		263	269	275	280	286	(mg/L)
Size of Primary Clarifiers								
Operating Surface Area (sf)	(sf)	INPUT	43,142	43,142	43,142	43,142	43,142	(sf)
Operating Volume (cf)	(cf)	INPUT	462,836	462,836	462,836	462,836	462,836	(cf)
Hydraulic Detention Time (hrs)	(hrs)		4.14	3.65	3.27	2.95	2.69	(hrs)
Surface Overflow Rate (SOR)	(gpd/sf)		465	527	590	652	715	(gpd/sf)
Removal Efficiency (%)								
BOD			52.3%	51.7%	51.1%	50.5%	49.8%	
TSS			71.9%	71.6%	71.4%	71.1%	70.9%	
Primary Effluent Concentration (mg/L)								
BOD	(mg/L)		83.7	83.4	83.1	82.7	82.3	(mg/L)
TSS	(mg/L)		74.0	76.3	78.6	80.8	83.2	(mg/L)
Primary Sludge								
Mass Rate (lbs/day)	(lbs/day)		31,684	36,572	41,601	46,770	52,074	(lbs/day)
Solids Concentration (%)		INPUT	4.0%	4.0%	4.0%	4.0%	4.0%	
Flow Rate (MGD)	(MGD)		0.095	0.110	0.125	0.140	0.156	(MGD)
Volatile Solids	(lbs/day)	CALC	22,179	25,600	29,121	32,739	36,452	(lbs/day)
3.) ????????????????								
4.) Aeration Tanks								
Flow Rate (MGD)	(MGD)		19.97	22.65	25.32	28.00	30.68	(MGD)
Influent Concentrations								
BOD (mg/L)	(mg/L)		83.7	83.4	83.1	82.7	82.3	(mg/L)
TSS (mg/L)	(mg/L)		74.0	76.3	78.6	80.8	83.2	(mg/L)
Effluent Concentration (mg/L)								
BOD (mg/L)	(mg/L)	CALC	8.0	8.0	7.9	7.9	7.8	(mg/L)
TSS (mg/L)	(mg/L)	CALC	8.1	8.4	8.6	8.9	9.1	(mg/L)
Aeration Tank Operating Volume (MG)	(Mgal)	INPUT	10.0	10.0	10.0	10.0	10.0	(Mgal)
Hydraulic Detention Time (hrs)	(hrs)		12.0	10.6	9.5	8.6	7.8	(hrs)
SRT (days)			12.86	11.34	10.15	9.19	8.40	
Solids Production								
WAS Yield (mg TSS / mg BOD removed)		INPUT	0.976	0.976	0.976	0.976	0.976	
WAS Solids Production (TSS mg/L)	(mg/L)		73.9	73.7	73.4	73.0	72.7	(mg/L)
Effluent TSS (mg/L)	(mg/L)		8.1	8.4	8.6	8.9	9.1	(mg/L)
Total Solids Production (TSS mg/L)	(mg/L)		82.1	82.1	82.0	81.9	81.8	(mg/L)
True Yield (mg TSS / mg BOD removed)			1.08	1.09	1.09	1.09	1.10	
Mixed Liquor Suspended Solids								
MLSS [Xa=srt*Xtss*Q/Va] (mg/L)	(mg/L)	INPUT	2,108	2,108	2,108	2,108	2,108	(mg/L)
Volatile Ratio		INPUT	0.69	0.69	0.69	0.69	0.69	
MLVSS (mg/L)	(mg/L)		1,455	1,455	1,455	1,455	1,455	(mg/L)
RAS Ratio		INPUT	0.26	0.26	0.26	0.26	0.26	
Ferric Chloride Added [BioP Removal] lbs/day	(lbs/day)	CALC	2,144	2,431	2,719	3,006	3,293	(lbs/day)
WAS								
WAS Concentration [Xr=Xlp*(1+r)/r] (mg/L)	(mg/L)		10,216	10,216	10,216	10,216	10,216	(mg/L)

WAS waste qty (lbs/day)	(lbs/day)		14,458	16,345	18,213	20,060	21,882	(lbs/day)
WAS waste flow (MGD)	(MGD)		0.17	0.19	0.21	0.24	0.26	(MGD)
F/M [lb BOD applied / lb VSS]			0.02	0.02	0.02	0.02	0.02	
Volume Loading (lbs/1000 cf)			10.43	11.79	13.13	14.45	15.75	
5.) Secondary Clarifiers								
Flow (MGD)	(MGD)		19.80	22.45	25.11	27.76	30.42	(MGD)
Number of Clarifiers								
Total		INPUT	9	9	9	9	9	
Operating		INPUT	8	8	8	8	8	
Size of Clarifiers								
Inside Diameter (ft.)	(ft.)	INPUT	92.20	92.20	92.20	92.20	92.20	(ft.)
Water Depth (ft.)	(ft.)	INPUT	11.00	11.00	11.00	11.00	11.00	(ft.)
Operating Surface Area (sf)	(sf)		53,412	53,412	53,412	53,412	53,412	(sf)
Operating Volume (cf)	(cf)		587,536	587,536	587,536	587,536	587,536	(cf)
Hydraulic Detention Time (hrs)	(hrs)		5.3	4.7	4.2	3.8	3.5	(hrs)
Surface Overflow Rate (gpd/sf)	(gpd/sf)		371	420	470	520	570	(gpd/sf)
Solids Loading Rate								
RAS Rate (r)			0.26	0.26	0.26	0.26	0.26	
Loading Rate (lbs/sf/d)			8.3	9.4	10.5	11.6	12.7	
6.) Gravity Thickeners								
Number of Tanks								
Total		INPUT	3.00	3.00	3.00	3.00	3.00	
Operating		INPUT	1.00	1.00	1.00	1.00	1.00	
Size of Thickeners								
Diameter (ft)		INPUT	70.00	70.00	70.00	70.00	70.00	
Water Depth (ft)		INPUT	12.00	12.00	12.00	12.00	12.00	
Operating Surface Area (sf)			3,848	3,848	3,848	3,848	3,848	
Operating Volume (cf)			46,181	46,181	46,181	46,181	46,181	
Sludge to Thickeners								
Sludge Flow (MGD)	(MGD)		0.26	0.30	0.34	0.38	0.41	(MGD)
Dilution Water (MGD)	(MGD)	CALC	0.01	0.01	0.01	0.01	0.01	(MGD)
Total Flow (MGD)	(MGD)		0.27	0.31	0.35	0.39	0.43	(MGD)
Sludge Quantity (lbs/day)	(lbs/day)		46,142	52,917	59,815	66,830	73,957	(lbs/day)
Sludge Conc. to Thickeners (mg/L)	(mg/L)		20,183	20,321	20,458	20,596	20,734	(mg/L)
Hydraulic Detention Time (hrs)	(hrs)		30.24	26.55	23.65	21.31	19.38	(hrs)
Surface Overflow Rate (gpd/sf)	(gpd/sf)		71	81	91	101	111	(gpd/sf)
Solids Loading Rate (lbs/sf/day)	(lbs/day/sf)		11.99	13.75	15.54	17.37	19.22	(lbs/day/sf)
Thickened Sludge								
Solids Capture (%)		INPUT	77.5%	77.5%	77.5%	77.5%	77.5%	
Sludge Quantity (lbs/day)	(lbs/day)		35,760	41,011	46,356	51,793	57,316	(lbs/day)
Sludge Concentration (mg/L)	(mg/L)	INPUT	37,334	37,334	37,334	37,334	37,334	(mg/L)
Volatile Solids	*(lbs/day)*		*24,920*	*28,581*	*32,308*	*36,100*	*39,952*	*(lbs/day)*
Sludge Flow (MGD)	(MGD)		0.114849	0.131713	0.148881	0.166341	0.184081	(MGD)
Supernatant								
Sludge Quantity (lbs/day)	(lbs/day)		10,382	11,906	13,458	15,037	16,640	(lbs/day)
Supernatant Flow (MGD)	(MGD)		0.16	0.18	0.20	0.22	0.24	(MGD)
TSS Concentration (mg/L)	(mg/L)		7,816	7,908	8,001	8,095	8,191	(mg/L)
6A) 2PAD Process								
Volatile Destruction (%)	*(%)*		*60%*	*60%*	*60%*	*60%*	*60%*	*(%)*
2PAD Sludge Output								
Hydraulic Flow	*(MGD)*		*0.114849*	*0.131713*	*0.148881*	*0.166341*	*0.184081*	*(MGD)*
Solids Mass Flow	*(lbs/day)*		*20,808*	*23,862*	*26,971*	*30,133*	*33,345*	*(lbs/day)*
% Solids	*(%)*		*2.17%*	*2.17%*	*2.17%*	*2.17%*	*2.17%*	*(%)*
VS Destroyed	*(lbs/day)*		*14,952*	*17,149*	*19,385*	*21,660*	*23,971*	*(lbs/day)*
7.) Sludge Chemical Conditioning								
Conditioning Chemicals (lbs/day)								
[assumed 80% retained in sludge mass]								
Ferric Chloride	(lbs/day)	CALC	-	-	-	-	-	(lbs/day)
Lime	(lbs/day)	CALC	-	-	-	-	-	(lbs/day)
GBT Polymer	*(lbs/day)*		*96*	*110*	*124*	*139*	*153*	*(lbs/day)*
CFG Polymer	*(lbs/day)*		*70*	*81*	*91*	*102*	*113*	*(lbs/day)*
Ferric Chloride Flow (MGD)	(MGD)		-	-	-	-	-	(MGD)
Lime Flow (MGD)	(MGD)		-	-	-	-	-	(MGD)
GBT Polymer Flow	*(MGD)*		*0.002*	*0.002*	*0.003*	*0.003*	*0.003*	*(MGD)*
CFG Polymer Flow	*(MGD)*		*0.004934*	*0.006*	*0.006*	*0.007*	*0.008*	*(MGD)*
8.) Gravity Belt Thickening (GBT)								
Conditioned Sludge Feed to GBT								
Sludge Flow (MGD)	*(MGD)*		*0.12*	*0.13*	*0.15*	*0.17*	*0.19*	*(MGD)*
Sludge Quantity (lbs/day)	*(lbs/day)*		*20,904*	*23,972*	*27,095*	*30,272*	*33,499*	*(lbs/day)*
Sludge Concentration (mg/L)	*(mg/L)*		*21,418*	*21,417*	*21,416*	*21,415*	*21,414*	*(mg/L)*
GBT Sludge								
Solids Capture (%)		*INPUT*	*95%*	*95%*	*95%*	*95%*	*95%*	
GBT Sludge Solids (lbs/day)	*(lbs/day)*		*19,859*	*22,773*	*25,741*	*28,758*	*31,824*	*(lbs/day)*

GBT Sludge Solids Content (%)		*INPUT*	*4.2%*	*4.2%*	*4.2%*	*4.2%*	*4.2%*	
GBT Sludge Volume (cf/d)	*(cf/d)*		*7,579*	*8,692*	*9,824*	*10,976*	*12,146*	*(cf/d)*
Wet Weight @ sg=1.02	*(lbs/day)*		*482,282*	*553,069*	*625,131*	*698,413*	*772,862*	*(lbs/day)*
GBT Recycle								
Flow Rate (MGD)	*(MGD)*		*0.060*	*0.069*	*0.078*	*0.087*	*0.097*	*(MGD)*
Solids Quantity (lbs/day)	*(lbs/day)*		*1,045*	*1,199*	*1,355*	*1,514*	*1,675*	*(lbs/day)*
TSS (mg/L)	*(mg/L)*		*2,077*	*2,077*	*2,077*	*2,077*	*2,077*	*(mg/L)*
9.) Dewatering								
Dewatered Sludge								
Solids Capture (%)		*INPUT*	*95%*	*95%*	*95%*	*95%*	*95%*	
Dewatered Sludge Solids (lbs/day)	*(lbs/day)*		*18,933*	*21,712*	*24,540*	*27,417*	*30,340*	*(lbs/day)*
Dewatered Sludge Solids Content (%)		*INPUT*	*32.0%*	*32.0%*	*32.0%*	*32.0%*	*32.0%*	
Dewatered Sludge Volume (cf/d)	*(cf/d)*		*948*	*1,088*	*1,229*	*1,373*	*1,520*	*(cf/d)*
Wet Weight @ sg=1.07	*(lbs/day)*		*63,306*	*72,598*	*82,057*	*91,676*	*101,449*	*(lbs/day)*
Dewatering Recycle								
Flow Rate (MGD)	*(MGD)*		*0.050*	*0.057*	*0.064*	*0.072*	*0.079*	*(MGD)*
Solids Quantity (lbs/day)	*(lbs/day)*		*926*	*1,062*	*1,200*	*1,341*	*1,484*	*(lbs/day)*
TSS (mg/L)	*(mg/L)*		*2,238*	*2,238*	*2,238*	*2,238*	*2,238*	*(mg/L)*
10.) Filter Backwash Water								
Flow Rate (MGD)	(MGD)	CALC	0.59	0.67	0.75	0.83	0.91	(MGD)
TSS Concentration (mg/L)	(mg/L)	INPUT	100	100	100	100	100	(mg/L)
Solids Quantity (lbs/day)	(lbs/day)		495	562	628	695	761	(lbs/day)
11.) Recycle Stream								
Gravity Thickener Supernatant								
Flow Rate (MGD)	(MGD)		0.159	0.181	0.202	0.223	0.244	(MGD)
TSS (lbs/day)	(lbs/day)		10,382	11,906	13,458	15,037	16,640	(lbs/day)
BOD (lbs/day)	(lbs/day)	CALC	2,699	3,096	3,499	3,910	4,326	(lbs/day)
GBT Recycle								
Flow Rate (MGD)	*(MGD)*		*0.060*	*0.069*	*0.078*	*0.087*	*0.097*	*(MGD)*
TSS (lbs/day)	*(lbs/day)*		*1,045*	*1,199*	*1,355*	*1,514*	*1,675*	*(lbs/day)*
BOD (lbs/day)	*(lbs/day)*	*CALC*	*272*	*312*	*352*	*394*	*435*	*(lbs/day)*
Dewatering Recycle								
Flow Rate (MGD)	*(MGD)*		*0.050*	*0.057*	*0.064*	*0.072*	*0.079*	*(MGD)*
TSS (lbs/day)	*(lbs/day)*		*926*	*1,062*	*1,200*	*1,341*	*1,484*	*(lbs/day)*
BOD (lbs/day)	*(lbs/day)*	*CALC*	*241*	*276*	*312*	*349*	*386*	*(lbs/day)*
Filter Backwash Water								
Flow Rate (MGD)			0.59	0.67	0.75	0.83	0.91	
TSS (lbs/day)	(lbs/day)		495	562	628	695	761	(lbs/day)
BOD (lbs/day)	(lbs/day)	CALC	248	281	314	347	381	(lbs/day)
Combined Recycle Stream								
Flow Rate (MGD)	(MGD)		0.86	0.98	1.10	1.21	1.33	(MGD)
TSS (lbs/day)	(lbs/day)		12,848.50	14,728.63	16,641.52	18,585.82	20,560.13	(lbs/day)
TSS Concentration (mg/L)	(mg/L)		1,784.82	1,801.67	1,818.18	1,834.37	1,850.25	(mg/L)
BOD (lbs/day)	(lbs/day)		3,459.49	3,964.27	4,477.57	4,999.03	5,528.30	(lbs/day)
BOD Concentration (mg/L)	(mg/L)		480.57	484.93	489.20	493.39	497.50	(mg/L)

Rows in Italics were added to the original model layout to account for 2PAD process & new thickening dewatering processes.

Appendix C

Scenario 1A: BM-E onto a Green Field – Drying

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1A: BM-E onto Green Field - Drying
Disposal Costs

Ultimate Disposal - Current Loads to 2PAD CHP

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,106	$ 17	$ 18,801
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,106	$ 17	$ 18,801
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	3,146	$ 17	$ 53,479
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 116,081**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,268	$ 17	$ 21,561
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,268	$ 17	$ 21,561
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	3,608	$ 17	$ 61,330
Total Annual Disposal Costs (Year 2010):				**$ 129,453**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,434	$ 17	$ 24,372
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,434	$ 17	$ 24,372
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	4,078	$ 17	$ 69,324
Total Annual Disposal Costs (Year 2015):				**$ 143,067**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,602	$ 17	$ 27,230
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,602	$ 17	$ 27,230
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	4,556	$ 17	$ 77,453
Total Annual Disposal Costs (Year 2020):				**$ 156,913**

Ultimate Disposal - Year 2025

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,773	$ 17	$ 30,133
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,773	$ 17	$ 30,133
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	5,042	$ 17	$ 85,713
Total Annual Disposal Costs (Year 2025):				**$ 170,980**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1A: BM-E onto Green Field - Drying
Operation & Maintenance Costs

Energy Consumption

	Current		2010		2015		2020		2025	
Electrical	$ 0.075 /kWh									
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Digester system / Feed pumps		$ 65,000		$ 65,000		$ 65,000		$ 65,000		$ 65,000
Transfer Pump System	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901				$ -
Gravity Belt Thickening	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Centrifuge	465,504	$ 34,913	465,504	$ 34,913	465,504	$ 34,913	465,504	$ 34,913	465,504	$ 34,913
Gas Cleaning System	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154
Dryer	1,061,710	$ 79,628	1,217,589	$ 91,319	1,376,284	$ 103,221	1,537,678	$ 115,326	1,701,652	$ 127,624
Electrical Subtotal:		$ 201,597		$ 213,287		$ 225,190		$ 232,393		$ 244,691
Natural Gas	$ - /CCF									
Equipment	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Consumption		**$ 201,597**		**$ 213,287**		**$ 225,190**		**$ 232,393**		**$ 244,691**

Chemical Consumption

Description	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*
Annual Polymer Usage (17.3 lbs. active / dry ton)	26,356	$ 1,581	30,226	$ 1,814	34,165	$ 2,050	38,172	$ 2,290	42,242	$ 2,535
Lime	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 1,581**		**$ 1,814**		**$ 2,050**		**$ 2,290**		**$ 2,535**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

	Current		2010		2015		2020		2025	
Operation:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
* Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
* Centrifuge Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
Dryer Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
Operations Subtotal:	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280
Maintenance:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
* Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
* Centrifuge Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
Total Annual Labor:	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**

Generator Maintenance Contract $ 0.01 /kWhr

Description	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator Maintenance Contract ($0.01/kWh)	5,367,500	$ 53,675	6,156,247	$ 61,562	6,959,405	$ 69,594	7,776,379	$ 77,764	8,606,576	$ 86,066
Dried La **Total Annual Generator Maintenance Contract:**		**$ 53,675**		**$ 61,562**		**$ 69,594**		**$ 77,764**		**$ 86,066**

Ultimate Disposal

Description	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*
Liquid Land Application (7% Solids EQ Liquid: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
	(wet-tons/yr)	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*
Land Fill	1,106	$ 18,801	1,268	$ 21,561	1,434	$ 24,372	1,602	$ 27,230	1,773	$ 30,133
Cake Land Application (32% EQ Cake: Class A)	1,106	$ 18,801	1,268	$ 21,561	1,434	$ 24,372	1,602	$ 27,230	1,773	$ 30,133
Dried Land Application (90% EQ Granule: Class A)	3,146	$ 53,479	3,608	$ 61,330	4,078	$ 69,324	4,556	$ 77,453	5,042	$ 85,713
Total Annual Disposal Costs:		**$ 116,081**		**$ 129,453**		**$ 143,067**		**$ 156,913**		**$ 170,980**

Energy Production *(Cost Savings)* $ 0.075 /kWh

	Current		2010		2015		2020		2025	
Electrical										
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator	5,367,500	$ (402,563)	6,156,247	$ (461,719)	6,959,405	$ (521,955)	7,776,379	$ (583,228)	8,606,576	$ (645,493)
Electrical Cost / (Savings) Subtotal		$ (402,563)		$ (461,719)		$ (521,955)		$ (583,228)		$ (645,493)
Heat	$ - /CCF									
Description	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings)		**$ (402,563)**		**$ (461,719)**		**$ (521,955)**		**$ (583,228)**		**$ (645,493)**
TOTAL ANNUAL O&M COSTS:		**$ 570,371**		**$ 544,398**		**$ 517,946**		**$ 486,131**		**$ 458,778**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1A: BM-E onto Green Field - Drying
Capital Costs

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*		
Digestion System Subtotal:					$	3,996,000
Gas & Generation Systems Subtotal:					$	1,330,000
Liquid Reduction Systems Subtotal:					$	1,830,000
Equipment Subtotal					**$**	**7,156,000**
Installation	50%			3,578,000		
Subtotal:					**$**	**10,734,000**
Miscellaneous 15%	15%			1,610,100		
Process Piping and Valves 10%	10%			1,073,400		
Plumbing at 3%	3%			322,020		
Electrical at 10%	10%			1,073,400		
Instrumentation and Controls at 6%	6%			644,040		
Subtotal:				4,722,960	**$**	**15,456,960**
Structural Subtotal:				1,440,000		
Subtotal:					**$**	**16,896,960**
Contingencies at 30%	30%			5,069,088		
Contractors Overhead and Profit at 25%	25%			4,224,240		
				9,293,328	**$**	**26,190,288**
TOTAL CAPITAL COST					**$**	**26,190,288**
Annualized Capital Cost (20 YRS @ 5.6%)					$	(2,209,804)
Annualized Capital Cost (20 YRS @ 2.0% SRF)					$	(1,601,712)
Annualized Capital Cost (15 YRS @ 0.0% CREB)					$	(1,746,019)

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1A: BM-E onto Green Field - Drying

Digestion System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Digestion System:				
Feed Sequencing Tank (FST): 24 ft. dia. X 20 ft. insul. w/ cover (installed	ea	1	$ 56,000	$ 56,000
Thermophilic Digester Tank (TD): 45 ft. dia. X 24 ft. insul. w/ fixed cover (	EA	2	$ 168,000	$ 336,000
Mesophilic Digester Tank (MD): 85 ft. dia. X 29 ft. insul. (installed)	EA	2	$ 500,000	$ 1,000,000
Installation (Credit to Reduce Values to Equipment/Materials Only)				$ (696,000)
Infilco 2PAD System (including the following):	LS	1	$ 3,300,000	$ 3,300,000
Fixed Cover - Thermophilic Digester	EA	2		
Floating Gas Holder Cover - Mesophilic Digester	EA	2		
Cannon Mixing System - Thermophilic				
Cannon Mixers - 24 inch	EA	6		
Nash Liquid Ring Gas Compressors	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
Cannon Mixing System - Mesophilic				
Cannon Mixers - 30 inch (with Heating Jackets)	EA	12		
Nash Liquid Ring Gas Compressors	EA	4		
Separators	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
2PAD Standard Digester Heating System				
Boiler	EA	1		
Heat Recovery Heat Exchange System (HXs, pumps, controls)	LS	1		
External Recirculation Sludge Heating System	LS	1		
Mesophilic Htg Jacket Pumps & Controls	LS	1		
Gas Safety Handling System & Flare	LS	1		
2PAD System Control Panel with PLC	LS	1		
Sludge Grinder	EA	1		
Sludge Feed Pumps	EA	2		
Sludge Transfer Pumps	EA	9		
Instrumentation				
Pressure / Vacuum Indicator Transmitters	EA	60		
Flow Indicator Transmitters	EA	14		
Temperature Indicator Transmitters	EA	55		
Level Indicator Transmitters	EA	5		
Valves				
Plug Valves	EA	51		
Check Valves	EA	12		
			Digestion System Subtotal:	**$ 3,996,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1A: BM-E onto Green Field - Drying
Gas & Generator Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Gas Cleaning				
Unison Solutions - Biogas Scrubber Skid	ea	1	$ 260,000	$ 260,000
Gas Blending System	ea	1	$ 50,000	$ 50,000
Multi-Point Gas Analysis Metering System (CH4, CO2, O2, H2S)	ea	1	$ 20,000	$ 20,000
Generation				
GE Jenbacher 848	ea	1	$ 550,000	$ 550,000
GE Jenbacher 540	ea	1	$ 380,000	$ 380,000
Switchgear / Electrical Control System	ea	2	$ 35,000	$ 70,000
Heat Dump Radiator	ea		$ -	$ -
			Gas & Generation Systems Subtotal:	**$ 1,330,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1A: BM-E onto Green Field - Drying
Liquid Reduction Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Sludge Storage				
Digested Sludge Storage Tank: 24 ft. dia. X 20 ft. w/ cover (installed)	ea	2	$ 50,000	$ 100,000
Dewatering System				
Centrifuge (100 HP, 185 gpm, 2100 lbs/hr)	ea	**2**	$ 400,000	$ 800,000
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System	ea	1	$ 150,000	$ 150,000
Dewatered Sludge Storage				
Conveyance - Belt Conveyors	LF	100	$ 800	$ 80,000
Roll-Off Container Area Equipment (Two 40-ton roll-off units)	LS	1	$ 25,000	$ 25,000
(Note: Equivalent to 4.5 days dried sludge storage at 2025 Loading Rates)				
(Note: Back-up Only. Equivalent to 1 day dewatered sludge storage at 2025 Loading Rates)				
(Note: Area included in structural cost opinion)				
Drying System				
Scott Model 548 AST Drying System	ea	1	$ 550,000	$ 550,000
Dryer Exhaust Heat Recovery System	ea	1	$ 125,000	$ 125,000
			Liquid Reduction Systems Subtotal:	**$ 1,830,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1A: BM-E onto Green Field - Drying

Structural

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD & Solids Handling Building				
Sludge Transfer Pumping	sf	576	$ 100	$ 57,600
Sludge Recirculation Pumping	sf	440	$ 100	$ 44,000
Heat Recovery System (HX, Pumps, Controls)	sf	500	$ 100	$ 50,000
Thermo HXs	sf	500	$ 100	$ 50,000
Boiler & Recirculation	sf	450	$ 100	$ 45,000
Meso Water Pumps	sf	500	$ 100	$ 50,000
Thermo Water Pumps	sf	500	$ 100	$ 50,000
Gas Mixing System (Compressors, Safety, Balancing)	sf	500	$ 100	$ 50,000
Gas Scrubber System & Blending System	sf	324	$ 100	$ 32,400
Centrifuge Area	sf	500	$ 100	$ 50,000
Conveyance	sf	1,000	$ 100	$ 100,000
Truck / Roll-off Loading (40' X 100')	sf	4,000	$ 100	$ 400,000
Generator System	sf	1,500	$ 100	$ 150,000
Dryer	sf	400	$ 100	$ 40,000
Admin	sf	500	$ 100	$ 50,000
Shop	sf	1,000	$ 100	$ 100,000
Lockers	sf	500	$ 100	$ 50,000
Miscellaneous	sf	710	$ 100	$ 71,000
	TOTAL AREA:	14,400		
			Structural Subtotal:	**$ 1,440,000**

Ann Arbor WWTP - Feasibility Study

SCENARIO 1A: BM-E onto a "Green Field" - Drying

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Plant Influent							
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50	(MGD)
BOD	(mg/L)	162	159	156	152	149	(mg/L)
TSS	(mg/L)	195	200	205	210	215	(mg/L)
Primary Sludge							
Hydraulic Flow	(gal./day)	92,270	106,535	121,222	136,322	151,827	(gal./day)
Solids Mass Flow	(lbs/day)	30,781	35,540	40,440	45,477	50,649	(lbs/day)
Volatile Solids	*(lbs/day)*	*21,547*	*24,878*	*28,308*	*31,834*	*35,455*	*(lbs/day)*
WAS							
Hydraulic Flow	(gal./day)	168,098	189,993	211,651	233,043	254,143	(gal./day)
Solids Mass Flow	(lbs/day)	14,322	16,187	18,032	19,855	21,653	(lbs/day)
Volatile Solids	*(lbs/day)*	*9,882*	*11,169*	*12,442*	*13,700*	*14,940*	*(lbs/day)*
Gravity Thickener Loading							
Hydraulic Load							
Combined Sludge	(gal./day)	269,667	307,119	344,761	382,557	420,469	(gal./day)
Solids Load							
Combined Sludge	(lbs/day)	45,103	51,727	58,472	65,332	72,302	(lbs/day)
Combined Sludge	(dt/yr)	8,231	9,440	10,671	11,923	13,195	(dt/yr)
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*	*(%)*
Volatile Solids	*(lbs/day)*	*31,429*	*36,047*	*40,750*	*45,534*	*50,395*	*(lbs/day)*
Gravity Thickened Combined Sludge							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	34,955	40,089	45,316	50,632	56,034	(lbs/day)
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%	(%)
Volatile Solids	*(lbs/day)*	*24,357*	*27,937*	*31,581*	*35,289*	*39,056*	*(lbs/day)*
2PAD							
Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%	(%)
2PAD Sludge Output							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	20,340	23,327	26,367	29,459	32,600	(lbs/day)
Solids Mass Flow	(dt/yr)	3,712	4,257	4,812	5,376	5,950	(dt/yr)
% Solids	(%)	2.17%	2.17%	2.17%	2.17%	2.17%	(%)
VS Destroyed	(lbs/day)	14,614	16,762	18,949	21,173	23,434	(lbs/day)
Biogas Production							
	cf/lbs VSS destroyed	17.00	17.00	17.00	17.00	17.00	cf/lbs VSS de
	cf/day	248,445	284,954	322,130	359,945	398,372	cf/day
	cf/hr	10,352	11,873	13,422	14,998	16,599	cf/hr
	BTU/cf	600	600	600	600	600	BTU/cf
	BTU/hr	6,211,130	7,123,848	8,053,241	8,998,622	9,959,304	BTU/hr
	BTU/day	149,067,130	170,972,341	193,277,781	215,966,930	239,023,293	BTU/day
Heat Available from 80% Efficient Boiler							
BTU/hr		4,968,904	5,699,078	6,442,593	7,198,898	7,967,443	BTU/hr
Meso Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	156,448	156,448	156,448	156,448	156,448	BTU/hr
Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,734	22,734	22,734	22,734	22,734	BTU/hr
Total Meso Heat Loss	BTU/hr	45,468	45,468	45,468	45,468	45,468	BTU/hr
Thermo Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	60,788	60,788	60,788	60,788	60,788	BTU/hr
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,719	22,719	22,719	22,719	22,719	BTU/hr
Total Thermo Heat Loss	BTU/hr	45,438	45,438	45,438	45,438	45,438	BTU/hr
Thermo Batch Heating Demand							
BTU/batch		5,128,488	6,382,579	7,659,488	8,958,226	10,277,805	
hrs/batch		3.00	3.00	3.00	3.00	3.00	
Batch BTU/hr		1,709,496	2,127,526	2,553,163	2,986,075	3,425,935	
Worst Case Heat Demand	BTU/hr	2,143,968	2,561,998	2,987,635	3,420,547	3,860,407	BTU/hr
Heat Supply							
Boiler	BTU/hr	-	-	-	-	-	BTU/hr
Generator Exhaust	BTU/hr	-	-	-	-	-	BTU/hr
Generator Cooling Jacket	BTU/hr	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	BTU/hr
Generator 2nd Stage Intercoole	BTU/hr	121,694	139,577	157,786	176,309	195,131	BTU/hr
Dryer Exhaust	BTU/hr	1,117,837	1,282,226	1,449,648	1,619,977	1,793,092	BTU/hr
Heat Surplus (Deficit)	%	19%	14%	11%	8%	6%	%

Ann Arbor WWTP - Feasibility Study

SCENARIO 1A: BM-E onto a "Green Field" - Drying

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Transfer Pumping							
Energy Consumption							
Connected HP	(HP)	20	20	20	20	20	(HP)
Operation	(hrs/yr)	4,380	4,380	4,380	4,380	4,380	(hrs/yr)
Electrical Demand	(kW*hr/yr)	65,350	65,350	65,350	65,350	65,350	(kW*hr/yr)
2PAD Sludge Storage							
Number of Tanks							
Total		2	2	2	2	2	
Operating		2	2	2	2	2	
Tank Size							
Diameter (ft)	(ft)	24	24	24	24	24	(ft)
Water Depth (ft)	(ft)	20	20	20	20	20	(ft)
Operating Surface Area (s	(sf)	452	452	452	452	452	(sf)
Operating Volume (cf)	(cf)	9,048	9,048	9,048	9,048	9,048	(cf)
Sludge to Storage							
Sludge Flow (MGD)	(MGD)	112,263	128,751	145,539	162,614	179,963	(MGD)
Available Holding Time (hours)	(hours)	29	25	22	20	18	(hours)
Centrifuge Polymer Dose	(lbs active/dt)	7.1	7.1	7.1	7.1	7.1	(lbs active/dt)
Centrifuge Polymer Feed	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / y
Total Polymer Consumption	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / y
Centrifuge Dewatering (7 d/wk, 3 shift/day)							
Number of Units Operating		1.0	1.0	1.0	1.0	1.0	
Number of Units Standby		1.0	1.0	1.0	1.0	1.0	
Shifts / Day		3.0	3.0	3.0	3.0	3.0	
Hours in Service / Shift	(hours)	8.0	8.0	8.0	8.0	8.0	(hours)
Hydraulic Loading / Unit	(gal./day)	164,243	188,357	212,907	237,874	263,240	(gal./day)
Mass Loading / Unit	(lbs/day)	28,578	32,773	37,045	41,389	45,803	(lbs/day)
Hydraulic Loading / Unit	(gpm)	114.1	130.8	147.9	165.2	182.8	(gpm)
Mass Loading / Unit	(lbs/hr)	1,191	1,366	1,544	1,725	1,908	(lbs/hr)
Centrifuge Energy Consumption							
Unit HP	(HP)	100	100	100	100	100	(HP)
Operation	(hrs/yr)	6,240	6,240	6,240	6,240	6,240	(hrs/yr)
Electrical Demand	(kW*hr/yr)	465,504	465,504	465,504	465,504	465,504	(kW*hr/yr)
Electrical Cost	($/yr)	$ 34,913	$ 34,913	$ 34,913	$ 34,913	$ 34,913	($/yr)
Dewatered Sludge Output							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Solids Mass Flow	(lbs/day)	19,392	22,239	25,138	28,085	31,080	(lbs/day)
Percent Solids	(%)	32%	32%	32%	32%	32%	(%)
Density	(lbs/cf)	66.8	66.8	66.8	66.8	66.8	(lbs/cf)
Volumetric Flow	(cy/day)	33.6	38.5	43.6	48.7	53.9	(cy/day)
Wet Weight	(tons/day)	30.3	34.7	39.3	43.9	48.6	(tons/day)
Dry Weight	(tons/day)	9.7	11.1	12.6	14.0	15.5	(tons/day)
Annual Totals							
Volume	(cy/year)	12,264	14,064	15,897	17,762	19,656	(cy/year)
Wet Weight	(tons/year)	11,059	12,683	14,336	16,017	17,726	(tons/year)
Dry Weight	(tons/year)	3,539	4,059	4,588	5,126	5,672	(tons/year)
Recycle from Centrifuge Operations							
Hydraulic Flow	*(gal./day)*	*104,997*	*120,412*	*136,106*	*152,067*	*168,283*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*948*	*1,088*	*1,229*	*1,374*	*1,520*	*(lbs/day)*
Dewatered Sludge Storage							
Number of Hoppers		2	2	2	2	2	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	104	104	104	104	104	(cy)
Total Storage Capacity	(wet tons)	80	80	80	80	80	(wet tons)
Total Storage Capacity	(days)	2.6	2.3	2.0	1.8	1.6	(days)
Gas Cleaning Skid							
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	35	35	35	35	35	(HP)
Turn-down	(%)	0%	0%	0%	0%	0%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	228,724	228,724	228,724	228,724	228,724	(kW*hr/yr)
Generation							
Energy Output	(kW)	645	740	836	934	1,034	(kW)
Exhaust Air Flow	(lbs/hr)	8,514	9,765	11,039	12,335	13,651	(lbs/hr)
Exhaust Gas Temperature	(F)	991	991	991	991	991	(F)
Exhaust Gas Heat	(BTU/hr)	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	(BTU/hr)
Cooling Jacket Heat	(BTU/hr)	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	(BTU/hr)
2nd Stage Intercooler Heat	(BTU/hr)	121,694	139,577	157,786	176,309	195,131	(BTU/hr)
Uptime	(%)	95%	95%	95%	95%	95%	(%)
Downtime	(hrs/yr)	438	438	438	438	438	(hrs/yr)
Electricity Production	(kW*hr/yr)	5,367,500	6,156,247	6,959,405	7,776,379	8,606,576	(kW*hr/yr)
Solids Drying							
Dried Solids Content	(%)	90%	90%	90%	90%	90%	(%)
Solids Mass In-Flow	(dry lbs/hr)	808	927	1,047	1,170	1,295	(dry lbs/hr)
Solids Mass Out-Flow	(wet lbs/hr)	898	1,030	1,164	1,300	1,439	(wet lbs/hr)
Evaporation Out-Flow	(lbs/hr)	1,627	1,866	2,109	2,357	2,608	(lbs/hr)
Air Demand	(lb/lb H2O)	9.44	9.44	9.44	9.44	9.44	(lb/lb H2O)
Air Demand	(lb/hr)	15,361	17,616	19,912	22,247	24,620	(lb/hr)
Heat Demand	(BTU/lb H2O)	1,475	1,475	1,475	1,475	1,475	(BTU/lb H2O)
Heat Demand	(BTU/hr)	2,400,148	2,752,535	3,111,288	3,476,142	3,846,830	(BTU/hr)
Heat Input - Gen Exhaust	(BTU/hr)	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	(BTU/hr)
Heat Input - Make-up Air	(BTU/hr)	322,253	369,295	417,125	465,708	515,006	(BTU/hr)
Drier Inlet Air Temp	(F)	720	720	720	720	720	(F)

Ann Arbor WWTP - Feasibility Study

SCENARIO 1A: BM-E onto a "Green Field" - Drying

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	275	275	275	275	275	(HP)
Turn-down	(%)	41%	32%	23%	14%	5%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	1,061,710	1,217,589	1,376,284	1,537,678	1,701,652	(kW*hr/yr)
Solids Drying Output							
Solids Content	(%)	90%	90%	90%	90%	90%	(%)
Density	(lbs/cf)	30.2	30.2	30.2	30.2	30.2	(lbs/cf)
Solids Mass Flow	(lbs/day)	19,392	22,239	25,138	28,085	31,080	(lbs/day)
Wet Weight	(lbs/day)	21,547	24,710	27,931	31,206	34,534	(lbs/day)
Wet Weight	(tons/year)	3,932	4,510	5,097	5,695	6,302	(tons/year)
Volume	(cy/day)	26	30	34	38	42	(cy/day)
Volume	(cy/year)	9,645	11,061	12,503	13,969	15,458	(cy/year)
Heat Recovery	(%)	60%	60%	60%	60%	60%	(%)
Recovered Heat	(BTU/hr)	1,440,089	1,651,521	1,866,773	2,085,685	2,308,098	(BTU/hr)
Dried Sludge Storage							
Number of Hoppers		2	2	2	2	2	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	104	104	104	104	104	(cy)
Total Storage Capacity	(wet tons)	80	80	80	80	80	(wet tons)
Total Storage Capacity	(days)	3.9	3.4	3.0	2.7	2.5	(days)

Appendix D

Scenario 1B: BM-E onto a Green Field – Centrifuge Dewatering

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1B: BM-E onto a Green Field - Centrifuge Dewatering
Disposal Costs

Ultimate Disposal - Current Loads to 2PAD CHP

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	2,765	$ 17	$ 47,003
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	8,295	$ 17	$ 141,008
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 213,011**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	3,171	$ 17	$ 53,904
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	9,512	$ 17	$ 161,711
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2010):				**$ 240,615**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	3,584	$ 17	$ 60,929
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	10,752	$ 17	$ 182,788
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2015):				**$ 268,717**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	4,004	$ 17	$ 68,074
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	12,013	$ 17	$ 204,223
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2020):				**$ 297,297**

Ultimate Disposal - Year 2025

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	4,431	$ 17	$ 75,334
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	13,294	$ 17	$ 226,001
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2025):				**$ 326,334**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1B: BM-E onto a Green Field - Centrifuge Dewatering
Operation & Maintenance Cost

Energy Consumption

	Current		2010		2015		2020		2025	
Electrical	$ 0.075 /kWh									
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Digester system / Feed pumps		$ 65,000		$ 65,000		$ 65,000		$ 65,000		$ 65,000
Transfer Pump System	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901
Gravity Belt Thickening	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Centrifuge	310,336	$ 23,275	372,403	$ 27,930	403,437	$ 30,258	434,470	$ 32,585	465,504	$ 34,913
Gas Cleaning System	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154
Dryer	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Electrical Subtotal:		$ 110,331		$ 114,986		$ 117,313		$ 119,641		$ 121,968
Natural Gas	$ - /CCF									
Equipment	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Consumption		**$ 110,331**		**$ 114,986**		**$ 117,313**		**$ 119,641**		**$ 121,968**

Chemical Consumption

Description	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*
Annual Polymer Usage (17.3 lbs. active / dry ton)	26,356	$ 1,581	30,226	$ 1,814	34,165	$ 2,050	38,172	$ 2,290	42,242	$ 2,535
Lime	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 1,581**		**$ 1,814**		**$ 2,050**		**$ 2,290**		**$ 2,535**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

	(hrs/yr)	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
Operation:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
* Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
* Centrifuge Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
Dryer Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
Operations Subtotal:	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280
Maintenance:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
* Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
* Centrifuge Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
Total Annual Labor:	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**

Generator Maintenance Contract $ 0.01 /kWhr

Description	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator Maintenance Contract ($0.01/kWh)	5,367,500	$ 53,675	6,156,247	$ 61,562	6,959,405	$ 69,594	7,776,379	$ 77,764	8,606,576	$ 86,066
Total Annual Generator Maintenance Contract:		**$ 53,675**		**$ 61,562**		**$ 69,594**		**$ 77,764**		**$ 86,066**

Ultimate Disposal

Description	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*
Liquid Land Application (7% Solids EQ Liquid: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
	(wet-tons/yr)	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*
Land Fill	2,765	$ 47,003	3,171	$ 53,904	3,584	$ 60,929	4,004	$ 68,074	4,431	$ 75,334
Cake Land Application (32% EQ Cake: Class A)	8,295	$ 141,008	9,512	$ 161,711	10,752	$ 182,788	12,013	$ 204,223	13,294	$ 226,001
Dried Land Application (90% EQ Granule: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Disposal Costs:		**$ 213,011**		**$ 240,615**		**$ 268,717**		**$ 297,297**		**$ 326,334**

Energy Production *(Cost Savings)* $ 0.075 /kWh

Electrical										
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator	5,367,500	$ (402,563)	6,156,247	$ (461,719)	6,959,405	$ (521,955)	7,776,379	$ (583,228)	8,606,576	$ (645,493)
Electrical Cost / (Savings) Subtotal		$ (402,563)		$ (461,719)		$ (521,955)		$ (583,228)		$ (645,493)
Heat	$ - /CCF									
Description	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings)		**$ (402,563)**		**$ (461,719)**		**$ (521,955)**		**$ (583,228)**		**$ (645,493)**

TOTAL ANNUAL O&M COSTS:		**$ 576,036**		**$ 557,258**		**$ 535,719**		**$ 513,764**		**$ 491,410**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1B: BM-E onto a Green Field - Centrifuge Dewatering
Capital Costs

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension $1,000*		
Digestion System Subtotal:					$	3,996,000
Gas & Generation Systems Subtotal:					$	1,355,000
Liquid Reduction Systems Subtotal:					$	1,555,000
Equipment Subtotal					**$**	**6,906,000**
Installation	50%			3,453,000		
Subtotal:					**$**	**10,359,000**
Miscellaneous 15%	15%			1,553,850		
Process Piping and Valves 10%	10%			1,035,900		
Plumbing at 3%	3%			310,770		
Electrical at 10%	10%			1,035,900		
Instrumentation and Controls at 6%	6%			621,540		
Subtotal:				4,557,960	**$**	**14,916,960**
Structural Subtotal:				1,440,000		
Subtotal:					**$**	**16,356,960**
Contingencies at 30%	30%			4,907,088		
Contractors Overhead and Profit at 25%	25%			4,089,240		
				8,996,328	**$**	**25,353,288**
TOTAL CAPITAL COST					**$**	**25,353,288**
Annualized Capital Cost (20 YRS @ 5.6%)					$	(2,139,183)
Annualized Capital Cost (20 YRS @ 2.0% SRF)					$	(1,550,524)
Annualized Capital Cost (15 YRS @ 0.0% CREB)					$	(1,690,219)

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1B: BM-E onto a Green Field - Centrifuge Dewatering
Digestion System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Digestion System:				
Feed Sequencing Tank (FST): 24 ft. dia. X 20 ft. insul. w/ cover (installed	ea	1	$ 56,000	$ 56,000
Thermophilic Digester Tank (TD): 45 ft. dia. X 24 ft. insul. w/ fixed cover (	EA	2	$ 168,000	$ 336,000
Mesophilic Digester Tank (MD): 85 ft. dia. X 29 ft. insul. (installed)	EA	2	$ 500,000	$ 1,000,000
Installation (Credit to Reduce Values to Equipment/Materials Only)				$ (696,000)
Infilco 2PAD System (including the following):	LS	1	$ 3,300,000	$ 3,300,000
Fixed Cover - Thermophilic Digester	EA	2		
Floating Gas Holder Cover - Mesophilic Digester	EA	2		
Cannon Mixing System - Thermophilic				
Cannon Mixers - 24 inch	EA	6		
Nash Liquid Ring Gas Compressors	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
Cannon Mixing System - Mesophilic				
Cannon Mixers - 30 inch (with Heating Jackets)	EA	12		
Nash Liquid Ring Gas Compressors	EA	4		
Separators	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
2PAD Standard Digester Heating System				
Boiler	EA	1		
Heat Recovery Heat Exchange System (HXs, pumps, controls)	LS	1		
External Recirculation Sludge Heating System	LS	1		
Mesophilic Htg Jacket Pumps & Controls	LS	1		
Gas Safety Handling System & Flare	LS	1		
2PAD System Control Panel with PLC	LS	1		
Sludge Grinder	EA	1		
Sludge Feed Pumps	EA	2		
Sludge Transfer Pumps	EA	9		
Instrumentation				
Pressure / Vacuum Indicator Transmitters	EA	60		
Flow Indicator Transmitters	EA	14		
Temperature Indicator Transmitters	EA	55		
Level Indicator Transmitters	EA	5		
Valves				
Plug Valves	EA	51		
Check Valves	EA	12		
			Digestion System Subtotal:	**$ 3,996,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1B: BM-E onto a Green Field - Centrifuge Dewatering
Gas & Generator Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Gas Cleaning				
Unison Solutions - Biogas Scrubber Skid	ea	1	$ 260,000	$ 260,000
Gas Blending System	ea	1	$ 50,000	$ 50,000
Multi-Point Gas Analysis Metering System (CH4, CO2, O2, H2S)	ea	1	$ 20,000	$ 20,000
Generation				
GE Jenbacher 848	ea	1	$ 550,000	$ 550,000
GE Jenbacher 540	ea	1	$ 380,000	$ 380,000
Switchgear / Electrical Control System	ea	2	$ 35,000	$ 70,000
Heat Dump Radiator	ea	1	$ 25,000	$ 25,000
			Gas & Generation Systems Subtotal:	**$ 1,355,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1B: BM-E onto a Green Field - Centrifuge Dewatering
Liquid Reduction Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Sludge Storage				
Digested Sludge Storage Tank: 24 ft. dia. X 20 ft. w/ cover (installed)	ea	2	$ 50,000	$ 100,000
Dewatering System				
Centrifuge (100 HP, 185 gpm, 2100 lbs/hr)	ea	**3**	$ 400,000	$ 1,200,000
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System	ea	1	$ 150,000	$ 150,000
Dewatered Sludge Storage				
Conveyance - Belt Conveyors	LF	100	$ 800	$ 80,000
Roll-Off Container Area Equipment (Two 40-ton roll-off units)	LS	1	$ 25,000	$ 25,000
(Note: Equivalent to 4.5 days dried sludge storage at 2025 Loading Rates)				
(Note: Back-up Only. Equivalent to 1 day dewatered sludge storage at 2025 Loading Rates)				
(Note: Area included in structural cost opinion)				
Drying System				
Scott Model 548 AST Drying System	ea	0	$ 550,000	$ -
Dryer Exhaust Heat Recovery System	ea	0	$ 125,000	$ -
			Liquid Reduction Systems Subtotal:	**$ 1,555,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1B: BM-E onto a Green Field - Centrifuge Dewatering
Structural

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD & Solids Handling Building				
Sludge Transfer Pumping	sf	576	$ 100	$ 57,600
Sludge Recirculation Pumping	sf	440	$ 100	$ 44,000
Heat Recovery System (HX, Pumps, Controls)	sf	500	$ 100	$ 50,000
Thermo HXs	sf	500	$ 100	$ 50,000
Boiler & Recirculation	sf	450	$ 100	$ 45,000
Meso Water Pumps	sf	500	$ 100	$ 50,000
Thermo Water Pumps	sf	500	$ 100	$ 50,000
Gas Mixing System (Compressors, Safety, Balancing)	sf	500	$ 100	$ 50,000
Gas Scrubber System & Blending System	sf	324	$ 100	$ 32,400
Centrifuge Area	sf	500	$ 100	$ 50,000
Conveyance	sf	1,000	$ 100	$ 100,000
Truck / Roll-off Loading (40' X 100')	sf	4,000	$ 100	$ 400,000
Generator System	sf	1,500	$ 100	$ 150,000
Dryer	sf	400	$ 100	$ 40,000
Admin	sf	500	$ 100	$ 50,000
Shop	sf	1,000	$ 100	$ 100,000
Lockers	sf	500	$ 100	$ 50,000
Miscellaneous	sf	710	$ 100	$ 71,000
	TOTAL AREA:	14,400		
			Structural Subtotal:	**$ 1,440,000**

Ann Arbor WWTP - Feasibility Study

SCENARIO 1B: BM-E onto a "Green Field" - Centrifuge Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Plant Influent							
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50	(MGD)
BOD	(mg/L)	162	159	156	152	149	(mg/L)
TSS	(mg/L)	195	200	205	210	215	(mg/L)
Primary Sludge							
Hydraulic Flow	(gal./day)	92,270	106,535	121,222	136,322	151,827	(gal./day)
Solids Mass Flow	(lbs/day)	30,781	35,540	40,440	45,477	50,649	(lbs/day)
Volatile Solids	*(lbs/day)*	*21,547*	*24,878*	*28,308*	*31,834*	*35,455*	*(lbs/day)*
WAS							
Hydraulic Flow	(gal./day)	168,098	189,993	211,651	233,043	254,143	(gal./day)
Solids Mass Flow	(lbs/day)	14,322	16,187	18,032	19,855	21,653	(lbs/day)
Volatile Solids	*(lbs/day)*	*9,882*	*11,169*	*12,442*	*13,700*	*14,940*	*(lbs/day)*
Gravity Thickener Loading							
Hydraulic Load							
Combined Sludge	(gal./day)	269,667	307,119	344,761	382,557	420,469	(gal./day)
Solids Load							
Combined Sludge	(lbs/day)	45,103	51,727	58,472	65,332	72,302	(lbs/day)
Combined Sludge	(dt/yr)	8,231	9,440	10,671	11,923	13,195	(dt/yr)
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*	*(%)*
Volatile Solids	*(lbs/day)*	*31,429*	*36,047*	*40,750*	*45,534*	*50,395*	*(lbs/day)*
Gravity Thickened Combined Sludge							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	34,955	40,089	45,316	50,632	56,034	(lbs/day)
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%	(%)
Volatile Solids	*(lbs/day)*	*24,357*	*27,937*	*31,581*	*35,289*	*39,056*	*(lbs/day)*
2PAD							
Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%	(%)
2PAD Sludge Output							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	20,340	23,327	26,367	29,459	32,600	(lbs/day)
Solids Mass Flow	(dt/yr)	3,712	4,257	4,812	5,376	5,950	(dt/yr)
% Solids	(%)	2.17%	2.17%	2.17%	2.17%	2.17%	(%)
VS Destroyed	(lbs/day)	14,614	16,762	18,949	21,173	23,434	(lbs/day)
Biogas Production							
	cf/lbs VSS destroyed	17.00	17.00	17.00	17.00	17.00	cf/lbs VSS de
	cf/day	248,445	284,954	322,130	359,945	398,372	cf/day
	cf/hr	10,352	11,873	13,422	14,998	16,599	cf/hr
	BTU/cf	600	600	600	600	600	BTU/cf
	BTU/hr	6,211,130	7,123,848	8,053,241	8,998,622	9,959,304	BTU/hr
	BTU/day	149,067,130	170,972,341	193,277,781	215,966,930	239,023,293	BTU/day
Heat Available from 80% Efficient Boiler							
BTU/hr		4,968,904	5,699,078	6,442,593	7,198,898	7,967,443	BTU/hr
Meso Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	156,448	156,448	156,448	156,448	156,448	BTU/hr
Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,734	22,734	22,734	22,734	22,734	BTU/hr
Total Meso Heat Loss	BTU/hr	45,468	45,468	45,468	45,468	45,468	BTU/hr
Thermo Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	60,788	60,788	60,788	60,788	60,788	BTU/hr
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,719	22,719	22,719	22,719	22,719	BTU/hr
Total Thermo Heat Loss	BTU/hr	45,438	45,438	45,438	45,438	45,438	BTU/hr
Thermo Batch Heating Demand							
BTU/batch		5,128,488	6,382,579	7,659,488	8,958,226	10,277,805	
hrs/batch		3.00	3.00	3.00	3.00	3.00	
Batch BTU/hr		1,709,496	2,127,526	2,553,163	2,986,075	3,425,935	

Ann Arbor WWTP - Feasibility Study

SCENARIO 1B: BM-E onto a "Green Field" - Centrifuge Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Worst Case Heat Demand	BTU/hr	2,143,968	2,561,998	2,987,635	3,420,547	3,860,407	BTU/hr
Heat Supply							
Boiler	BTU/hr	-	-	-	-	-	BTU/hr
Generator Exhaust	BTU/hr	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	BTU/hr
Generator Cooling Jacket	BTU/hr	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	BTU/hr
Generator 2nd Stage Intercoole	BTU/hr	121,694	139,577	157,786	176,309	195,131	BTU/hr
Dryer Exhaust	BTU/hr	-	-	-	-	-	BTU/hr
Heat Surplus (Deficit)	%	64%	57%	52%	49%	46%	%
Transfer Pumping							
Energy Consumption							
Connected HP	(HP)	20	20	20	20	20	(HP)
Operation	(hrs/yr)	4,380	4,380	4,380	4,380	4,380	(hrs/yr)
Electrical Demand	(kW*hr/yr)	65,350	65,350	65,350	65,350	65,350	(kW*hr/yr)
2PAD Sludge Storage							
Number of Tanks							
Total		2	2	2	2	2	
Operating		2	2	2	2	2	
Tank Size							
Diameter (ft)	(ft)	24	24	24	24	24	(ft)
Water Depth (ft)	(ft)	20	20	20	20	20	(ft)
Operating Surface Area (s	(sf)	452	452	452	452	452	(sf)
Operating Volume (cf)	(cf)	9,048	9,048	9,048	9,048	9,048	(cf)
Sludge to Storage							
Sludge Flow (MGD)	(MGD)	112,263	128,751	145,539	162,614	179,963	(MGD)
Available Holding Time (hours)	(hours)	29	25	22	20	18	(hours)
Centrifuge Polymer Dose	(lbs active/dt)	7.1	7.1	7.1	7.1	7.1	(lbs active/dt)
Centrifuge Polymer Feed	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / y
Total Polymer Consumption	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / y
Centrifuge Dewatering (5 d/wk, 2 shift/day)							
Number of Units Operating		2.0	2.0	2.0	2.0	2.0	
Number of Units Standby		1.0	1.0	1.0	1.0	1.0	
Shifts / Day		1.0	1.2	1.3	1.4	1.5	
Hours in Service / Shift	(hours)	8.0	8.0	8.0	8.0	8.0	(hours)
Hydraulic Loading / Unit	(gal./day)	82,122	94,179	106,453	118,937	131,620	(gal./day)
Mass Loading / Unit	(lbs/day)	14,289	16,387	18,522	20,695	22,901	(lbs/day)
Hydraulic Loading / Unit	(gpm)	171.1	163.5	170.6	177.0	182.8	(gpm)
Mass Loading / Unit	(lbs/hr)	1,786	1,707	1,781	1,848	1,908	(lbs/hr)
Centrifuge Energy Consumption							
Unit HP	(HP)	100	100	100	100	100	(HP)
Operation	(hrs/yr)	4,160	4,992	5,408	5,824	6,240	(hrs/yr)
Electrical Demand	(kW*hr/yr)	310,336	372,403	403,437	434,470	465,504	(kW*hr/yr)
Electrical Cost	($/yr)	$ 23,275	$ 27,930	$ 30,258	$ 32,585	$ 34,913	($/yr)
Dewatered Sludge Output							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Solids Mass Flow	(lbs/day)	19,392	22,239	25,138	28,085	31,080	(lbs/day)
Percent Solids	(%)	32%	32%	32%	32%	32%	(%)
Density	(lbs/cf)	66.8	66.8	66.8	66.8	66.8	(lbs/cf)
Volumetric Flow	(cy/day)	33.6	38.5	43.6	48.7	53.9	(cy/day)
Wet Weight	(tons/day)	30.3	34.7	39.3	43.9	48.6	(tons/day)
Dry Weight	(tons/day)	9.7	11.1	12.6	14.0	15.5	(tons/day)
Annual Totals							
Volume	(cy/year)	12,264	14,064	15,897	17,762	19,656	(cy/year)
Wet Weight	(tons/year)	11,059	12,683	14,336	16,017	17,726	(tons/year)
Dry Weight	(tons/year)	3,539	4,059	4,588	5,126	5,672	(tons/year)
Recycle from Centrifuge Operations							
Hydraulic Flow	*(gal./day)*	*104,997*	*120,412*	*136,106*	*152,067*	*168,283*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*948*	*1,088*	*1,229*	*1,374*	*1,520*	*(lbs/day)*
Dewatered Sludge Storage							
Number of Hoppers		2	2	2	2	2	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	104	104	104	104	104	(cy)
Total Storage Capacity	(wet tons)	80	80	80	80	80	(wet tons)

Ann Arbor WWTP - Feasibility Study

SCENARIO 1B: BM-E onto a "Green Field" - Centrifuge Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Total Storage Capacity	(days)	2.6	2.3	2.0	1.8	1.6	(days)
Gas Cleaning Skid							
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	35	35	35	35	35	(HP)
Turn-down	(%)	0%	0%	0%	0%	0%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	228,724	228,724	228,724	228,724	228,724	(kW*hr/yr)
Generation							
Energy Output	(kW)	645	740	836	934	1,034	(kW)
Exhaust Air Flow	(lbs/hr)	8,514	9,765	11,039	12,335	13,651	(lbs/hr)
Exhaust Gas Temperature	(F)	991	991	991	991	991	(F)
Exhaust Gas Heat	(BTU/hr)	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	(BTU/hr)
Cooling Jacket Heat	(BTU/hr)	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	(BTU/hr)
2nd Stage Intercooler Heat	(BTU/hr)	121,694	139,577	157,786	176,309	195,131	(BTU/hr)
Uptime	(%)	95%	95%	95%	95%	95%	(%)
Downtime	(hrs/yr)	438	438	438	438	438	(hrs/yr)
Electricity Production	(kW*hr/yr)	5,367,500	6,156,247	6,959,405	7,776,379	8,606,576	(kW*hr/yr)
Solids Drying							
Dried Solids Content	(%)	32%	32%	32%	32%	32%	(%)
Solids Mass In-Flow	(dry lbs/hr)	808	927	1,047	1,170	1,295	(dry lbs/hr)
Solids Mass Out-Flow	(wet lbs/hr)	2,525	2,896	3,273	3,657	4,047	(wet lbs/hr)
Evaporation Out-Flow	(lbs/hr)	-	-	-	-	-	(lbs/hr)
Air Demand	(lb/lb H2O)	9.44	9.44	9.44	9.44	9.44	(lb/lb H2O)
Air Demand	(lb/hr)	-	-	-	-	-	(lb/hr)
Heat Demand	(BTU/lb H2O)	1,475	1,475	1,475	1,475	1,475	(BTU/lb H2O)
Heat Demand	(BTU/hr)	-	-	-	-	-	(BTU/hr)
Heat Input - Gen Exhaust	(BTU/hr)	-	-	-	-	-	(BTU/hr)
Heat Input - Make-up Air	(BTU/hr)	-	-	-	-	-	(BTU/hr)
Drier Inlet Air Temp	(F)	720	720	720	720	720	(F)
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	275	275	275	275	275	(HP)
Turn-down	(%)	100%	100%	100%	100%	100%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	-	-	-	-	-	(kW*hr/yr)
Solids Drying Output							
Solids Content	(%)	32%	32%	32%	32%	32%	(%)
Density	(lbs/cf)	30.2	30.2	30.2	30.2	30.2	(lbs/cf)
Solids Mass Flow	(lbs/day)	-	-	-	-	-	(lbs/day)
Wet Weight	(lbs/day)	-	-	-	-	-	(lbs/day)
Wet Weight	(tons/year)	-	-	-	-	-	(tons/year)
Volume	(cy/day)	-	-	-	-	-	(cy/day)
Volume	(cy/year)	-	-	-	-	-	(cy/year)
Heat Recovery	(%)	60%	60%	60%	60%	60%	(%)
Recovered Heat	(BTU/hr)	-	-	-	-	-	(BTU/hr)
Dried Sludge Storage							
Number of Hoppers		2	2	2	2	2	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	104	104	104	104	104	(cy)
Total Storage Capacity	(wet tons)	80	80	80	80	80	(wet tons)
Total Storage Capacity	(days)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	(days)

Appendix E

Scenario 1C: BM-E onto a Green Field – Belt Filter Press Dewatering

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1C: BM-E onto a Green Field - Belt Filter Press Dewatering
Disposal Costs

Ultimate Disposal - Current Loads to 2PAD CHP

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	3,847	$ 17	$ 65,395
Cake Land Application (23% EQ Cake: Class A)	Wet Ton	11,540	$ 17	$ 196,186
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 286,581**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	4,412	$ 17	$ 74,996
Cake Land Application (23% EQ Cake: Class A)	Wet Ton	13,235	$ 17	$ 224,989
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2010):				**$ 324,986**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	4,987	$ 17	$ 84,771
Cake Land Application (23% EQ Cake: Class A)	Wet Ton	14,960	$ 17	$ 254,313
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2015):				**$ 364,084**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	5,571	$ 17	$ 94,712
Cake Land Application (23% EQ Cake: Class A)	Wet Ton	16,714	$ 17	$ 284,136
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2020):				**$ 403,848**

Ultimate Disposal - Year 2025

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	6,165	$ 17	$ 104,812
Cake Land Application (23% EQ Cake: Class A)	Wet Ton	18,496	$ 17	$ 314,436
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2025):				**$ 444,248**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1C: BM-E onto a Green Field - Belt Filter Press Dewatering
Operation & Maintenance Costs

Energy Consumption

	Current		2010		2015		2020		2025	
Electrical	$ 0.075 /kWh									
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Digester system / Feed pumps		$ 65,000		$ 65,000		$ 65,000		$ 65,000		$ 65,000
Transfer Pump System	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901
Gravity Belt Thickening	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
BFP Dewatering	61,097	$ 4,582	69,826	$ 5,237	78,554	$ 5,892	87,282	$ 6,546	96,010	$ 7,201
Gas Cleaning System	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154
Dryer	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Electrical Subtotal:		$ 91,638		$ 92,292		$ 92,947		$ 93,602		$ 94,256
Natural Gas	$ - /CCF									
Equipment	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Consumption:		**$ 91,638**		**$ 92,292**		**$ 92,947**		**$ 93,602**		**$ 94,256**

Chemical Consumption

Description	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*
Annual Polymer Usage (17.3 lbs. active / dry ton)	26,356	$ 1,581	30,226	$ 1,814	34,165	$ 2,050	38,172	$ 2,290	42,242	$ 2,535
Lime	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 1,581**		**$ 1,814**		**$ 2,050**		**$ 2,290**		**$ 2,535**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

Operation:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
* Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
* Centrifuge Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
Dryer Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
Operations Subtotal:	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280
Maintenance:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
* Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
* Centrifuge Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
Total Annual Labor:	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**

Generator Maintenance Contract $ 0.01 /kWhr

Description	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator Maintenance Contract ($0.01/kWh)	5,367,500	$ 53,675	6,156,247	$ 61,562	6,959,405	$ 69,594	7,776,379	$ 77,764	8,606,576	$ 86,066
Total Annual Generator Maintenance Contract:		**$ 53,675**		**$ 61,562**		**$ 69,594**		**$ 77,764**		**$ 86,066**

Ultimate Disposal

Description	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*
Liquid Land Application (7% Solids EQ Liquid: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
	(wet-tons/yr)	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*
Land Fill	3,847	$ 65,395	4,412	$ 74,996	4,987	$ 84,771	5,571	$ 94,712	6,165	$ 104,812
Cake Land Application (23% EQ Cake: Class A)	11,540	$ 196,186	13,235	$ 224,989	14,960	$ 254,313	16,714	$ 284,136	18,496	$ 314,436
Dried Land Application (90% EQ Granule: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Disposal Costs:		**$ 286,581**		**$ 324,986**		**$ 364,084**		**$ 403,848**		**$ 444,248**

Energy Production *(Cost Savings)* $ 0.075 /kWh

Electrical										
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator	5,367,500	$ (402,563)	6,156,247	$ (461,719)	6,959,405	$ (521,955)	7,776,379	$ (583,228)	8,606,576	$ (645,493)
Electrical Cost / (Savings) Subtotal		$ (402,563)		$ (461,719)		$ (521,955)		$ (583,228)		$ (645,493)
Heat	$ - /CCF									
Description	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings)		**$ (402,563)**		**$ (461,719)**		**$ (521,955)**		**$ (583,228)**		**$ (645,493)**

TOTAL ANNUAL O&M COSTS:		**$ 630,912**		**$ 618,936**		**$ 606,720**		**$ 594,275**		**$ 581,611**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1C: BM-E onto a Green Field - Belt Filter Press Dewatering
Capital Costs

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension $1,000*		
Digestion System Subtotal:					$	3,996,000
Gas & Generation Systems Subtotal:					$	1,355,000
Liquid Reduction Systems Subtotal:					$	1,455,000
Equipment Subtotal					**$**	**6,806,000**
Installation	50%			3,403,000		
Subtotal:					**$**	**10,209,000**
Miscellaneous 15%	15%			1,531,350		
Process Piping and Valves 10%	10%			1,020,900		
Plumbing at 3%	3%			306,270		
Electrical at 10%	10%			1,020,900		
Instrumentation and Controls at 6%	6%			612,540		
Subtotal:				4,491,960	**$**	**14,700,960**
Structural Subtotal:				1,550,000		
Subtotal:					**$**	**16,250,960**
Contingencies at 30%	30%			4,875,288		
Contractors Overhead and Profit at 25%	25%			4,062,740		
				8,938,028	**$**	**25,188,988**
TOTAL CAPITAL COST					**$**	**25,188,988**
Annualized Capital Cost (20 YRS @ 5.6%)					$	(2,125,320)
Annualized Capital Cost (20 YRS @ 2.0% SRF)					$	(1,540,476)
Annualized Capital Cost (15 YRS @ 0.0% CREB)					$	(1,679,266)

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1C: BM-E onto a Green Field - Belt Filter Press Dewatering
Digestion System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Digestion System:				
Feed Sequencing Tank (FST): 24 ft. dia. X 20 ft. insul. w/ cover (installed	ea	1	$ 56,000	$ 56,000
Thermophilic Digester Tank (TD): 45 ft. dia. X 24 ft. insul. w/ fixed cover (	EA	2	$ 168,000	$ 336,000
Mesophilic Digester Tank (MD): 85 ft. dia. X 29 ft. insul. (installed)	EA	2	$ 500,000	$ 1,000,000
Installation (CREDIT to Reduce FST, TD, MD Costs to Equipment/Materials Only)				$ (696,000)
Infilco 2PAD System (including the following):	LS	1	$ 3,300,000	$ 3,300,000
Fixed Cover - Thermophilic Digester	EA	2		
Floating Gas Holder Cover - Mesophilic Digester	EA	2		
Cannon Mixing System - Thermophilic				
Cannon Mixers - 24 inch	EA	6		
Nash Liquid Ring Gas Compressors	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
Cannon Mixing System - Mesophilic				
Cannon Mixers - 30 inch (with Heating Jackets)	EA	12		
Nash Liquid Ring Gas Compressors	EA	4		
Separators	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
2PAD Standard Digester Heating System				
Boiler	EA	1		
Heat Recovery Heat Exchange System (HXs, pumps, controls)	LS	1		
External Recirculation Sludge Heating System	LS	1		
Mesophilic Htg Jacket Pumps & Controls	LS	1		
Gas Safety Handling System & Flare	LS	1		
2PAD System Control Panel with PLC	LS	1		
Sludge Grinder	EA	1		
Sludge Feed Pumps	EA	2		
Sludge Transfer Pumps	EA	9		
Instrumentation				
Pressure / Vacuum Indicator Transmitters	EA	60		
Flow Indicator Transmitters	EA	14		
Temperature Indicator Transmitters	EA	55		
Level Indicator Transmitters	EA	5		
Valves				
Plug Valves	EA	51		
Check Valves	EA	12		
			Digestion System Subtotal:	**$ 3,996,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1C: BM-E onto a Green Field - Belt Filter Press Dewatering
Gas & Generator Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Gas Cleaning				
Unison Solutions - Biogas Scrubber Skid	ea	1	$ 260,000	$ 260,000
Gas Blending System	ea	1	$ 50,000	$ 50,000
Multi-Point Gas Analysis Metering System (CH4, CO2, O2, H2S)	ea	1	$ 20,000	$ 20,000
Generation				
GE Jenbacher 848	ea	1	$ 550,000	$ 550,000
GE Jenbacher 540	ea	1	$ 380,000	$ 380,000
Switchgear / Electrical Control System	ea	2	$ 35,000	$ 70,000
Heat Dump Radiator	ea	1	$ 25,000	$ 25,000
			Gas & Generation Systems Subtotal:	**$ 1,355,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1C: BM-E onto a Green Field - Belt Filter Press Dewatering
Liquid Reduction Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Sludge Storage				
Digested Sludge Storage Tank: 24 ft. dia. X 20 ft. w/ cover (installed)	ea	2	$ 50,000	$ 100,000
Dewatering System				
BFP (15 HP, 2m Belt, 70 gpm/m, 1400 lbs/hr/m)	ea	**4**	$ 275,000	$ 1,100,000
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System	ea	1	$ 150,000	$ 150,000
Dewatered Sludge Storage				
Conveyance - Belt Conveyors	LF	100	$ 800	$ 80,000
Roll-Off Container Area Equipment (Two 40-ton roll-off units)	LS	1	$ 25,000	$ 25,000
(Note: Equivalent to 4.5 days dried sludge storage at 2025 Loading Rates)				
(Note: Back-up Only. Equivalent to 1 day dewatered sludge storage at 2025 Loading Rates)				
(Note: Area included in structural cost opinion)				
Drying System				
Scott Model 548 AST Drying System	ea	0	$ 550,000	$ -
Dryer Exhaust Heat Recovery System	ea	0	$ 125,000	$ -
			Liquid Reduction Systems Subtotal:	**$ 1,455,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 1C: BM-E onto a Green Field - Belt Filter Press Dewatering
Structural

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD & Solids Handling Building				
Sludge Transfer Pumping	sf	576	$ 100	$ 57,600
Sludge Recirculation Pumping	sf	440	$ 100	$ 44,000
Heat Recovery System (HX, Pumps, Controls)	sf	500	$ 100	$ 50,000
Thermo HXs	sf	500	$ 100	$ 50,000
Boiler & Recirculation	sf	450	$ 100	$ 45,000
Meso Water Pumps	sf	500	$ 100	$ 50,000
Thermo Water Pumps	sf	500	$ 100	$ 50,000
Gas Mixing System (Compressors, Safety, Balancing)	sf	500	$ 100	$ 50,000
Gas Scrubber System & Blending System	sf	324	$ 100	$ 32,400
BFP Area	sf	1,600	$ 100	$ 160,000
Conveyance	sf	1,000	$ 100	$ 100,000
Truck / Roll-off Loading (40' X 100')	sf	4,000	$ 100	$ 400,000
Generator System	sf	1,500	$ 100	$ 150,000
Dryer	sf	400	$ 100	$ 40,000
Admin	sf	500	$ 100	$ 50,000
Shop	sf	1,000	$ 100	$ 100,000
Lockers	sf	500	$ 100	$ 50,000
Miscellaneous	sf	710	$ 100	$ 71,000
	TOTAL AREA:	15,500		
			Structural Subtotal:	**$ 1,550,000**

Ann Arbor WWTP - Feasibility Study

SCENARIO 1C: BM-E onto a "Green Field" - Belt Filter Press Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Plant Influent							
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50	(MGD)
BOD	(mg/L)	162	159	156	152	149	(mg/L)
TSS	(mg/L)	195	200	205	210	215	(mg/L)
Primary Sludge							
Hydraulic Flow	(gal./day)	92,270	106,535	121,222	136,322	151,827	(gal./day)
Solids Mass Flow	(lbs/day)	30,781	35,540	40,440	45,477	50,649	(lbs/day)
Volatile Solids	*(lbs/day)*	*21,547*	*24,878*	*28,308*	*31,834*	*35,455*	*(lbs/day)*
WAS							
Hydraulic Flow	(gal./day)	168,098	189,993	211,651	233,043	254,143	(gal./day)
Solids Mass Flow	(lbs/day)	14,322	16,187	18,032	19,855	21,653	(lbs/day)
Volatile Solids	*(lbs/day)*	*9,882*	*11,169*	*12,442*	*13,700*	*14,940*	*(lbs/day)*
Gravity Thickener Loading							
Hydraulic Load							
Combined Sludge	(gal./day)	269,667	307,119	344,761	382,557	420,469	(gal./day)
Solids Load							
Combined Sludge	(lbs/day)	45,103	51,727	58,472	65,332	72,302	(lbs/day)
Combined Sludge	(dt/yr)	8,231	9,440	10,671	11,923	13,195	(dt/yr)
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*	*(%)*
Volatile Solids	*(lbs/day)*	*31,429*	*36,047*	*40,750*	*45,534*	*50,395*	*(lbs/day)*
Gravity Thickened Combined Sludge							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	34,955	40,089	45,316	50,632	56,034	(lbs/day)
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%	(%)
Volatile Solids	*(lbs/day)*	*24,357*	*27,937*	*31,581*	*35,289*	*39,056*	*(lbs/day)*
2PAD							
Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%	(%)
2PAD Sludge Output							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	20,340	23,327	26,367	29,459	32,600	(lbs/day)
Solids Mass Flow	(dt/yr)	3,712	4,257	4,812	5,376	5,950	(dt/yr)
% Solids	(%)	2.17%	2.17%	2.17%	2.17%	2.17%	(%)
VS Destroyed	(lbs/day)	14,614	16,762	18,949	21,173	23,434	(lbs/day)
Biogas Production							
	cf/lbs VSS destroyed	17.00	17.00	17.00	17.00	17.00	cf/lbs VSS des
	cf/day	248,445	284,954	322,130	359,945	398,372	cf/day
	cf/hr	10,352	11,873	13,422	14,998	16,599	cf/hr
	BTU/cf	600	600	600	600	600	BTU/cf
	BTU/hr	6,211,130	7,123,848	8,053,241	8,998,622	9,959,304	BTU/hr
	BTU/day	149,067,130	170,972,341	193,277,781	215,966,930	239,023,293	BTU/day
Heat Available from 80% Efficient Boiler							
BTU/hr		4,968,904	5,699,078	6,442,593	7,198,898	7,967,443	BTU/hr
Meso Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	156,448	156,448	156,448	156,448	156,448	BTU/hr
Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,734	22,734	22,734	22,734	22,734	BTU/hr
Total Meso Heat Loss	BTU/hr	45,468	45,468	45,468	45,468	45,468	BTU/hr
Thermo Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	60,788	60,788	60,788	60,788	60,788	BTU/hr
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,719	22,719	22,719	22,719	22,719	BTU/hr
Total Thermo Heat Loss	BTU/hr	45,438	45,438	45,438	45,438	45,438	BTU/hr
Thermo Batch Heating Demand							
BTU/batch		5,128,488	6,382,579	7,659,488	8,958,226	10,277,805	
hrs/batch		3.00	3.00	3.00	3.00	3.00	
Batch BTU/hr		1,709,496	2,127,526	2,553,163	2,986,075	3,425,935	
Worst Case Heat Demand	BTU/hr	2,143,968	2,561,998	2,987,635	3,420,547	3,860,407	BTU/hr
Heat Supply							
Boiler	BTU/hr	-	-	-	-	-	BTU/hr
Generator Exhaust	BTU/hr	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	BTU/hr
Generator Cooling Jacket	BTU/hr	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	BTU/hr
Generator 2nd Stage Intercoole	BTU/hr	121,694	139,577	157,786	176,309	195,131	BTU/hr
Dryer Exhaust	BTU/hr	-	-	-	-	-	BTU/hr
Heat Surplus (Deficit)	%	64%	57%	52%	49%	46%	%

Ann Arbor WWTP - Feasibility Study

SCENARIO 1C: BM-E onto a "Green Field" - Belt Filter Press Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Transfer Pumping							
Energy Consumption							
Connected HP	(HP)	20	20	20	20	20	(HP)
Operation	(hrs/yr)	4,380	4,380	4,380	4,380	4,380	(hrs/yr)
Electrical Demand	(kW*hr/yr)	65,350	65,350	65,350	65,350	65,350	(kW*hr/yr)
2PAD Sludge Storage							
Number of Tanks							
Total		2	2	2	2	2	
Operating		2	2	2	2	2	
Tank Size							
Diameter (ft)	(ft)	24	24	24	24	24	(ft)
Water Depth (ft)	(ft)	20	20	20	20	20	(ft)
Operating Surface Area (s	(sf)	452	452	452	452	452	(sf)
Operating Volume (cf)	(cf)	9,048	9,048	9,048	9,048	9,048	(cf)
Sludge to Storage							
Sludge Flow (MGD)	(MGD)	112,263	128,751	145,539	162,614	179,963	(MGD)
Available Holding Time (hours)	(hours)	29	25	22	20	18	(hours)
Centrifuge Polymer Dose	(lbs active/dt)	7.1	7.1	7.1	7.1	7.1	(lbs active/dt)
Centrifuge Polymer Feed	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / y
Total Polymer Consumption	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / y
BFP Dewatering (5 d/wk, 2 shift/day)							
Number of Units Operating		3.0	3.0	3.0	3.0	3.0	
Number of Units Standby		1.0	1.0	1.0	1.0	1.0	
Shifts / Day		1.0	1.0	1.0	1.0	1.0	
Hours in Service / Shift	(hours)	7.0	8.0	9.0	10.0	11.0	(hours)
Hydraulic Loading / Unit	(gal./day)	54,748	62,786	70,969	79,291	87,747	(gal./day)
Mass Loading / Unit	(lbs/day)	9,526	10,924	12,348	13,796	15,268	(lbs/day)
Hydraulic Loading / Unit	(gpm)	130.4	130.8	131.4	132.2	132.9	(gpm)
Mass Loading / Unit	(lbs/hr)	1,361	1,366	1,372	1,380	1,388	(lbs/hr)
BFP Energy Consumption							
Unit HP	(HP)	15	15	15	15	15	(HP)
Operation	(hrs/yr)	5,460	6,240	7,020	7,800	8,580	(hrs/yr)
Electrical Demand	(kW*hr/yr)	61,097	69,826	78,554	87,282	96,010	(kW*hr/yr)
Electrical Cost	($/yr)	$ 4,582	$ 5,237	$ 5,892	$ 6,546	$ 7,201	($/yr)
Dewatered Sludge Output							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Solids Mass Flow	(lbs/day)	19,392	22,239	25,138	28,085	31,080	(lbs/day)
Percent Solids	(%)	23%	23%	23%	23%	23%	(%)
Density	(lbs/cf)	66.8	66.8	66.8	66.8	66.8	(lbs/cf)
Volumetric Flow	(cy/day)	46.7	53.6	60.6	67.7	74.9	(cy/day)
Wet Weight	(tons/day)	42.2	48.3	54.6	61.1	67.6	(tons/day)
Dry Weight	(tons/day)	9.7	11.1	12.6	14.0	15.5	(tons/day)
Annual Totals							
Volume	(cy/year)	17,063	19,568	22,118	24,712	27,347	(cy/year)
Wet Weight	(tons/year)	15,387	17,646	19,946	22,285	24,662	(tons/year)
Dry Weight	(tons/year)	3,539	4,059	4,588	5,126	5,672	(tons/year)
Recycle from Dewatering Operations							
Hydraulic Flow	*(gal./day)*	*102,153*	*117,151*	*132,421*	*147,949*	*163,726*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*948*	*1,088*	*1,229*	*1,374*	*1,520*	*(lbs/day)*
Dewatered Sludge Storage							
Number of Hoppers		2	2	2	2	2	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	104	104	104	104	104	(cy)
Total Storage Capacity	(wet tons)	80	80	80	80	80	(wet tons)
Total Storage Capacity	(days)	1.9	1.7	1.5	1.3	1.2	(days)
Gas Cleaning Skid							
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	35	35	35	35	35	(HP)
Turn-down	(%)	0%	0%	0%	0%	0%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	228,724	228,724	228,724	228,724	228,724	(kW*hr/yr)
Generation							
Energy Output	(kW)	645	740	836	934	1,034	(kW)
Exhaust Air Flow	(lbs/hr)	8,514	9,765	11,039	12,335	13,651	(lbs/hr)
Exhaust Gas Temperature	(F)	991	991	991	991	991	(F)
Exhaust Gas Heat	(BTU/hr)	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	(BTU/hr)
Cooling Jacket Heat	(BTU/hr)	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	(BTU/hr)
2nd Stage Intercooler Heat	(BTU/hr)	121,694	139,577	157,786	176,309	195,131	(BTU/hr)
Uptime	(%)	95%	95%	95%	95%	95%	(%)
Downtime	(hrs/yr)	438	438	438	438	438	(hrs/yr)
Electricity Production	(kW*hr/yr)	5,367,500	6,156,247	6,959,405	7,776,379	8,606,576	(kW*hr/yr)
Solids Drying							
Dried Solids Content	(%)	23%	23%	23%	23%	23%	(%)
Solids Mass In-Flow	(dry lbs/hr)	808	927	1,047	1,170	1,295	(dry lbs/hr)
Solids Mass Out-Flow	(wet lbs/hr)	3,513	4,029	4,554	5,088	5,631	(wet lbs/hr)
Evaporation Out-Flow	(lbs/hr)	-	-	-	-	-	(lbs/hr)
Air Demand	(lb/lb H2O)	9.44	9.44	9.44	9.44	9.44	(lb/lb H2O)
Air Demand	(lb/hr)	-	-	-	-	-	(lb/hr)
Heat Demand	(BTU/lb H2O)	1,475	1,475	1,475	1,475	1,475	(BTU/lb H2O)
Heat Demand	(BTU/hr)	-	-	-	-	-	(BTU/hr)
Heat Input - Gen Exhaust	(BTU/hr)	-	-	-	-	-	(BTU/hr)
Heat Input - Make-up Air	(BTU/hr)	-	-	-	-	-	(BTU/hr)
Drier Inlet Air Temp	(F)	720	720	720	720	720	(F)

Ann Arbor WWTP - Feasibility Study

SCENARIO 1C: BM-E onto a "Green Field" - Belt Filter Press Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	275	275	275	275	275	(HP)
Turn-down	(%)	100%	100%	100%	100%	100%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	-	-	-	-	-	(kW*hr/yr)
Solids Drying Output							
Solids Content	(%)	23%	23%	23%	23%	23%	(%)
Density	(lbs/cf)	30.2	30.2	30.2	30.2	30.2	(lbs/cf)
Solids Mass Flow	(lbs/day)	-	-	-	-	-	(lbs/day)
Wet Weight	(lbs/day)	-	-	-	-	-	(lbs/day)
Wet Weight	(tons/year)	-	-	-	-	-	(tons/year)
Volume	(cy/day)	-	-	-	-	-	(cy/day)
Volume	(cy/year)	-	-	-	-	-	(cy/year)
Heat Recovery	(%)	60%	60%	60%	60%	60%	(%)
Recovered Heat	(BTU/hr)	-	-	-	-	-	(BTU/hr)
Dried Sludge Storage							
Number of Hoppers		2	2	2	2	2	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	104	104	104	104	104	(cy)
Total Storage Capacity	(wet tons)	80	80	80	80	80	(wet tons)
Total Storage Capacity	(days)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	(days)

Appendix F

Scenario 2A

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2A: Stand Alone BM-E System - Drying
Disposal Costs

Ultimate Disposal - Current Loads to 2PAD CHP

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,106	$ 17	$ 18,801
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,106	$ 17	$ 18,801
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	3,146	$ 17	$ 53,479
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 116,081**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,268	$ 17	$ 21,561
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,268	$ 17	$ 21,561
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	3,608	$ 17	$ 61,330
Total Annual Disposal Costs (Year 2010):				**$ 129,453**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,434	$ 17	$ 24,372
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,434	$ 17	$ 24,372
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	4,078	$ 17	$ 69,324
Total Annual Disposal Costs (Year 2015):				**$ 143,067**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,602	$ 17	$ 27,230
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,602	$ 17	$ 27,230
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	4,556	$ 17	$ 77,453
Total Annual Disposal Costs (Year 2020):				**$ 156,913**

Ultimate Disposal - Year 2025

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	1,773	$ 17	$ 30,133
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	1,773	$ 17	$ 30,133
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	5,042	$ 17	$ 85,713
Total Annual Disposal Costs (Year 2025):				**$ 170,980**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2A: Stand Alone BM-E System - Drying
Operation & Maintenance Cost

Energy Consumption

	Current		2010		2015		2020		2025	
Electrical	$ 0.075	/kWh								
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Digester system / Feed pumps		$ 65,000		$ 65,000		$ 65,000		$ 65,000		$ 65,000
Transfer Pump System	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901
Gravity Belt Thickening	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Centrifuge	465,504	$ 34,913	465,504	$ 34,913	465,504	$ 34,913	465,504	$ 34,913	465,504	$ 34,913
Gas Cleaning System	645	$ 48	740	$ 55	836	$ 63	934	$ 70	1,034	$ 78
Dryer	1,061,710	$ 79,628	1,217,589	$ 91,319	1,376,284	$ 103,221	1,537,678	$ 115,326	1,701,652	$ 127,624
Electrical Subtotal:		$ 184,491		$ 196,189		$ 208,098		$ 220,210		$ 232,516
Natural Gas	$ -	/CCF								
Equipment	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Consumption:		**$ 184,491**		**$ 196,189**		**$ 208,098**		**$ 220,210**		**$ 232,516**

Chemical Consumption

Description	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*
Annual Polymer Usage (17.3 lbs. active / dry ton)	26,356	$ 1,581	30,226	$ 1,814	34,165	$ 2,050	38,172	$ 2,290	42,242	$ 2,535
Lime	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 1,581**		**$ 1,814**		**$ 2,050**		**$ 2,290**		**$ 2,535**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

Operation:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
* Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
* Centrifuge Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
Dryer Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
Operations Subtotal:	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280
Maintenance:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
* Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
* Centrifuge Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
Total Annual Labor:	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**

Generator Maintenance Contract $ 0.01 /kWhr

Description	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator Maintenance Contract ($0.01/kWh)	5,367,500	$ 53,675	6,156,247	$ 61,562	6,959,405	$ 69,594	7,776,379	$ 77,764	8,606,576	$ 86,066
Total Annual Generator Maintenance Contract:		**$ 53,675**		**$ 61,562**		**$ 69,594**		**$ 77,764**		**$ 86,066**

Ultimate Disposal

Description	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*
Liquid Land Application (7% Solids EQ Liquid: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
	(wet-tons/yr)	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*
Land Fill	1,106	$ 18,801	1,268	$ 21,561	1,434	$ 24,372	1,602	$ 27,230	1,773	$ 30,133
Cake Land Application (32% EQ Cake: Class A)	1,106	$ 18,801	1,268	$ 21,561	1,434	$ 24,372	1,602	$ 27,230	1,773	$ 30,133
Dried Land Application (90% EQ Granule: Class A)	3,146	$ 53,479	3,608	$ 61,330	4,078	$ 69,324	4,556	$ 77,453	5,042	$ 85,713
Total Annual Disposal Costs:		**$ 116,081**		**$ 129,453**		**$ 143,067**		**$ 156,913**		**$ 170,980**

Energy Production *(Cost Savings)* $ 0.075 /kWh

Electrical										
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator	5,367,500	$ (402,563)	6,156,247	$ (461,719)	6,959,405	$ (521,955)	7,776,379	$ (583,228)	8,606,576	$ (645,493)
Electrical Cost / (Savings) Subtotal		$ (402,563)		$ (461,719)		$ (521,955)		$ (583,228)		$ (645,493)
Heat	$ -	/CCF								
Description	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings)		**$ (402,563)**		**$ (461,719)**		**$ (521,955)**		**$ (583,228)**		**$ (645,493)**

TOTAL ANNUAL O&M COSTS:		**$ 553,265**		**$ 527,299**		**$ 500,854**		**$ 473,948**		**$ 446,602**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2A: Stand Alone BM-E System - Drying
Capital Costs

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension $1,000*		
Digestion System Subtotal:					$	3,996,000
Gas & Generation Systems Subtotal:					$	1,355,000
Liquid Reduction Systems Subtotal:					$	3,305,000
Equipment Subtotal					**$**	**8,656,000**
Installation	50%			4,328,000		
Subtotal:					**$**	**12,984,000**
Miscellaneous 15%	15%			1,947,600		
Process Piping and Valves 10%	10%			1,298,400		
Plumbing at 3%	3%			389,520		
Electrical at 10%	10%			1,298,400		
Instrumentation and Controls at 6%	6%			779,040		
Subtotal:				5,712,960	**$**	**18,696,960**
Structural Subtotal:				1,481,900		
Subtotal:					**$**	**20,178,860**
Contingencies at 30%	30%			6,053,658		
Contractors Overhead and Profit at 25%	25%			5,044,715		
				11,098,373	**$**	**31,277,233**
TOTAL CAPITAL COST					**$**	**31,277,233**
Annualized Capital Cost (20 YRS @ 5.6%)					$	(2,639,015)
Annualized Capital Cost (20 YRS @ 2.0% SRF)					$	(1,912,813)
Annualized Capital Cost (15 YRS @ 0.0% CREB)					$	(2,085,149)

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2A: Stand Alone BM-E System - Drying
Digestion System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Digestion System:				
Feed Sequencing Tank (FST): 24 ft. dia. X 20 ft. insul. w/ cover (installed	ea	1	$ 56,000	$ 56,000
Thermophilic Digester Tank (TD): 45 ft. dia. X 24 ft. insul. w/ fixed cover (	EA	2	$ 168,000	$ 336,000
Mesophilic Digester Tank (MD): 85 ft. dia. X 29 ft. insul. (installed)	EA	2	$ 500,000	$ 1,000,000
Installation (CREDIT to Reduce FST, TD, MD Costs to Equipment/Materials Only)				$ (696,000)
Infilco 2PAD System (including the following):	LS	1	$ 3,300,000	$ 3,300,000
Fixed Cover - Thermophilic Digester	EA	2		
Floating Gas Holder Cover - Mesophilic Digester	EA	2		
Cannon Mixing System - Thermophilic				
Cannon Mixers - 24 inch	EA	6		
Nash Liquid Ring Gas Compressors	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
Cannon Mixing System - Mesophilic				
Cannon Mixers - 30 inch (with Heating Jackets)	EA	12		
Nash Liquid Ring Gas Compressors	EA	4		
Separators	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
2PAD Standard Digester Heating System				
Boiler	EA	1		
Heat Recovery Heat Exchange System (HXs, pumps, controls)	LS	1		
External Recirculation Sludge Heating System	LS	1		
Mesophilic Htg Jacket Pumps & Controls	LS	1		
Gas Safety Handling System & Flare	LS	1		
2PAD System Control Panel with PLC	LS	1		
Sludge Grinder	EA	1		
Sludge Feed Pumps	EA	2		
Sludge Transfer Pumps	EA	9		
Instrumentation				
Pressure / Vacuum Indicator Transmitters	EA	60		
Flow Indicator Transmitters	EA	14		
Temperature Indicator Transmitters	EA	55		
Level Indicator Transmitters	EA	5		
Valves				
Plug Valves	EA	51		
Check Valves	EA	12		
			Digestion System Subtotal:	**$ 3,996,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2A: Stand Alone BM-E System - Drying
Gas & Generator Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Gas Cleaning				
Unison Solutions - Biogas Scrubber Skid	ea	1	$ 260,000	$ 260,000
Gas Blending System	ea	1	$ 50,000	$ 50,000
Multi-Point Gas Analysis Metering System (CH4, CO2, O2, H2S)	ea	1	$ 20,000	$ 20,000
Generation				
GE Jenbacher 848	ea	1	$ 550,000	$ 550,000
GE Jenbacher 540	ea	1	$ 380,000	$ 380,000
Switchgear / Electrical Control System	ea	2	$ 35,000	$ 70,000
Heat Dump Radiator	ea	1	$ 25,000	$ 25,000
			Gas & Generation Systems Subtotal:	**$ 1,355,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2A: Stand Alone BM-E System - Drying
Liquid Reduction Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Sludge Storage				
Digested Sludge Storage Tank: 24 ft. dia. X 20 ft. w/ cover (installed)	ea	2	$ 50,000	$ 100,000
Dewatering System				
Centrifuge (100 HP, 185 gpm, 2100 lbs/hr)	ea	**2**	$ 400,000	$ 800,000
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System	ea	1	$ 150,000	$ 150,000
Dewatered Sludge Storage				
Conveyance - Belt Conveyors	LF	225	$ 800	$ 180,000
Live Bottom Bin (52 cy, 40 ton capacity)	LS	8	$ 175,000	$ 1,400,000
(Note: Equivalent to 10 days dried sludge storage at 2025 Loading Rates)				
(Note: Equivalent to 7 days dewatered cake storage at 2025 Loading Rates)				
Drying System				
Scott Model 548 AST Drying System	ea	1	$ 550,000	$ 550,000
Dryer Exhaust Heat Recovery System	ea	1	$ 125,000	$ 125,000
			Liquid Reduction Systems Subtotal:	**$ 3,305,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2A: Stand Alone BM-E System - Drying
Structural

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Building				
Sludge Transfer Pumping	sf	576	$ 100	$ 57,600
Sludge Recirculation Pumping	sf	440	$ 100	$ 44,000
Heat Recovery System (HX, Pumps, Controls)	sf	500	$ 100	$ 50,000
Thermo HXs	sf	500	$ 100	$ 50,000
Boiler & Recirculation	sf	450	$ 100	$ 45,000
Meso Water Pumps	sf	500	$ 100	$ 50,000
Thermo Water Pumps	sf	500	$ 100	$ 50,000
Gas Mixing System (Compressors, Safety, Balancing)	sf	500	$ 100	$ 50,000
Gas Scrubber System & Blending System	sf	324	$ 75	$ 24,300
Admin	sf	500	$ 100	$ 50,000
Shop	sf	1,000	$ 100	$ 100,000
Lockers	sf	500	$ 100	$ 50,000
Miscellaneous	sf	2,110	$ 100	$ 211,000
	TOTAL AREA:	8,400		
Solids Handling Building - Renovation				
Demolition of Existing Incinerator Equipment (per floor)	ea	4	$ 50,000	$ 200,000
Re-work Floors & Openings				
Centrifuge Area	sf	500	$ 75	$ 37,500
Conveyance	sf	1,000	$ 75	$ 75,000
Cake / Dry Solids Storage Live Bins	sf	2,600	$ 75	$ 195,000
Generator System	sf	1,500	$ 75	$ 112,500
Dryer	sf	400	$ 75	$ 30,000
	TOTAL AREA:	6,000		
			Structural Subtotal:	**$ 1,481,900**

Ann Arbor WWTP - Feasibility Study

SCENARIO 2A: Stand Alone BM-E System - Drying

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Plant Influent							
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50	(MGD)
BOD	(mg/L)	162	159	156	152	149	(mg/L)
TSS	(mg/L)	195	200	205	210	215	(mg/L)
Primary Sludge							
Hydraulic Flow	(gal./day)	92,270	106,535	121,222	136,322	151,827	(gal./day)
Solids Mass Flow	(lbs/day)	30,781	35,540	40,440	45,477	50,649	(lbs/day)
Volatile Solids	*(lbs/day)*	*21,547*	*24,878*	*28,308*	*31,834*	*35,455*	*(lbs/day)*
WAS							
Hydraulic Flow	(gal./day)	168,098	189,993	211,651	233,043	254,143	(gal./day)
Solids Mass Flow	(lbs/day)	14,322	16,187	18,032	19,855	21,653	(lbs/day)
Volatile Solids	*(lbs/day)*	*9,882*	*11,169*	*12,442*	*13,700*	*14,940*	*(lbs/day)*
Gravity Thickener Loading							
Hydraulic Load							
Combined Sludge	(gal./day)	269,667	307,119	344,761	382,557	420,469	(gal./day)
Solids Load							
Combined Sludge	(lbs/day)	45,103	51,727	58,472	65,332	72,302	(lbs/day)
Combined Sludge	(dt/yr)	8,231	9,440	10,671	11,923	13,195	(dt/yr)
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*	*(%)*
Volatile Solids	*(lbs/day)*	*31,429*	*36,047*	*40,750*	*45,534*	*50,395*	*(lbs/day)*
Gravity Thickened Combined Sludge							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	34,955	40,089	45,316	50,632	56,034	(lbs/day)
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%	(%)
Volatile Solids	*(lbs/day)*	*24,357*	*27,937*	*31,581*	*35,289*	*39,056*	*(lbs/day)*
2PAD							
Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%	(%)
2PAD Sludge Output							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	20,340	23,327	26,367	29,459	32,600	(lbs/day)
Solids Mass Flow	(dt/yr)	3,712	4,257	4,812	5,376	5,950	(dt/yr)
% Solids	(%)	2.17%	2.17%	2.17%	2.17%	2.17%	(%)
VS Destroyed	(lbs/day)	14,614	16,762	18,949	21,173	23,434	(lbs/day)
Biogas Production							
	cf/lbs VSS destroyed	17.00	17.00	17.00	17.00	17.00	cf/lbs VSS destroyed
	cf/day	248,445	284,954	322,130	359,945	398,372	cf/day
	cf/hr	10,352	11,873	13,422	14,998	16,599	cf/hr
	BTU/cf	600	600	600	600	600	BTU/cf
	BTU/hr	6,211,130	7,123,848	8,053,241	8,998,622	9,959,304	BTU/hr
	BTU/day	149,067,130	170,972,341	193,277,781	215,966,930	239,023,293	BTU/day
Heat Available from 80% Efficient Boiler							
BTU/hr		4,968,904	5,699,078	6,442,593	7,198,898	7,967,443	BTU/hr
Meso Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	156,448	156,448	156,448	156,448	156,448	BTU/hr
Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,734	22,734	22,734	22,734	22,734	BTU/hr
Total Meso Heat Loss	BTU/hr	45,468	45,468	45,468	45,468	45,468	BTU/hr
Thermo Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	60,788	60,788	60,788	60,788	60,788	BTU/hr
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,719	22,719	22,719	22,719	22,719	BTU/hr
Total Thermo Heat Loss	BTU/hr	45,438	45,438	45,438	45,438	45,438	BTU/hr
Thermo Batch Heating Demand							
BTU/batch		5,128,488	6,382,579	7,659,488	8,958,226	10,277,805	
hrs/batch		3.00	3.00	3.00	3.00	3.00	
Batch BTU/hr		1,709,496	2,127,526	2,553,163	2,986,075	3,425,935	
Worst Case Heat Demand	BTU/hr	2,143,968	2,561,998	2,987,635	3,420,547	3,860,407	BTU/hr
Heat Supply							
Boiler	BTU/hr	-	-	-	-	-	BTU/hr
Generator Exhaust	BTU/hr	-	-	-	-	-	BTU/hr
Generator Cooling Jacket	BTU/hr	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	BTU/hr
Generator 2nd Stage Intercooler	BTU/hr	121,694	139,577	157,786	176,309	195,131	BTU/hr
Dryer Exhaust	BTU/hr	1,117,837	1,282,226	1,449,648	1,619,977	1,793,092	BTU/hr
Heat Surplus (Deficit)	%	19%	14%	11%	8%	6%	%

Ann Arbor WWTP - Feasibility Study

SCENARIO 2A: Stand Alone BM-E System - Drying

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025		
Transfer Pumping								
Energy Consumption								
Connected HP	(HP)	20	20	20	20	20	(HP)	
Operation	(hrs/yr)	4,380	4,380	4,380	4,380	4,380	(hrs/yr)	
Electrical Demand	(kW*hr/yr)	65,350	65,350	65,350	65,350	65,350	(kW*hr/yr)	
2PAD Sludge Storage								
Number of Tanks								
Total		2	2	2	2	2		
Operating		1	1	2	2	2		
Tank Size								
Diameter (ft)	(ft)	70	70	70	70	70	(ft)	
Water Depth (ft)	(ft)	12	12	12	12	12	(ft)	
Operating Surface Area (sf	(sf)	3,848	3,848	3,848	3,848	3,848	(sf)	
Operating Volume (cf)	(cf)	46,182	46,182	46,182	46,182	46,182	(cf)	
Sludge to Storage								
Sludge Flow (MGD)	(MGD)	112,263	128,751	145,539	162,614	179,963	(MGD)	
Available Holding Time (hours)	(hours)	74	64	114	102	92	(hours)	
Centrifuge Polymer Dose	(lbs active/dt)	7.1	7.1	7.1	7.1	7.1	(lbs active/dt)	
Centrifuge Polymer Feed	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / yr)	
Total Polymer Consumption	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / yr)	
Centrifuge Dewatering (7 d/wk, 3 shift/day)								
Number of Units Operating		1.0	1.0	1.0	1.0	1.0		
Number of Units Standby		1.0	1.0	1.0	1.0	1.0		
Shifts / Day		3.0	3.0	3.0	3.0	3.0		
Hours in Service / Shift	(hours)	8.0	8.0	8.0	8.0	8.0	(hours)	
Hydraulic Loading / Unit	(gal./day)	164,243	188,357	212,907	237,874	263,240	(gal./day)	
Mass Loading / Unit	(lbs/day)	28,578	32,773	37,045	41,389	45,803	(lbs/day)	
Hydraulic Loading / Unit	(gpm)	114.1	130.8	147.9	165.2	182.8	(gpm)	
Mass Loading / Unit	(lbs/hr)	1,191	1,366	1,544	1,725	1,908	(lbs/hr)	
Centrifuge Energy Consumption								
Unit HP	(HP)	100	100	100	100	100	(HP)	
Operation	(hrs/yr)	6,240	6,240	6,240	6,240	6,240	(hrs/yr)	
Electrical Demand	(kW*hr/yr)	465,504	465,504	465,504	465,504	465,504	(kW*hr/yr)	
Electrical Cost	($/yr)	$ 34,913	$ 34,913	$ 34,913	$ 34,913	$ 34,913	($/yr)	
Dewatered Sludge Output								
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)	
Solids Mass Flow	(lbs/day)	19,392	22,239	25,138	28,085	31,080	(lbs/day)	
Percent Solids	(%)	32%	32%	32%	32%	32%	(%)	
Density	(lbs/cf)	66.8	66.8	66.8	66.8	66.8	(lbs/cf)	
Volumetric Flow	(cy/day)	33.6	38.5	43.6	48.7	53.9	(cy/day)	
Wet Weight	(tons/day)	30.3	34.7	39.3	43.9	48.6	(tons/day)	
Dry Weight	(tons/day)	9.7	11.1	12.6	14.0	15.5	(tons/day)	
Annual Totals								
Volume	(cy/year)	12,264	14,064	15,897	17,762	19,656	(cy/year)	
Wet Weight	(tons/year)	11,059	12,683	14,336	16,017	17,726	(tons/year)	
Dry Weight	(tons/year)	3,539	4,059	4,588	5,126	5,672	(tons/year)	
Recycle from Centrifuge Operations								
Hydraulic Flow	*(gal./day)*	*104,997*	*120,412*	*136,106*	*152,067*	*168,283*	*(gal./day)*	
Solids Mass Flow	*(lbs/day)*	*948*	*1,088*	*1,229*	*1,374*	*1,520*	*(lbs/day)*	
Dewatered Sludge Storage								
Number of Hoppers		8	8	8	8	8		
Hopper Volume	(cy)	52	52	52	52	52	(cy)	
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)	
Total Storage Capacity	(cy)	416	416	416	416	416	(cy)	
Total Storage Capacity	(wet tons)	320	320	320	320	320	(wet tons)	
Total Storage Capacity	(days)	10.6	9.2	8.1	7.3	6.6	(days)	
Gas Cleaning Skid								
Energy Consumption (300 kWh/dt)								
Connected HP	(HP)	35	35	35	35	35	(HP)	
Turn-down	(%)	0%	0%	0%	0%	0%	(%)	
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)	
Electrical Demand	(kW*hr/yr)	228,724	228,724	228,724	228,724	228,724	(kW*hr/yr)	
Generation								
Energy Output	(kW)	645	740	836	934	1,034	(kW)	
Exhaust Air Flow	(lbs/hr)	8,514	9,765	11,039	12,335	13,651	(lbs/hr)	13.2
Exhaust Gas Temperature	(F)	991	991	991	991	991	(F)	
Exhaust Gas Heat	(BTU/hr)	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	(BTU/hr)	0.265
Cooling Jacket Heat	(BTU/hr)	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	(BTU/hr)	
2nd Stage Intercooler Heat	(BTU/hr)	121,694	139,577	157,786	176,309	195,131	(BTU/hr)	
Uptime	(%)	95%	95%	95%	95%	95%	(%)	
Downtime	(hrs/yr)	438	438	438	438	438	(hrs/yr)	
Electricity Production	(kW*hr/yr)	5,367,500	6,156,247	6,959,405	7,776,379	8,606,576	(kW*hr/yr)	

Ann Arbor WWTP - Feasibility Study

SCENARIO 2A: Stand Alone BM-E System - Drying

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Solids Drying							
Dried Solids Content	(%)	90%	90%	90%	90%	90%	(%)
Solids Mass In-Flow	(dry lbs/hr)	808	927	1,047	1,170	1,295	(dry lbs/hr)
Solids Mass Out-Flow	(wet lbs/hr)	898	1,030	1,164	1,300	1,439	(wet lbs/hr)
Evaporation Out-Flow	(lbs/hr)	1,627	1,866	2,109	2,357	2,608	(lbs/hr)
Air Demand	(lb/lb H2O)	9.44	9.44	9.44	9.44	9.44	(lb/lb H2O)
Air Demand	(lb/hr)	15,361	17,616	19,912	22,247	24,620	(lb/hr)
Heat Demand	(BTU/lb H2O)	1,475	1,475	1,475	1,475	1,475	(BTU/lb H2O)
Heat Demand	(BTU/hr)	2,400,148	2,752,535	3,111,288	3,476,142	3,846,830	(BTU/hr)
Heat Input - Gen Exhaust	(BTU/hr)	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	(BTU/hr)
Heat Input - Make-up Air	(BTU/hr)	322,253	369,295	417,125	465,708	515,006	(BTU/hr)
Drier Inlet Air Temp	(F)	720	720	720	720	720	(F)
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	275	275	275	275	275	(HP)
Turn-down	(%)	41%	32%	23%	14%	5%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	1,061,710	1,217,589	1,376,284	1,537,678	1,701,652	(kW*hr/yr)
Solids Drying Output							
Solids Content	(%)	90%	90%	90%	90%	90%	(%)
Density	(lbs/cf)	30.2	30.2	30.2	30.2	30.2	(lbs/cf)
Solids Mass Flow	(lbs/day)	19,392	22,239	25,138	28,085	31,080	(lbs/day)
Wet Weight	(lbs/day)	21,547	24,710	27,931	31,206	34,534	(lbs/day)
Wet Weight	(tons/year)	3,932	4,510	5,097	5,695	6,302	(tons/year)
Volume	(cy/day)	26	30	34	38	42	(cy/day)
Volume	(cy/year)	9,645	11,061	12,503	13,969	15,458	(cy/year)
Heat Recovery	(%)	60%	60%	60%	60%	60%	(%)
Recovered Heat	(BTU/hr)	1,440,089	1,651,521	1,866,773	2,085,685	2,308,098	(BTU/hr)
Dried Sludge Storage							
Number of Hoppers		8	8	8	8	8	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	416	416	416	416	416	(cy)
Total Storage Capacity	(wet tons)	320	320	320	320	320	(wet tons)
Total Storage Capacity	(days)	15.7	13.7	12.1	10.9	9.8	(days)

Appendix G

Scenario 2B

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2B: Stand Alone BM-E System - Centrifuge Dewatering
Disposal Costs

Ultimate Disposal - Current Loads to 2PAD CHP

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	2,765	$ 17	$ 47,003
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	8,295	$ 17	$ 141,008
Dried Land Application (90% EQ Granual: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 213,011**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	3,171	$ 17	$ 53,904
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	9,512	$ 17	$ 161,711
Dried Land Application (90% EQ Granual: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2010):				**$ 240,615**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	3,584	$ 17	$ 60,929
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	10,752	$ 17	$ 182,788
Dried Land Application (90% EQ Granual: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2015):				**$ 268,717**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	4,004	$ 17	$ 68,074
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	12,013	$ 17	$ 204,223
Dried Land Application (90% EQ Granual: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2020):				**$ 297,297**

Ultimate Disposal - Year 2025

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	4,431	$ 17	$ 75,334
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	13,294	$ 17	$ 226,001
Dried Land Application (90% EQ Granual: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2025):				**$ 326,334**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2B: Stand Alone BM-E System - Centrifuge Dewatering
Operation & Maintenance Costs

Energy Consumption

	Current		2010		2015		2020		2025	
Electrical	$ 0.075	/kWh								
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Digester system / Feed pumps		$ 65,000		$ 65,000		$ 65,000		$ 65,000		$ 65,000
Transfer Pump System	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901
Gravity Belt Thickening	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Centrifuge	310,336	$ 23,275	341,370	$ 25,603	372,403	$ 27,930	434,470	$ 32,585	465,504	$ 34,913
Gas Cleaning System	645	$ 48	740	$ 55	836	$ 63	934	$ 70	1,034	$ 78
Dryer	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Electrical Subtotal:		$ 93,225		$ 95,559		$ 97,894		$ 102,557		$ 104,892
Natural Gas	$ -	/CCF								
Equipment	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Consumption		**$ 93,225**		**$ 95,559**		**$ 97,894**		**$ 102,557**		**$ 104,892**

Chemical Consumption

Description	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*
Annual Polymer Usage (17.3 lbs. active / dry ton)	26,356	$ 1,581	30,226	$ 1,814	34,165	$ 2,050	38,172	$ 2,290	42,242	$ 2,535
Lime	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 1,581**		**$ 1,814**		**$ 2,050**		**$ 2,290**		**$ 2,535**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

	Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
	Operation:										
	2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
*	Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
*	Centrifuge Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
	Dryer Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
	Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
	Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
	On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
	Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
	Operations Subtotal:	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280
	Maintenance:										
	Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
	Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
	Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
	Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
	Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
	Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
	Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
	General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
*	Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
*	Centrifuge Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
	Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
	Total Annual Labor:	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**

Generator Maintenance Contract $ 0.01 /kWhr

Description	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator Maintenance Contract ($0.01/kWh)	5,367,500	$ 53,675	6,156,247	$ 61,562	6,959,405	$ 69,594	7,776,379	$ 77,764	8,606,576	$ 86,066
Total Annual Generator Maintenane Contract:		**$ 53,675**		**$ 61,562**		**$ 69,594**		**$ 77,764**		**$ 86,066**

Ultimate Disposal

Description	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*
Liquid Land Application (7% Solids EQ Liquid: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
	(wet-tons/yr)	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*
Land Fill	2,765	$ 47,003	3,171	$ 53,904	3,584	$ 60,929	4,004	$ 68,074	4,431	$ 75,334
Cake Land Application (32% EQ Cake: Class A)	8,295	$ 141,008	9,512	$ 161,711	10,752	$ 182,788	12,013	$ 204,223	13,294	$ 226,001
Dried Land Application (90% EQ Granual: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Disposal Costs:		**$ 213,011**		**$ 240,615**		**$ 268,717**		**$ 297,297**		**$ 326,334**

Energy Production *(Cost Savings)* $ 0.075 /kWh

Electrical										
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator	5,367,500	$ (402,563)	6,156,247	$ (461,719)	6,959,405	$ (521,955)	7,776,379	$ (583,228)	8,606,576	$ (645,493)
Electrical Cost / (Savings) Subtotal		$ (402,563)		$ (461,719)		$ (521,955)		$ (583,228)		$ (645,493)
Heat	$ -	/CCF								
Description	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings)		**$ (402,563)**		**$ (461,719)**		**$ (521,955)**		**$ (583,228)**		**$ (645,493)**
TOTAL ANNUAL O&M COSTS:		**$ 558,930**		**$ 537,832**		**$ 516,300**		**$ 496,679**		**$ 474,333**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2B: Stand Alone BM-E System - Centrifuge Dewatering
Capital Cost

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension $1,000*		
Digestion System Subtotal:					$	3,996,000
Gas & Generation Systems Subtotal:					$	1,355,000
Liquid Reduction Systems Subtotal:					$	3,030,000
Equipment Subtotal					**$**	**8,381,000**
Installation	50%			4,190,500		
Subtotal:					**$**	**12,571,500**
Miscellaneous 15%	15%			1,885,725		
Process Piping and Valves 10%	10%			1,257,150		
Plumbing at 3%	3%			377,145		
Electrical at 10%	10%			1,257,150		
Instrumentation and Controls at 6%	6%			754,290		
Subtotal:				5,531,460	**$**	**18,102,960**
Structural Subtotal:				1,451,900		
Subtotal:					**$**	**19,554,860**
Contingencies at 30%	30%			5,866,458		
Contractors Overhead and Profit at 25%	25%			4,888,715		
				10,755,173	**$**	**30,310,033**
TOTAL CAPITAL COST					**$**	**30,310,033**
Annualized Capital Cost (20 YRS @ 5.6%)					$	(2,557,408)
Annualized Capital Cost (20 YRS @ 2.0% SRF)					$	(1,853,662)
Annualized Capital Cost (15 YRS @ 0.0% CREB)					$	(2,020,669)

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2B: Stand Alone BM-E System - Centrifuge Dewatering
Digestion System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Digestion System:				
Feed Sequencing Tank (FST): 24 ft. dia. X 20 ft. insul. w/ cover (installed	ea	1	$ 56,000	$ 56,000
Thermophilic Digester Tank (TD): 45 ft. dia. X 24 ft. insul. w/ fixed cover (	EA	2	$ 168,000	$ 336,000
Mesophilic Digester Tank (MD): 85 ft. dia. X 29 ft. insul. (installed)	EA	2	$ 500,000	$ 1,000,000
Installation (CREDIT to Reduce FST, TD, MD Costs to Equipment/Materials Only)				$ (696,000)
Infilco 2PAD System (including the following):	LS	1	$ 3,300,000	$ 3,300,000
Fixed Cover - Thermophilic Digester	EA	2		
Floating Gas Holder Cover - Mesophilic Digester	EA	2		
Cannon Mixing System - Thermophilic				
Cannon Mixers - 24 inch	EA	6		
Nash Liquid Ring Gas Compressors	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
Cannon Mixing System - Mesophilic				
Cannon Mixers - 30 inch (with Heating Jackets)	EA	12		
Nash Liquid Ring Gas Compressors	EA	4		
Separators	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
2PAD Standard Digester Heating System				
Boiler	EA	1		
Heat Recovery Heat Exchange System (HXs, pumps, controls)	LS	1		
External Recirculation Sludge Heating System	LS	1		
Mesophilic Htg Jacket Pumps & Controls	LS	1		
Gas Safety Handling System & Flare	LS	1		
2PAD System Control Panel with PLC	LS	1		
Sludge Grinder	EA	1		
Sludge Feed Pumps	EA	2		
Sludge Transfer Pumps	EA	9		
Instrumentation				
Pressure / Vacuum Indicator Transmitters	EA	60		
Flow Indicator Transmitters	EA	14		
Temperature Indicator Transmitters	EA	55		
Level Indicator Transmitters	EA	5		
Valves				
Plug Valves	EA	51		
Check Valves	EA	12		
			Digestion System Subtotal:	**$ 3,996,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2B: Stand Alone BM-E System - Centrifuge Dewatering
Gas & Generator Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Gas Cleaning				
Unison Solutions - Biogas Scrubber Skid	ea	1	$ 260,000	$ 260,000
Gas Blending System	ea	1	$ 50,000	$ 50,000
Multi-Point Gas Analysis Metering System (CH4, CO2, O2, H2S)	ea	1	$ 20,000	$ 20,000
Generation				
GE Jenbacher 848	ea	1	$ 550,000	$ 550,000
GE Jenbacher 540	ea	1	$ 380,000	$ 380,000
Switchgear / Electrical Control System	ea	2	$ 35,000	$ 70,000
Heat Dump Radiator	ea	1	$ 25,000	$ 25,000
			Gas & Generation Systems Subtotal:	**$ 1,355,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2B: Stand Alone BM-E System - Centrifuge Dewatering
Liquid Reduction Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Sludge Storage				
Digested Sludge Storage Tank: 24 ft. dia. X 20 ft. w/ cover (installed)	ea	2	$ 50,000	$ 100,000
Dewatering System				
Centrifuge (100 HP, 185 gpm, 2100 lbs/hr)	ea	**3**	$ 400,000	$ 1,200,000
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System	ea	1	$ 150,000	$ 150,000
Dewatered Sludge Storage				
Conveyance - Belt Conveyors	LF	225	$ 800	$ 180,000
Live Bottom Bin (52 cy, 40 ton capacity)	LS	8	$ 175,000	$ 1,400,000
(Note: Equivalent to 10 days dried sludge storage at 2025 Loading Rates)				
(Note: Equivalent to 7 days dewatered cake storage at 2025 Loading Rates)				
Drying System				
Scott Model 548 AST Drying System	ea	0	$ 550,000	$ -
Dryer Exhaust Heat Recovery System	ea	0	$ 125,000	$ -
			Liquid Reduction Systems Subtotal:	**$ 3,030,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2B: Stand Alone BM-E System - Centrifuge Dewatering
Structural

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Building				
Sludge Transfer Pumping	sf	576	$ 100	$ 57,600
Sludge Recirculation Pumping	sf	440	$ 100	$ 44,000
Heat Recovery System (HX, Pumps, Controls)	sf	500	$ 100	$ 50,000
Thermo HXs	sf	500	$ 100	$ 50,000
Boiler & Recirculation	sf	450	$ 100	$ 45,000
Meso Water Pumps	sf	500	$ 100	$ 50,000
Thermo Water Pumps	sf	500	$ 100	$ 50,000
Gas Mixing System (Compressors, Safety, Balancing)	sf	500	$ 100	$ 50,000
Gas Scrubber System & Blending System	sf	324	$ 75	$ 24,300
Admin	sf	500	$ 100	$ 50,000
Shop	sf	1,000	$ 100	$ 100,000
Lockers	sf	500	$ 100	$ 50,000
Miscellaneous	sf	2,110	$ 100	$ 211,000
	TOTAL AREA:	8,400		
Solids Handling Building - Renovation				
Demolition of Existing Incinerator Equipment (per floor)	ea	4	$ 50,000	$ 200,000
Re-work Floors & Openings				
Centrifuge Area	sf	500	$ 75	$ 37,500
Conveyance	sf	1,000	$ 75	$ 75,000
Cake / Dry Solids Storage Live Bins	sf	2,600	$ 75	$ 195,000
Generator System	sf	1,500	$ 75	$ 112,500
Dryer	sf	-	$ 75	$ -
	TOTAL AREA:	5,600		
			Structural Subtotal:	**$ 1,451,900**

Ann Arbor WWTP - Feasibility Study

SCENARIO 2B: Stand Alone BM-E System - Centrifuge Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Plant Influent							
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50	(MGD)
BOD	(mg/L)	162	159	156	152	149	(mg/L)
TSS	(mg/L)	195	200	205	210	215	(mg/L)
Primary Sludge							
Hydraulic Flow	(gal./day)	92,270	106,535	121,222	136,322	151,827	(gal./day)
Solids Mass Flow	(lbs/day)	30,781	35,540	40,440	45,477	50,649	(lbs/day)
Volatile Solids	*(lbs/day)*	*21,547*	*24,878*	*28,308*	*31,834*	*35,455*	*(lbs/day)*
WAS							
Hydraulic Flow	(gal./day)	168,098	189,993	211,651	233,043	254,143	(gal./day)
Solids Mass Flow	(lbs/day)	14,322	16,187	18,032	19,855	21,653	(lbs/day)
Volatile Solids	*(lbs/day)*	*9,882*	*11,169*	*12,442*	*13,700*	*14,940*	*(lbs/day)*
Gravity Thickener Loading							
Hydraulic Load							
Combined Sludge	(gal./day)	269,667	307,119	344,761	382,557	420,469	(gal./day)
Solids Load							
Combined Sludge	(lbs/day)	45,103	51,727	58,472	65,332	72,302	(lbs/day)
Combined Sludge	(dt/yr)	8,231	9,440	10,671	11,923	13,195	(dt/yr)
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*	*(%)*
Volatile Solids	*(lbs/day)*	*31,429*	*36,047*	*40,750*	*45,534*	*50,395*	*(lbs/day)*
Gravity Thickened Combined Sludge							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	34,955	40,089	45,316	50,632	56,034	(lbs/day)
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%	(%)
Volatile Solids	*(lbs/day)*	*24,357*	*27,937*	*31,581*	*35,289*	*39,056*	*(lbs/day)*
2PAD							
Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%	(%)
2PAD Sludge Output							
Hydraulic Flow	(gal./day)	112,263	128,751	145,539	162,614	179,963	(gal./day)
Solids Mass Flow	(lbs/day)	20,340	23,327	26,367	29,459	32,600	(lbs/day)
Solids Mass Flow	(dt/yr)	3,712	4,257	4,812	5,376	5,950	(dt/yr)
% Solids	(%)	2.17%	2.17%	2.17%	2.17%	2.17%	(%)
VS Destroyed	(lbs/day)	14,614	16,762	18,949	21,173	23,434	(lbs/day)
Biogas Production							
	cf/lbs VSS destroyed	17.00	17.00	17.00	17.00	17.00	cf/lbs VSS destroyed
	cf/day	248,445	284,954	322,130	359,945	398,372	cf/day
	cf/hr	10,352	11,873	13,422	14,998	16,599	cf/hr
	BTU/cf	600	600	600	600	600	BTU/cf
	BTU/hr	6,211,130	7,123,848	8,053,241	8,998,622	9,959,304	BTU/hr
	BTU/day	149,067,130	170,972,341	193,277,781	215,966,930	239,023,293	BTU/day
Heat Available from 80% Efficient Boiler							
BTU/hr		4,968,904	5,699,078	6,442,593	7,198,898	7,967,443	BTU/hr
Meso Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	156,448	156,448	156,448	156,448	156,448	BTU/hr
Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,734	22,734	22,734	22,734	22,734	BTU/hr
Total Meso Heat Loss	BTU/hr	45,468	45,468	45,468	45,468	45,468	BTU/hr
Thermo Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	60,788	60,788	60,788	60,788	60,788	BTU/hr
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,719	22,719	22,719	22,719	22,719	BTU/hr
Total Thermo Heat Loss	BTU/hr	45,438	45,438	45,438	45,438	45,438	BTU/hr
Thermo Batch Heating Demand							
BTU/batch		5,128,488	6,382,579	7,659,488	8,958,226	10,277,805	
hrs/batch		3.00	3.00	3.00	3.00	3.00	
Batch BTU/hr		1,709,496	2,127,526	2,553,163	2,986,075	3,425,935	
Worst Case Heat Demand	BTU/hr	2,143,968	2,561,998	2,987,635	3,420,547	3,860,407	BTU/hr
Heat Supply							
Boiler	BTU/hr	-	-	-	-	-	BTU/hr
Generator Exhaust	BTU/hr	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	BTU/hr
Generator Cooling Jacket	BTU/hr	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	BTU/hr
Generator 2nd Stage Intercoole	BTU/hr	121,694	139,577	157,786	176,309	195,131	BTU/hr
Dryer Exhaust	BTU/hr	-	-	-	-	-	BTU/hr
Heat Surplus (Deficit)	%	64%	57%	52%	49%	46%	%

Ann Arbor WWTP - Feasibility Study

SCENARIO 2B: Stand Alone BM-E System - Centrifuge Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025		
Transfer Pumping								
Energy Consumption								
Connected HP	(HP)	20	20	20	20	20	(HP)	
Operation	(hrs/yr)	4,380	4,380	4,380	4,380	4,380	(hrs/yr)	
Electrical Demand	(kW*hr/yr)	65,350	65,350	65,350	65,350	65,350	(kW*hr/yr)	
2PAD Sludge Storage								
Number of Tanks								
Total		2	2	2	2	2		
Operating		1	1	2	2	2		
Tank Size								
Diameter (ft)	(ft)	70	70	70	70	70	(ft)	
Water Depth (ft)	(ft)	12	12	12	12	12	(ft)	
Operating Surface Area (sf	(sf)	3,848	3,848	3,848	3,848	3,848	(sf)	
Operating Volume (cf)	(cf)	46,182	46,182	46,182	46,182	46,182	(cf)	
Sludge to Storage								
Sludge Flow (MGD)	(MGD)	112,263	128,751	145,539	162,614	179,963	(MGD)	
Available Holding Time (hours)	(hours)	74	64	114	102	92	(hours)	
Centrifuge Polymer Dose	(lbs active/dt)	7.1	7.1	7.1	7.1	7.1	(lbs active/dt)	
Centrifuge Polymer Feed	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / yr)	
Total Polymer Consumption	(lbs active / yr)	26,356	30,226	34,165	38,172	42,242	(lbs active / yr)	
Centrifuge Dewatering (5 d/wk, 2 shift/day)								
Number of Units Operating		2.0	2.0	2.0	2.0	2.0		
Number of Units Standby		1.0	1.0	1.0	1.0	1.0		
Shifts / Day		1.0	1.1	1.2	1.4	1.5		
Hours in Service / Shift	(hours)	8.0	8.0	8.0	8.0	8.0	(hours)	
Hydraulic Loading / Unit	(gal./day)	82,122	94,179	106,453	118,937	131,620	(gal./day)	
Mass Loading / Unit	(lbs/day)	14,289	16,387	18,522	20,695	22,901	(lbs/day)	
Hydraulic Loading / Unit	(gpm)	171.1	178.4	184.8	177.0	182.8	(gpm)	
Mass Loading / Unit	(lbs/hr)	1,786	1,862	1,929	1,848	1,908	(lbs/hr)	
Centrifuge Energy Consumption								
Unit HP	(HP)	100	100	100	100	100	(HP)	
Operation	(hrs/yr)	4,160	4,576	4,992	5,824	6,240	(hrs/yr)	
Electrical Demand	(kW*hr/yr)	310,336	341,370	372,403	434,470	465,504	(kW*hr/yr)	
Electrical Cost	($/yr)	$ 23,275	$ 25,603	$ 27,930	$ 32,585	$ 34,913	($/yr)	
Dewatered Sludge Output								
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)	
Solids Mass Flow	(lbs/day)	19,392	22,239	25,138	28,085	31,080	(lbs/day)	
Percent Solids	(%)	32%	32%	32%	32%	32%	(%)	
Density	(lbs/cf)	66.8	66.8	66.8	66.8	66.8	(lbs/cf)	
Volumetric Flow	(cy/day)	33.6	38.5	43.6	48.7	53.9	(cy/day)	
Wet Weight	(tons/day)	30.3	34.7	39.3	43.9	48.6	(tons/day)	
Dry Weight	(tons/day)	9.7	11.1	12.6	14.0	15.5	(tons/day)	
Annual Totals								
Volume	(cy/year)	12,264	14,064	15,897	17,762	19,656	(cy/year)	
Wet Weight	(tons/year)	11,059	12,683	14,336	16,017	17,726	(tons/year)	
Dry Weight	(tons/year)	3,539	4,059	4,588	5,126	5,672	(tons/year)	
Recycle from Centrifuge Operations								
Hydraulic Flow	*(gal./day)*	*104,997*	*120,412*	*136,106*	*152,067*	*168,283*	*(gal./day)*	
Solids Mass Flow	*(lbs/day)*	*948*	*1,088*	*1,229*	*1,374*	*1,520*	*(lbs/day)*	
Dewatered Sludge Storage								
Number of Hoppers		8	8	8	8	8		
Hopper Volume	(cy)	52	52	52	52	52	(cy)	
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)	
Total Storage Capacity	(cy)	416	416	416	416	416	(cy)	
Total Storage Capacity	(wet tons)	320	320	320	320	320	(wet tons)	
Total Storage Capacity	(days)	10.6	9.2	8.1	7.3	6.6	(days)	
Gas Cleaning Skid								
Energy Consumption (300 kWh/dt)								
Connected HP	(HP)	35	35	35	35	35	(HP)	
Turn-down	(%)	0%	0%	0%	0%	0%	(%)	
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)	
Electrical Demand	(kW*hr/yr)	228,724	228,724	228,724	228,724	228,724	(kW*hr/yr)	
Generation								
Energy Output	(kW)	645	740	836	934	1,034	(kW)	
Exhaust Air Flow	(lbs/hr)	8,514	9,765	11,039	12,335	13,651	(lbs/hr)	13.2
Exhaust Gas Temperature	(F)	991	991	991	991	991	(F)	
Exhaust Gas Heat	(BTU/hr)	2,077,896	2,383,240	2,694,163	3,010,434	3,331,825	(BTU/hr)	0.265
Cooling Jacket Heat	(BTU/hr)	1,308,265	1,500,513	1,696,273	1,895,401	2,097,752	(BTU/hr)	
2nd Stage Intercooler Heat	(BTU/hr)	121,694	139,577	157,786	176,309	195,131	(BTU/hr)	
Uptime	(%)	95%	95%	95%	95%	95%	(%)	
Downtime	(hrs/yr)	438	438	438	438	438	(hrs/yr)	
Electricity Production	(kW*hr/yr)	5,367,500	6,156,247	6,959,405	7,776,379	8,606,576	(kW*hr/yr)	

Appendix H

Scenario 2C

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2C: Stand Alone BM-E System - Belt Filter Press Dewatering
Disposal Costs

Ultimate Disposal - Current Loads to 2PAD CHP

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	3,847	$ 17	$ 65,394
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	11,540	$ 17	$ 196,183
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 286,577**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	4,411	$ 17	$ 74,995
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	13,234	$ 17	$ 224,986
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2010):				**$ 324,982**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	4,986	$ 17	$ 84,770
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	14,959	$ 17	$ 254,310
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2015):				**$ 364,080**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	5,571	$ 17	$ 94,711
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	16,714	$ 17	$ 284,133
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2020):				**$ 403,843**

Ultimate Disposal - Year 2025

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	-	$ 0.027	$ -
Liquid Sludge Solids Content: 2.2%				
Land Fill	Wet Ton	6,165	$ 17	$ 104,811
Cake Land Application (32% EQ Cake: Class A)	Wet Ton	18,496	$ 17	$ 314,432
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2025):				**$ 444,242**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2C: Stand Alone BM-E System - Belt Filter Press Dewatering
Operation & Maintenance Costs

Energy Consumption

	Current		2010		2015		2020		2025	
Electrical	$ 0.075 /kWh									
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Digester system / Feed pumps		$ 65,000		$ 65,000		$ 65,000		$ 65,000		$ 65,000
Transfer Pump System	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901
Gravity Belt Thickening	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
BFP Dewatering	61,097	$ 4,582	69,826	$ 5,237	78,554	$ 5,892	87,282	$ 6,546	96,010	$ 7,201
Gas Cleaning System	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154
Dryer	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Electrical Subtotal:		$ 91,638		$ 92,292		$ 92,947		$ 93,602		$ 94,256
Natural Gas	$ - /CCF									
Equipment	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Consumption:		**$ 91,638**		**$ 92,292**		**$ 92,947**		**$ 93,602**		**$ 94,256**

Chemical Consumption

Description	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*
Annual Polymer Usage (17.3 lbs. active / dry ton)	26,356	$ 1,581	30,225	$ 1,814	34,165	$ 2,050	38,171	$ 2,290	42,242	$ 2,534
Lime	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 1,581**		**$ 1,814**		**$ 2,050**		**$ 2,290**		**$ 2,534**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

	Operation:										
	Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
	2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
*	Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
*	BFP Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
	Dryer Operations	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
	Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
	Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
	On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
	Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
	Operations Subtotal:	6,942	$ 416,520	6,942	$ 416,520	6,942	$ 416,520	6,942	$ 416,520	6,942	$ 416,520
	Maintenance:										
	Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
	Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
	Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
	Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
	Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
	Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
	Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
	Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
	General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
*	Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
*	BFP Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
	Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
	Total Annual Labor:	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**

Generator Maintenance Contract $ 0.01 /kWhr

Description	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator Maintenance Contract ($0.01/kWh)	5,367,434	$ 53,674	6,156,171	$ 61,562	6,959,319	$ 69,593	7,776,283	$ 77,763	8,606,470	$ 86,065
Total Annual Generator Maintenance Contract:		**$ 53,674**		**$ 61,562**		**$ 69,593**		**$ 77,763**		**$ 86,065**

Ultimate Disposal

Description	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*
Liquid Land Application (7% Solids EQ Liquid: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
	(wet-tons/yr)	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*
Land Fill	3,847	$ 65,394	4,411	$ 74,995	4,986	$ 84,770	5,571	$ 94,711	6,165	$ 104,811
Cake Land Application (32% EQ Cake: Class A)	11,540	$ 196,183	13,234	$ 224,986	14,959	$ 254,310	16,714	$ 284,133	18,496	$ 314,432
Dried Land Application (90% EQ Granule: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Disposal Costs:		**$ 286,577**		**$ 324,982**		**$ 364,080**		**$ 403,843**		**$ 444,242**

Energy Production *(Cost Savings)* $ 0.075 /kWh

Electrical										
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator	5,367,434	$ (402,558)	6,156,171	$ (461,713)	6,959,319	$ (521,949)	7,776,283	$ (583,221)	8,606,470	$ (645,485)
Electrical Cost / (Savings) Subtotal:		$ (402,558)		$ (461,713)		$ (521,949)		$ (583,221)		$ (645,485)
Heat	$ - /CCF									
Description	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings):		**$ (402,558)**		**$ (461,713)**		**$ (521,949)**		**$ (583,221)**		**$ (645,485)**

TOTAL ANNUAL O&M COSTS:		**$ 598,153**		**$ 586,177**		**$ 573,961**		**$ 561,517**		**$ 548,853**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2C: Stand Alone BM-E System - Belt Filter Press Dewatering
Capital Costs

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*		
Digestion System Subtotal:					$	3,996,000
Gas & Generation Systems Subtotal:					$	1,355,000
Liquid Reduction Systems Subtotal:					$	2,500,000
Equipment Subtotal					**$**	**7,851,000**
Installation	50%			3,925,500		
Subtotal:					**$**	**11,776,500**
Miscellaneous 15%	15%			1,766,475		
Process Piping and Valves 10%	10%			1,177,650		
Plumbing at 3%	3%			353,295		
Electrical at 10%	10%			1,177,650		
Instrumentation and Controls at 6%	6%			706,590		
Subtotal:				5,181,660	**$**	**16,958,160**
Structural Subtotal:				1,609,000		
Subtotal:					**$**	**18,567,160**
Contingencies at 30%	30%			5,570,148		
Contractors Overhead and Profit at 25%	25%			4,641,790		
				10,211,938	**$**	**28,779,098**
TOTAL CAPITAL COST					**$**	**28,779,098**
Annualized Capital Cost (20 YRS @ 5.6%)					$	(2,428,235)
Annualized Capital Cost (20 YRS @ 2.0% SRF)					$	(1,760,035)
Annualized Capital Cost (15 YRS @ 0.0% CREB)					$	(1,918,607)

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2C: Stand Alone BM-E System - Belt Filter Press Dewatering
Digestion System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Digestion System:				
Feed Sequencing Tank (FST): 24 ft. dia. X 20 ft. insul. w/ cover (installed)	ea	1	$ 56,000	$ 56,000
Thermophilic Digester Tank (TD): 45 ft. dia. X 24 ft. insul. w/ fixed cover (i	EA	2	$ 168,000	$ 336,000
Mesophilic Digester Tank (MD): 85 ft. dia. X 29 ft. insul.	EA	2	$ 500,000	$ 1,000,000
Installation (CREDIT to Reduce FST, TD, MD Costs to Equipment/Materials Only)				$ (696,000)
Infilco 2PAD System (including the following):	LS	1	$ 3,300,000	$ 3,300,000
Fixed Cover - Thermophilic Digester	EA	2		
Floating Gas Holder Cover - Mesophilic Digester	EA	2		
Cannon Mixing System - Thermophilic				
Cannon Mixers - 24 inch	EA	6		
Nash Liquid Ring Gas Compressors	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
Cannon Mixing System - Mesophilic				
Cannon Mixers - 30 inch (with Heating Jackets)	EA	12		
Nash Liquid Ring Gas Compressors	EA	4		
Separators	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
2PAD Standard Digester Heating System				
Boiler	EA	1		
Heat Recovery Heat Exchange System (HXs, pumps, controls)	LS	1		
External Recirculation Sludge Heating System	LS	1		
Mesophilic Htg Jacket Pumps & Controls	LS	1		
Gas Safety Handling System & Flare	LS	1		
2PAD System Control Panel with PLC	LS	1		
Sludge Grinder	EA	1		
Sludge Feed Pumps	EA	2		
Sludge Transfer Pumps	EA	9		
Instrumentation				
Pressure / Vacuum Indicator Transmitters	EA	60		
Flow Indicator Transmitters	EA	14		
Temperature Indicator Transmitters	EA	55		
Level Indicator Transmitters	EA	5		
Valves				
Plug Valves	EA	51		
Check Valves	EA	12		
			Digestion System Subtotal:	**$ 3,996,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2C: Stand Alone BM-E System - Belt Filter Press Dewatering
Gas & Generator Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Gas Cleaning				
Unison Solutions - Biogas Scrubber Skid	ea	1	$ 260,000	$ 260,000
Gas Blending System	ea	1	$ 50,000	$ 50,000
Multi-Point Gas Analysis Metering System (CH4, CO2, O2, H2S)	ea	1	$ 20,000	$ 20,000
Generation				
GE Jenbacher 848	ea	1	$ 550,000	$ 550,000
GE Jenbacher 540	ea	1	$ 380,000	$ 380,000
Switchgear / Electrical Control System	ea	2	$ 35,000	$ 70,000
Heat Dump Radiator	ea	1	$ 25,000	$ 25,000
			Gas & Generation Systems Subtotal:	**$ 1,355,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2C: Stand Alone BM-E System - Belt Filter Press Dewatering
Liquid Reduction Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Sludge Storage				
Existing Gravity Thickener Tanks (46,182 cf / tank)	ea	2	$ -	$ -
(Note: Equivalent to 4 days storage at 2025 Loading Rates)				
Thickening System				
Gravity Belt Thickener (5 HP, 2 m Belt, 250 gpm/m)	ea	**0**	$ 221,000	$ -
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System				$ -
Thickened Sludge Storage				
Existing Sludge Storage Tanks (140,000 gal. / tank)	ea	4	$ -	$ -
(Note: Equivalent to 10 days storage at 2025 Loading Rates)				
Dewatering System				
BFP (15 HP, 2 m Belt, 70 gpm/m, 1400 lbs/hr/m)	ea	**4**	$ 275,000	$ 1,100,000
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System				$ -
Dewatered Sludge Storage				
Bulk Material Live Bottom Bin (52 cy, 40 ton capacity)	ea	8	$ 175,000	$ 1,400,000
(Note: Equivalent to 5 days dewatered sludge storage at 2025 Loading Rates)				
Drying System				
Scott Model 548 AST Drying System	ea	0	$ 550,000	$ -
Dryer Exhaust Heat Recovery System	ea	0	$ 125,000	$ -
			Liquid Reduction Systems Subtotal:	**$ 2,500,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 2C: Stand Alone BM-E System - Belt Filter Press Dewatering
Structural

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Building				
Sludge Transfer Pumping	sf	576	$ 100	$ 57,600
Sludge Recirculation Pumping	sf	440	$ 100	$ 44,000
Heat Recovery System (HX, Pumps, Controls)	sf	500	$ 100	$ 50,000
Thermo HXs	sf	500	$ 100	$ 50,000
Boiler & Recirculation	sf	450	$ 100	$ 45,000
Meso Water Pumps	sf	500	$ 100	$ 50,000
Thermo Water Pumps	sf	500	$ 100	$ 50,000
Gas Mixing System (Compressors, Safety, Balancing)	sf	500	$ 100	$ 50,000
Gas Scrubber System & Blending System	sf	324	$ 100	$ 32,400
Generator System	sf	1500	$ 100	$ 150,000
Admin	sf	500	$ 100	$ 50,000
Shop	sf	1000	$ 100	$ 100,000
Lockers	sf	500	$ 100	$ 50,000
Miscellaneous	sf	2100	$ 100	$ 210,000
Existing Solids Handling Building Renovation				$ -
Demolition of Existing Incinerator Equipment (per floor)	ea	4	$ 50,000	$ 200,000
Re-work Floors & Openings				
Centrifuge Area	sf	500	$ 75	$ 37,500
Conveyance	sf	1,000	$ 75	$ 75,000
Cake / Dry Solids Storage Live Bins	sf	2,600	$ 75	$ 195,000
Generator System	sf	1,500	$ 75	$ 112,500
			Structural Subtotal:	**$ 1,609,000**

Ann Arbor WWTP - Feasibility Study

SCENARIO 2C: Stand Alone BM-E System - Belt Filter Press Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Plant Influent							
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50	(MGD)
BOD	(mg/L)	162	159	156	152	149	(mg/L)
TSS	(mg/L)	195	200	205	210	215	(mg/L)
Primary Sludge							
Hydraulic Flow	(gal./day)	92,270	106,535	121,222	136,322	151,827	(gal./day)
Solids Mass Flow	(lbs/day)	30,781	35,540	40,440	45,477	50,649	(lbs/day)
Volatile Solids	*(lbs/day)*	*21,547*	*24,878*	*28,308*	*31,834*	*35,455*	*(lbs/day)*
WAS							
Hydraulic Flow	(gal./day)	168,092	189,986	211,642	233,033	254,132	(gal./day)
Solids Mass Flow	(lbs/day)	14,321	16,187	18,032	19,854	21,652	(lbs/day)
Volatile Solids	*(lbs/day)*	*9,882*	*11,169*	*12,442*	*13,699*	*14,940*	*(lbs/day)*
Gravity Thickener Loading							
Hydraulic Load							
Combined Sludge	(gal./day)	269,660	307,111	344,752	382,546	420,458	(gal./day)
Solids Load							
Combined Sludge	(lbs/day)	45,102	51,727	58,471	65,331	72,301	(lbs/day)
Combined Sludge	(dt/yr)	8,231	9,440	10,671	11,923	13,195	(dt/yr)
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*	*(%)*
Volatile Solids	*(lbs/day)*	*31,428*	*36,047*	*40,750*	*45,533*	*50,394*	*(lbs/day)*
Gravity Thickened Combined Sludge							
Hydraulic Flow	(gal./day)	112,262	128,750	145,537	162,612	179,960	(gal./day)
Solids Mass Flow	(lbs/day)	34,954	40,088	45,315	50,632	56,033	(lbs/day)
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%	(%)
Volatile Solids	*(lbs/day)*	*24,357*	*27,936*	*31,581*	*35,288*	*39,056*	*(lbs/day)*
2PAD							
Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%	(%)
2PAD Sludge Output							
Hydraulic Flow	(gal./day)	112,262	128,750	145,537	162,612	179,960	(gal./day)
Solids Mass Flow	(lbs/day)	20,340	23,326	26,367	29,459	32,600	(lbs/day)
Solids Mass Flow	(dt/yr)	3,712	4,257	4,812	5,376	5,950	(dt/yr)
% Solids	(%)	2.17%	2.17%	2.17%	2.17%	2.17%	(%)
VS Destroyed	(lbs/day)	14,614	16,762	18,949	21,173	23,433	(lbs/day)
Biogas Production							
	cf/lbs VSS destroyed	17.00	17.00	17.00	17.00	17.00	cf/lbs VSS des
	cf/day	248,442	284,950	322,126	359,940	398,367	cf/day
	cf/hr	10,352	11,873	13,422	14,998	16,599	cf/hr
	BTU/cf	600	600	600	600	600	BTU/cf
	BTU/hr	6,211,053	7,123,759	8,053,141	8,998,511	9,959,181	BTU/hr
	BTU/day	149,065,282	170,970,216	193,275,380	215,964,257	239,020,356	BTU/day
Heat Available from 80% Efficient Boiler							
BTU/hr		4,968,843	5,699,007	6,442,513	7,198,809	7,967,345	BTU/hr
Meso Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	156,448	156,448	156,448	156,448	156,448	BTU/hr
Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,734	22,734	22,734	22,734	22,734	BTU/hr
Total Meso Heat Loss	BTU/hr	45,468	45,468	45,468	45,468	45,468	BTU/hr
Thermo Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	60,788	60,788	60,788	60,788	60,788	BTU/hr
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,719	22,719	22,719	22,719	22,719	BTU/hr
Total Thermo Heat Loss	BTU/hr	45,438	45,438	45,438	45,438	45,438	BTU/hr

Ann Arbor WWTP - Feasibility Study

SCENARIO 2C: Stand Alone BM-E System - Belt Filter Press Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Thermo Batch Heating Demand							
BTU/batch		5,128,412	6,382,503	7,659,335	8,958,074	10,277,576	
hrs/batch		3.00	3.00	3.00	3.00	3.00	
Batch BTU/hr		1,709,471	2,127,501	2,553,112	2,986,025	3,425,859	
Worst Case Heat Demand	BTU/hr	2,143,943	2,561,973	2,987,584	3,420,497	3,860,331	BTU/hr
Heat Supply							
Boiler	BTU/hr	-	-	-	-	-	BTU/hr
Generator Exhaust	BTU/hr	2,077,870	2,383,210	2,694,129	3,010,397	3,331,784	BTU/hr
Generator Cooling Jacket	BTU/hr	1,308,249	1,500,494	1,696,252	1,895,378	2,097,726	BTU/hr
Generator 2nd Stage Intercoole	BTU/hr	121,692	139,575	157,784	176,307	195,129	BTU/hr
Dryer Exhaust	BTU/hr	-	-	-	-	-	BTU/hr
Heat Surplus (Deficit)	%	64%	57%	52%	49%	46%	%
Transfer Pumping							
Energy Consumption							
Connected HP	(HP)	20	20	20	20	20	(HP)
Operation	(hrs/yr)	4,380	4,380	4,380	4,380	4,380	(hrs/yr)
Electrical Demand	(kW*hr/yr)	65,350	65,350	65,350	65,350	65,350	(kW*hr/yr)
2PAD Sludge Storage							
Number of Tanks							
Total		2	2	2	2	2	
Operating		1	1	2	2	2	
Tank Size							
Diameter (ft)		24	24	24	24	24	
Water Depth (ft)		20	20	20	20	20	
Operating Surface Area (sf)		452	452	452	452	452	
Operating Volume (cf)		9,048	9,048	9,048	9,048	9,048	
Sludge to Storage							
Sludge Flow (MGD)		112,262	128,750	145,537	162,612	179,960	
Available Holding Time (hours)		14	13	22	20	18	
BFP Dewatering (5 d/wk, 1 shift/day)							
Number of Units Operating		3.0	3.0	3.0	3.0	3.0	
Number of Units Standby		1.0	1.0	1.0	1.0	1.0	
Shifts / Day		1.0	1.0	1.0	1.0	1.0	
Hours in Service / Shift	(hours)	7.0	8.0	9.0	10.0	11.0	(hours)
Hydraulic Loading / Unit	(gal./day)	54,747	62,785	70,968	79,290	87,746	(gal./day)
Mass Loading / Unit	(lbs/day)	9,526	10,924	12,348	13,796	15,267	(lbs/day)
Hydraulic Loading / Unit	(gpm)	130.4	130.8	131.4	132.2	132.9	(gpm)
Mass Loading / Unit	(lbs/hr)	1,361	1,366	1,372	1,380	1,388	(lbs/hr)
BFP Energy Consumption							
Unit HP	(HP)	15	15	15	15	15	(HP)
Operation	(hrs/yr)	5,460	6,240	7,020	7,800	8,580	(hrs/yr)
Electrical Demand	(kW*hr/yr)	61,097	69,826	78,554	87,282	96,010	(kW*hr/yr)
Electrical Cost	($/yr)	$ 4,582	$ 5,237	$ 5,892	$ 6,546	$ 7,201	($/yr)
Dewatered Sludge Output							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Solids Mass Flow	(lbs/day)	19,392	22,239	25,137	28,085	31,080	(lbs/day)
Percent Solids	(%)	23%	23%	23%	23%	23%	(%)
Density	(lbs/cf)	66.8	66.8	66.8	66.8	66.8	(lbs/cf)
Volumetric Flow	(cy/day)	46.7	53.6	60.6	67.7	74.9	(cy/day)
Wet Weight	(tons/day)	42.2	48.3	54.6	61.1	67.6	(tons/day)
Dry Weight	(tons/day)	9.7	11.1	12.6	14.0	15.5	(tons/day)
Annual Totals							
Volume	(cy/year)	17,062	19,568	22,118	24,712	27,347	(cy/year)
Wet Weight	(tons/year)	15,387	17,646	19,946	22,285	24,661	(tons/year)
Dry Weight	(tons/year)	3,539	4,059	4,588	5,126	5,672	(tons/year)
Recycle from Dewatering Operations							
Hydraulic Flow	*(gal./day)*	*102,152*	*117,150*	*132,419*	*147,947*	*163,724*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*948*	*1,088*	*1,229*	*1,374*	*1,520*	*(lbs/day)*

Ann Arbor WWTP - Feasibility Study

SCENARIO 2C: Stand Alone BM-E System - Belt Filter Press Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Dewatered Sludge Storage							
Number of Hoppers		8	8	8	8	8	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	416	416	416	416	416	(cy)
Total Storage Capacity	(wet tons)	320	320	320	320	320	(wet tons)
Total Storage Capacity	(days)	7.6	6.6	5.9	5.2	4.7	(days)
Gas Cleaning Skid							
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	35	35	35	35	35	(HP)
Turn-down	(%)	0%	0%	0%	0%	0%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	228,724	228,724	228,724	228,724	228,724	(kW*hr/yr)
Generation							
Energy Output	(kW)	645	740	836	934	1,034	(kW)
Exhaust Air Flow	(lbs/hr)	8,514	9,765	11,039	12,334	13,651	(lbs/hr)
Exhaust Gas Temperature	(F)	991	991	991	991	991	(F)
Exhaust Gas Heat	(BTU/hr)	2,077,870	2,383,210	2,694,129	3,010,397	3,331,784	(BTU/hr)
Cooling Jacket Heat	(BTU/hr)	1,308,249	1,500,494	1,696,252	1,895,378	2,097,726	(BTU/hr)
2nd Stage Intercooler Heat	(BTU/hr)	121,692	139,575	157,784	176,307	195,129	(BTU/hr)
Uptime	(%)	95%	95%	95%	95%	95%	(%)
Downtime	(hrs/yr)	438	438	438	438	438	(hrs/yr)
Electricity Production	(kW*hr/yr)	5,367,434	6,156,171	6,959,319	7,776,283	8,606,470	(kW*hr/yr)

Appendix I

Scenario 3A

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3A: BM-E Integrated with SRMP - Drying
Disposal Costs

Ultimate Disposal - Current Loads to 2PAD CHP

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,034,659	$ 0.027	$ 27,936
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	540	$ 17	$ 9,178
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	1,080	$ 17	$ 18,356
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	3,071	$ 17	$ 52,212
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 132,682**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,186,523	$ 0.027	$ 32,036
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	619	$ 17	$ 10,525
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	1,238	$ 17	$ 21,050
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	3,522	$ 17	$ 59,876
Total Annual Disposal Costs (Year 2010):				**$ 148,487**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,341,120	$ 0.027	$ 36,210
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	700	$ 17	$ 11,896
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	1,400	$ 17	$ 23,793
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	3,981	$ 17	$ 67,677
Total Annual Disposal Costs (Year 2015):				**$ 164,576**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,498,335	$ 0.027	$ 40,455
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	782	$ 17	$ 13,291
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	1,564	$ 17	$ 26,582
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	4,448	$ 17	$ 75,611
Total Annual Disposal Costs (Year 2020):				**$ 180,939**

Ultimate Disposal - Year 2025

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,658,053	$ 0.027	$ 44,767
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	865	$ 17	$ 14,708
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	1,730	$ 17	$ 29,415
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	4,922	$ 17	$ 83,671
Total Annual Disposal Costs (Year 2025):				**$ 197,561**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3A: BM-E Integrated with SRMP - Drying
Operation & Maintenance Cost

Energy Consumption

	Current		2010		2015		2020		2025	
Electrical	$ 0.075	/kWh								
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Digester system / Feed pumps	866,667	$ 65,000	866,667	$ 65,000	866,667	$ 65,000	866,667	$ 65,000	866,667	$ 65,000
Transfer Pump System	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901
Gravity Belt Thickening	10,892	$ 817	10,892	$ 817	10,892	$ 817	10,892	$ 817	10,892	$ 817
Centrifuge	315,185	$ 23,639	363,675	$ 27,276	412,165	$ 30,912	460,655	$ 34,549	509,145	$ 38,186
Gas Cleaning System	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154
Dryer	1,036,565	$ 77,742	1,188,708	$ 89,153	1,343,590	$ 100,769	1,501,095	$ 112,582	1,661,107	$ 124,583
Electrical Subtotal:		$ 189,254		$ 204,301		$ 219,554		$ 235,004		$ 250,641
Natural Gas	$ -	/CCF								
Equipment	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Consumption:		**$ 189,254**		**$ 204,301**		**$ 219,554**		**$ 235,004**		**$ 250,641**

Chemical Consumption

Description	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*
Annual Polymer Usage (17.3 lbs. active / dry ton)	60,669	$ 3,640	69,573	$ 4,174	78,638	$ 4,718	87,857	$ 5,271	97,222	$ 5,833
Lime	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 3,640**		**$ 4,174**		**$ 4,718**		**$ 5,271**		**$ 5,833**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

	Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
	Operation:										
	2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
*	Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
*	Centrifuge Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
	Dryer Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
	Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
	Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
	On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
	Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
	Operations Subtotal:	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280
	Maintenance:										
	Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
	Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
	Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
	Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
	Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
	Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
	Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
	Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
	General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
*	Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
*	Centrifuge Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
	Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
	Total Annual Labor:	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**

Generator Maintenance Contract $ 0.01 /kWhr

Description	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator Maintenance Contract ($0.01/kWh)	5,491,499	$ 54,915	6,298,212	$ 62,982	7,119,603	$ 71,196	7,955,061	$ 79,551	8,803,977	$ 88,040
Total Annual Generator Maintenance Contract:		**$ 54,915**		**$ 62,982**		**$ 71,196**		**$ 79,551**		**$ 88,040**

Ultimate Disposal

Description	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*
Liquid Land Application (7% Solids EQ Liquid: Class A)	1,034,659	$ 27,936	1,186,523	$ 32,036	1,341,120	$ 36,210	1,498,335	$ 40,455	1,658,053	$ 44,767
	(wet-tons/yr)	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*
Land Fill	540	$ 9,178	619	$ 10,525	700	$ 11,896	782	$ 13,291	865	$ 14,708
Cake Land Application (32% EQ Cake: Class A)	1,080	$ 18,356	1,238	$ 21,050	1,400	$ 23,793	1,564	$ 26,582	1,730	$ 29,415
Dried Land Application (90% EQ Granule: Class A)	3,071	$ 52,212	3,522	$ 59,876	3,981	$ 67,677	4,448	$ 75,611	4,922	$ 83,671
Total Annual Disposal Costs:		**$ 132,682**		**$ 148,487**		**$ 164,576**		**$ 180,939**		**$ 197,561**

Energy Production ***(Cost Savings)*** $ 0.075 /kWh

Electrical										
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator	5,491,499	$ (411,862)	6,298,212	$ (472,366)	7,119,603	$ (533,970)	7,955,061	$ (596,630)	8,803,977	$ (660,298)
Electrical Cost / (Savings) Subtotal:		$ (411,862)		$ (472,366)		$ (533,970)		$ (596,630)		$ (660,298)
Heat	$ -	/CCF								
Description	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings):		**$ (411,862)**		**$ (472,366)**		**$ (533,970)**		**$ (596,630)**		**$ (660,298)**

TOTAL ANNUAL O&M COSTS:		**$ 568,628**		**$ 547,579**		**$ 526,075**		**$ 504,135**		**$ 481,777**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3A: BM-E Integrated with SRMP - Drying
Capital Cost

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*		
Digestion System Subtotal:					$	3,996,000
Gas & Generation Systems Subtotal:					$	1,355,000
Liquid Reduction Systems Subtotal:					$	675,000
Equipment Subtotal					**$**	**6,026,000**
Installation	50%			3,013,000		
Subtotal:					**$**	**9,039,000**
Miscellaneous 15%	15%			1,355,850		
Process Piping and Valves 10%	10%			903,900		
Plumbing at 3%	3%			271,170		
Electrical at 10%	10%			903,900		
Instrumentation and Controls at 6%	6%			542,340		
Subtotal:				3,977,160	**$**	**13,016,160**
Structural Subtotal:				1,500,036		
Subtotal:					**$**	**14,516,196**
Contingencies at 30%	30%			4,354,859		
Contractors Overhead and Profit at 25%	25%			3,629,049		
				7,983,908	**$**	**22,500,104**
TOTAL CAPITAL COST					**$**	**22,500,104**
Annualized Capital Cost (20 YRS @ 5.6%)					$	(1,898,445)
Annualized Capital Cost (20 YRS @ 2.0% SRF)					$	(1,376,033)
Annualized Capital Cost (15 YRS @ 0.0% CREB)					$	(1,500,007)

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3A: BM-E Integrated with SRMP - Drying
Digestion System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Digestion System:				
Feed Sequencing Tank (FST): 24 ft. dia. X 20 ft. insul. w/ cover (installed)	ea	1	$ 56,000	$ 56,000
Thermophilic Digester Tank (TD): 45 ft. dia. X 24 ft. insul. w/ fixed cover (i	EA	2	$ 168,000	$ 336,000
Mesophilic Digester Tank (MD): 85 ft. dia. X 29 ft. insul.	EA	2	$ 500,000	$ 1,000,000
Installation (CREDIT to Reduce FST, TD, MD Costs to Equipment/Materials Only)				$ (696,000)
Infilco 2PAD System (including the following):	LS	1	$ 3,300,000	$ 3,300,000
Fixed Cover - Thermophilic Digester	EA	2		
Floating Gas Holder Cover - Mesophilic Digester	EA	2		
Cannon Mixing System - Thermophilic				
Cannon Mixers - 24 inch	EA	6		
Nash Liquid Ring Gas Compressors	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
Cannon Mixing System - Mesophilic				
Cannon Mixers - 30 inch (with Heating Jackets)	EA	16		
Nash Liquid Ring Gas Compressors	EA	4		
Separators	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
2PAD Standard Digester Heating System				
Boiler	EA	1		
Heat Recovery Heat Exchange System (HXs, pumps, controls)	LS	1		
External Recirculation Sludge Heating System	LS	1		
Mesophilic Htg Jacket Pumps & Controls	LS	1		
Gas Safety Handling System & Flare	LS	1		
2PAD System Control Panel with PLC	LS	1		
Sludge Grinder	EA	1		
Sludge Feed Pumps	EA	2		
Sludge Transfer Pumps	EA	9		
Instrumentation				
Pressure / Vacuum Indicator Transmitters	EA	60		
Flow Indicator Transmitters	EA	14		
Temperature Indicator Transmitters	EA	55		
Level Indicator Transmitters	EA	5		
Valves				
Plug Valves	EA	51		
Check Valves	EA	12		
			Digestion System Subtotal:	**$ 3,996,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3A: BM-E Integrated with SRMP - Drying
Gas & Generator Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Gas Cleaning				
Unison Solutions - Biogas Scrubber Skid	ea	1	$ 260,000	$ 260,000
Gas Blending System	ea	1	$ 50,000	$ 50,000
Multi-Point Gas Analysis Metering System (CH4, CO2, O2, H2S)	ea	1	$ 20,000	$ 20,000
Generation				
GE Jenbacher 848	ea	1	$ 550,000	$ 550,000
GE Jenbacher 540	ea	1	$ 380,000	$ 380,000
Switchgear / Electrical Control System	ea	2	$ 35,000	$ 70,000
Heat Dump Radiator	ea	1	$ 25,000	$ 25,000
			Gas & Generation Systems Subtotal:	**$ 1,355,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3A: BM-E Integrated with SRMP - Drying
Liquid Reduction System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Sludge Storage				
Existing Gravity Thickener Tanks (46,182 cf / tank)	ea	2	$ -	$ -
(Note: Equivalent to 4 days storage at 2025 Loading Rates)				
Thickening System *(Furnished under SRMP)*				
Gravity Belt Thickener (5 HP, 2 m Belt, 250 gpm/m)	ea	**2**	$ -	$ -
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System				$ -
Thickened Sludge Storage				
Existing Sludge Storage Tanks (140,000 gal. / tank)	ea	4	$ -	$ -
(Note: Equivalent to 10 days storage at 2025 Loading Rates)				
Dewatering System *(Furnished under SRMP)*				
Centrifuge (250 HP, 225 gpm, 5000 lbs/hr)	ea	**2**	$ -	$ -
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System				$ -
Dewatered Sludge Storage *(Furnished under SRMP)*				
Bulk Material Hopper (Volume: 52 cy, Capacity: 40 tons)	ea	8	$ -	$ -
(Note: Equivalent to 7 days dewatered sludge storage at 2025 Loading Rates)				
(Note: Equivalent to 10 days dried sludge storage at 2025 Loading Rates)				
Drying System				
Scott Model 548 AST Drying System	ea	1	$ 550,000	$ 550,000
Dryer Exhaust Heat Recovery System	ea	1	$ 125,000	$ 125,000
			Liquid Reduction Systems Subtotal:	**$ 675,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3A: BM-E Integrated with SRMP - Drying
Structural

Description	*Unit*	*Estimated Quantity*	*Unit Cost*		*Extension*	
Mesophilic Digester						
Foundation: 85 ft. diameter	ea	2	$	63,018	$	126,036
					$	-
2PAD Building					$	-
Sludge Transfer Pumping	sf	576	$	100	$	57,600
Sludge Recirculation Pumping	sf	440	$	100	$	44,000
Heat Recovery System (HX, Pumps, Controls)	sf	500	$	100	$	50,000
Thermo HXs	sf	500	$	100	$	50,000
Meso Water Pumps	sf	500	$	100	$	50,000
Thermo Water Pumps	sf	500	$	100	$	50,000
Gas Mixing System (Compressors, Safety, Balancing)	sf	500	$	100	$	50,000
Gas Scrubber System & Blending System	sf	324	$	100	$	32,400
Generator System	sf	1500	$	100	$	150,000
Dryer	sf	400	$	100	$	40,000
Admin	sf	500	$	100	$	50,000
Shop	sf	1000	$	100	$	100,000
Lockers	sf	500	$	100	$	50,000
Existing Solids Handling Building Renovation					$	-
Demolition of Existing Incinerator Equipment (per floor)	ea	4	$	50,000	$	200,000
Rework Floors, Openings	ea	1	$	400,000	$	400,000
					$	-
				Structural Subtotal:	**$**	**1,500,036**

Ann Arbor WWTP - Feasibility Study

SCENARIO 3A: BM-E System Integrated with SRMP - Drying

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Plant Influent							
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50	(MGD)
BOD	(mg/L)	162	159	156	152	149	(mg/L)
TSS	(mg/L)	195	200	205	210	215	(mg/L)
Primary Sludge							
Hydraulic Flow	(gal./day)	94,977	109,628	124,704	140,197	156,098	(gal./day)
Solids Mass Flow	(lbs/day)	31,684	36,572	41,601	46,770	52,074	(lbs/day)
Volatile Solids	*(lbs/day)*	*22,179*	*25,600*	*29,121*	*32,739*	*36,452*	*(lbs/day)*
WAS							
Hydraulic Flow	(gal./day)	169,695	191,849	213,776	235,448	256,838	(gal./day)
Solids Mass Flow	(lbs/day)	14,458	16,345	18,213	20,060	21,882	(lbs/day)
Volatile Solids	*(lbs/day)*	*9,976*	*11,278*	*12,567*	*13,841*	*15,099*	*(lbs/day)*
Gravity Thickener Loading							
Hydraulic Load							
Combined Sludge	(gal./day)	274,125	312,244	350,568	389,060	427,684	(gal./day)
Solids Load							
Combined Sludge	(lbs/day)	46,142	52,917	59,815	66,830	73,957	(lbs/day)
Combined Sludge	(dt/yr)	8,421	9,657	10,916	12,196	13,497	(dt/yr)
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*	*(%)*
Volatile Solids	*(lbs/day)*	*32,155*	*36,879*	*41,688*	*46,580*	*51,551*	*(lbs/day)*
Gravity Thickened Combined Sludge							
Hydraulic Flow	(gal./day)	114,849	131,713	148,881	166,341	184,081	(gal./day)
Solids Mass Flow	(lbs/day)	35,760	41,011	46,356	51,793	57,316	(lbs/day)
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%	(%)
Volatile Solids	*(lbs/day)*	*24,920*	*28,581*	*32,308*	*36,100*	*39,952*	*(lbs/day)*
2PAD							
Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%	(%)
2PAD Sludge Output							
Hydraulic Flow	(gal./day)	114,849	131,713	148,881	166,341	184,081	(gal./day)
Solids Mass Flow	(lbs/day)	20,808	23,862	26,971	30,133	33,345	(lbs/day)
Solids Mass Flow	(dt/yr)	3,797	4,355	4,922	5,499	6,086	(dt/yr)
% Solids	(%)	2.17%	2.17%	2.17%	2.17%	2.17%	(%)
VS Destroyed	(lbs/day)	14,952	17,149	19,385	21,660	23,971	(lbs/day)
Biogas Production							
	cf/lbs VSSd	17.00	17.00	17.00	17.00	17.00	cf/lbs VSSd
	cf/day	254,185	291,525	329,545	368,216	407,509	cf/day
	cf/hr	10,591	12,147	13,731	15,342	16,980	cf/hr
	BTU/cf	600	600	600	600	600	BTU/cf
	BTU/hr	6,354,618	7,288,126	8,238,618	9,205,388	10,187,731	BTU/hr
	BTU/day	152,510,843	174,915,023	197,726,828	220,929,309	244,505,541	BTU/day
Heat Available from 80% Efficient Boiler							
BTU/hr		5,083,695	5,830,501	6,590,894	7,364,310	8,150,185	BTU/hr
Meso Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	156,448	156,448	156,448	156,448	156,448	BTU/hr
Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,734	22,734	22,734	22,734	22,734	BTU/hr
Total Meso Heat Loss	BTU/hr	45,468	45,468	45,468	45,468	45,468	BTU/hr
Thermo Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	60,788	60,788	60,788	60,788	60,788	BTU/hr
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,719	22,719	22,719	22,719	22,719	BTU/hr
Total Thermo Heat Loss	BTU/hr	45,438	45,438	45,438	45,438	45,438	BTU/hr
Thermo Batch Heating Demand							
BTU/batch		5,325,182	6,607,871	7,913,683	9,241,704	10,591,023	
hrs/batch		3.00	3.00	3.00	3.00	3.00	
Batch BTU/hr		1,775,061	2,202,624	2,637,894	3,080,568	3,530,341	
Worst Case Heat Demand	BTU/hr	2,209,533	2,637,096	3,072,366	3,515,040	3,964,813	
Heat Supply							
Boiler	BTU/hr	-	-	-	-	-	BTU/hr
Generator Exhaust	BTU/hr	-	-	-	-	-	BTU/hr
Generator Cooling Jacket	BTU/hr	1,338,489	1,535,115	1,735,320	1,938,953	2,145,866	BTU/hr
Generator 2nd Stage Intercooler	BTU/hr	124,505	142,795	161,418	180,360	199,607	BTU/hr
Dryer Exhaust	BTU/hr	1,188,577	1,363,300	1,541,228	1,722,230	1,906,175	BTU/hr
Heat Surplus (Deficit)	%	20%	15%	12%	9%	7%	%

Ann Arbor WWTP - Feasibility Study

SCENARIO 3A: BM-E System Integrated with SRMP - Drying

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Transfer Pumping							
Energy Consumption							
Connected HP	(HP)	20	20	20	20	20	(HP)
Operation	(hrs/yr)	4,380	4,380	4,380	4,380	4,380	(hrs/yr)
Electrical Demand	(kW*hr/yr)	65,350	65,350	65,350	65,350	65,350	(kW*hr/yr)
2PAD Sludge Storage							
Number of Tanks							
Total		2	2	2	2	2	
Operating		1	1	2	2	2	
Tank Size							
Diameter (ft)		70	70	70	70	70	
Water Depth (ft)		12	12	12	12	12	
Operating Surface Area (sf)		3,848	3,848	3,848	3,848	3,848	
Operating Volume (cf)		46,182	46,182	46,182	46,182	46,182	
Sludge to Storage							
Sludge Flow (MGD)		114,849	131,713	148,881	166,341	184,081	
Available Holding Time (hours)		72	63	111	100	90	
Gravity Belt Thickening							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Thickened Sludge Output							
Percent Solids	(%)	4.2%	4.2%	4.2%	4.2%	4.2%	(%)
Hydraulic Flow	(gal./day)	56,694	65,015	73,486	82,101	90,852	(gal./day)
Solids Mass Flow	(lbs/day)	19,859	22,773	25,741	28,758	31,824	(lbs/day)
Solids Mass Flow	(tons/year)	3,624	4,156	4,698	5,248	5,808	(tons/year)
Weight Weight (SG 1.02)	(tons/day)	241.1	276.5	312.6	349.2	386.4	(tons/day)
Dry Weight	(tons/day)	9.9	11.4	12.9	14.4	15.9	(tons/day)
Recycle from GBT Operations							
Hydraulic Flow	*(gal./day)*	*60,331*	*69,192*	*78,215*	*87,391*	*96,715*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*1,045*	*1,199*	*1,355*	*1,514*	*1,675*	*(lbs/day)*
Equipment Loading (8 hr / day)							
Belt Width	(m)	2.0	2.0	2.0	2.0	2.0	(m)
Number Operating		1.0	1.0	1.0	1.0	1.0	
Number Standby		1.0	1.0	1.0	1.0	1.0	
Sludge Feed Rate	(gpm)	244	280	316	353	391	(gpm)
Unit Feed Rate	(gpm/m)	122	140	158	177	195	(gpm/m)
GBT Energy Consumption							
Connected HP	(HP)	5	5	5	5	5	(HP)
Operation	(hrs/yr)	2,920	2,920	2,920	2,920	2,920	(hrs/yr)
Electrical Demand	(kW*hr/yr)	10,892	10,892	10,892	10,892	10,892	(kW*hr/yr)
GBT Sludge Storage							
Number of Tanks							
Total Available		4	4	4	4	4	
Operating		4	4	4	4	4	
Tank Size							
Unit Operating Volume	(gal.)	140,000	140,000	140,000	140,000	140,000	(gal.)
Available Holding Time	(hours)	237	207	183	164	148	(hours)
Available Holding Time	(days)	9.9	8.6	7.6	6.8	6.2	(days)
Polymer Consumption							
GBT Polymer Dose	(lbs active/dt)	9.2	9.2	9.2	9.2	9.2	(lbs active/dt)
GBT Polymer Feed	(lbs active / yr)	34,937	40,065	45,285	50,594	55,987	(lbs active / yr)
Centrifuge Polymer Dose	(lbs active/dt)	7.1	7.1	7.1	7.1	7.1	(lbs active/dt)
Centrifuge Polymer Feed	(lbs active / yr)	25,732	29,509	33,353	37,263	41,236	(lbs active / yr)
Total Polymer Consumption	(lbs active / yr)	60,669	69,573	78,638	87,857	97,222	(lbs active / yr)
Centrifuge Dewatering (5 d/wk, 1 shift/day)							
Number of Units Operating		1.0	1.0	1.0	1.0	1.0	
Number of Units Standby		1.0	1.0	1.0	1.0	1.0	
Shifts / Day		1.0	1.0	1.0	1.0	1.0	
Hours in Service / Shift	(hours)	6.5	7.5	8.5	9.5	10.5	(hours)
Hydraulic Loading / Unit	(gal./day)	86,279	98,942	111,834	124,944	138,262	(gal./day)
Mass Loading / Unit	(lbs/day)	27,901	31,996	36,165	40,404	44,711	(lbs/day)
Hydraulic Loading / Unit	(gpm)	221.2	219.9	219.3	219.2	219.5	(gpm)
Mass Loading / Unit	(lbs/hr)	4,292	4,266	4,255	4,253	4,258	(lbs/hr)
Centrifuge Energy Consumption							
Unit HP	(HP)	250	250	250	250	250	(HP)
Operation	(hrs/yr)	1,690	1,950	2,210	2,470	2,730	(hrs/yr)
Electrical Demand	(kW*hr/yr)	315,185	363,675	412,165	460,655	509,145	(kW*hr/yr)
Electrical Cost	($/yr)	$ 23,639	$ 27,276	$ 30,912	$ 34,549	$ 38,186	($/yr)
Dewatered Sludge Output							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Solids Mass Flow	(lbs/day)	18,933	21,712	24,540	27,417	30,340	(lbs/day)
Percent Solids	(%)	32%	32%	32%	32%	32%	(%)
Density	(lbs/cf)	66.8	66.8	66.8	66.8	66.8	(lbs/cf)
Volumetric Flow	(cy/day)	32.8	37.6	42.5	47.5	52.6	(cy/day)
Wet Weight	(tons/day)	29.6	33.9	38.3	42.8	47.4	(tons/day)
Dry Weight	(tons/day)	9.5	10.9	12.3	13.7	15.2	(tons/day)
Annual Totals							
Volume	(cy/year)	11,973	13,731	15,520	17,339	19,187	(cy/year)
Wet Weight	(tons/year)	10,798	12,382	13,996	15,636	17,303	(tons/year)
Dry Weight	(tons/year)	3,455	3,962	4,479	5,004	5,537	(tons/year)

Ann Arbor WWTP - Feasibility Study

SCENARIO 3A: BM-E System Integrated with SRMP - Drying

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Recycle from Centrifuge Operations							
Hydraulic Flow	*(gal./day)*	*49,600*	*56,880*	*64,291*	*71,827*	*79,484*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*926*	*1,062*	*1,200*	*1,341*	*1,484*	*(lbs/day)*
Dewatered Sludge Storage							
Number of Hoppers		8	8	8	8	8	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	416	416	416	416	416	(cy)
Total Storage Capacity	(wet tons)	320	320	320	320	320	(wet tons)
Total Storage Capacity	(days)	10.8	9.4	8.3	7.5	6.8	(days)
Gas Cleaning Skid							
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	35	35	35	35	35	(HP)
Turn-down	(%)	0%	0%	0%	0%	0%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	228,724	228,724	228,724	228,724	228,724	(kW*hr/yr)
Generation							
Energy Output	(kW)	660	757	856	956	1,058	(kW)
Exhaust Air Flow	(lbs/hr)	8,710	9,990	11,293	12,618	13,964	(lbs/hr)
Exhaust Gas Temperature	(F)	991	991	991	991	991	(F)
Exhaust Gas Heat	(BTU/hr)	2,125,899	2,438,198	2,756,180	3,079,607	3,408,243	(BTU/hr)
Cooling Jacket Heat	(BTU/hr)	1,338,489	1,535,115	1,735,320	1,938,953	2,145,866	(BTU/hr)
2nd Stage Intercooler Heat	(BTU/hr)	124,505	142,795	161,418	180,360	199,607	(BTU/hr)
Uptime	(%)	95%	95%	95%	95%	95%	(%)
Downtime	(hrs/yr)	438	438	438	438	438	(hrs/yr)
Electricity Production	(kW*hr/yr)	5,491,499	6,298,212	7,119,603	7,955,061	8,803,977	(kW*hr/yr)
Solids Drying							
Dried Solids Content	(%)	90%	90%	90%	90%	90%	(%)
Solids Mass In-Flow	(dry lbs/hr)	789	905	1,023	1,142	1,264	(dry lbs/hr)
Solids Mass Out-Flow	(wet lbs/hr)	877	1,005	1,136	1,269	1,405	(wet lbs/hr)
Evaporation Out-Flow	(lbs/hr)	1,589	1,822	2,059	2,301	2,546	(lbs/hr)
Air Demand	(lb/lb H2O)	9.44	9.44	9.44	9.44	9.44	(lb/lb H2O)
Air Demand	(lb/hr)	14,997	17,198	19,439	21,718	24,033	(lb/hr)
Heat Demand	(BTU/lb H2O)	1,475	1,475	1,475	1,475	1,475	(BTU/lb H2O)
Heat Demand	(BTU/hr)	2,343,304	2,687,246	3,037,379	3,393,441	3,755,172	(BTU/hr)
Heat Input - Gen Exhaust	(BTU/hr)	2,125,899	2,438,198	2,756,180	3,079,607	3,408,243	(BTU/hr)
Heat Input - Make-up Air	(BTU/hr)	217,405	249,048	281,199	313,834	346,928	(BTU/hr)
Drier Inlet Air Temp	(F)	720	720	720	720	720	(F)
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	275	275	275	275	275	(HP)
Turn-down	(%)	42%	34%	25%	16%	8%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	1,036,565	1,188,708	1,343,590	1,501,095	1,661,107	(kW*hr/yr)
Solids Drying Output							
Solids Content	(%)	90%	90%	90%	90%	90%	(%)
Density	(lbs/cf)	30.2	30.2	30.2	30.2	30.2	(lbs/cf)
Solids Mass Flow	(lbs/day)	18,933	21,712	24,540	27,417	30,340	(lbs/day)
Wet Weight	(lbs/day)	21,036	24,124	27,267	30,464	33,711	(lbs/day)
Wet Weight	(tons/year)	3,839	4,403	4,976	5,560	6,152	(tons/year)
Volume	(cy/day)	26	30	33	37	41	(cy/day)
Volume	(cy/year)	9,417	10,799	12,206	13,637	15,090	(cy/year)
Heat Recovery	(%)	60%	60%	60%	60%	60%	(%)
Recovered Heat	(BTU/hr)	1,405,983	1,612,348	1,822,427	2,036,065	2,253,103	(BTU/hr)
Dried Sludge Storage							
Number of Hoppers		8	8	8	8	8	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	416	416	416	416	416	(cy)
Total Storage Capacity	(wet tons)	320	320	320	320	320	(wet tons)
Total Storage Capacity	(days)	16.1	14.1	12.4	11.1	10.1	(days)

Appendix J Scenario 3B

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3B: BM-E Integrated with SRMP - Centrifuge Dewatering
Disposal Costs

Ultimate Disposal - Current Loads to 2PAD CHP

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,034,659	$ 0.027	$ 27,936
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	540	$ 17	$ 9,178
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	9,718	$ 17	$ 165,203
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 227,316**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,186,523	$ 0.027	$ 32,036
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	619	$ 17	$ 10,525
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	11,144	$ 17	$ 189,450
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2010):				**$ 257,012**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,341,120	$ 0.027	$ 36,210
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	700	$ 17	$ 11,896
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	12,596	$ 17	$ 214,135
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2015):				**$ 287,241**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,498,335	$ 0.027	$ 40,455
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	782	$ 17	$ 13,291
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	14,073	$ 17	$ 239,237
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2020):				**$ 317,983**

Ultimate Disposal - Year 2025

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,658,053	$ 0.027	$ 44,767
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	865	$ 17	$ 14,708
Solids Content: 32%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	15,573	$ 17	$ 264,739
Solids Content: 32%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2025):				**$ 349,214**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3B: BM-E Integrated with SRMP - Centrifuge Dewatering
Operation & Maintenance Cost

Energy Consumption

Electrical $ 0.075 /kWh

Equipment	Current (kW*hr/yr)	Current Annual Cost	2010 (kW*hr/yr)	2010 Annual Cost	2015 (kW*hr/yr)	2015 Annual Cost	2020 (kW*hr/yr)	2020 Annual Cost	2025 (kW*hr/yr)	2025 Annual Cost
Digester system / Feed pumps		$ 65,000		$ 65,000		$ 65,000		$ 65,000		$ 65,000
Transfer Pump System	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901
Gravity Belt Thickening	10,892	$ 817	10,892	$ 817	10,892	$ 817	10,892	$ 817	10,892	$ 817
Centrifuge	315,185	$ 23,639	363,675	$ 27,276	412,165	$ 30,912	460,655	$ 34,549	509,145	$ 38,186
Gas Cleaning System	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154
Dryer	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Electrical Subtotal:		$ 111,511		$ 115,148		$ 118,785		$ 122,421		$ 126,058

Natural Gas $ - /CCF

Equipment	Current (CCF/yr)	Current Annual Cost	2010 (CCF/yr)	2010 Annual Cost	2015 (CCF/yr)	2015 Annual Cost	2020 (CCF/yr)	2020 Annual Cost	2025 (CCF/yr)	2025 Annual Cost
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Consumption:		**$ 111,511**		**$ 115,148**		**$ 118,785**		**$ 122,421**		**$ 126,058**

Chemical Consumption

Description	Current (lbs/yr)	Current Annual Cost	2010 (lbs/yr)	2010 Annual Cost	2015 (lbs/yr)	2015 Annual Cost	2020 (lbs/yr)	2020 Annual Cost	2025 (lbs/yr)	2025 Annual Cost
Annual Polymer Usage (17.3 lbs. active / dry ton)	60,669	$ 3,640	69,573	$ 4,174	78,638	$ 4,718	87,857	$ 5,271	97,222	$ 5,833
Lime	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 3,640**		**$ 4,174**		**$ 4,718**		**$ 5,271**		**$ 5,833**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

Operation:

Description	Current (hrs/yr)	Current Annual Cost	2010 (hrs/yr)	2010 Annual Cost	2015 (hrs/yr)	2015 Annual Cost	2020 (hrs/yr)	2020 Annual Cost	2025 (hrs/yr)	2025 Annual Cost
2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
* Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
* Centrifuge Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
Dryer Operations	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
Operations Subtotal:	6,942	$ 416,520	6,942	$ 416,520	6,942	$ 416,520	6,942	$ 416,520	6,942	$ 416,520

Maintenance:

Description	Current (hrs/yr)	Current Annual Cost	2010 (hrs/yr)	2010 Annual Cost	2015 (hrs/yr)	2015 Annual Cost	2020 (hrs/yr)	2020 Annual Cost	2025 (hrs/yr)	2025 Annual Cost
Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
* Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
* Centrifuge Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
Total Annual Labor:	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**

Generator Maintenance Contract $ 0.01 /kWhr

Description	Current (kW*hr/yr)	Current Annual Cost	2010 (kW*hr/yr)	2010 Annual Cost	2015 (kW*hr/yr)	2015 Annual Cost	2020 (kW*hr/yr)	2020 Annual Cost	2025 (kW*hr/yr)	2025 Annual Cost
Generator Maintenance Contract ($0.01/kWh)	5,491,499	$ 54,915	6,298,212	$ 62,982	7,119,603	$ 71,196	7,955,061	$ 79,551	8,803,977	$ 88,040
Total Annual Generator Maintenance Contract:		**$ 54,915**		**$ 62,982**		**$ 71,196**		**$ 79,551**		**$ 88,040**

Ultimate Disposal

Description	Current Annual Fee	Current Annual Cost	2010 Annual Fee	2010 Annual Cost	2015 Annual Fee	2015 Annual Cost	2020 Annual Fee	2020 Annual Cost	2025 Annual Fee	2025 Annual Cost
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	Annual Cost	(gal./yr)	Annual Cost	(gal./yr)	Annual Cost	(gal./yr)	Annual Cost	(gal./yr)	Annual Cost
Liquid Land Application (7% Solids EQ Liquid: Class A)	1,034,659	$ 27,936	1,186,523	$ 32,036	1,341,120	$ 36,210	1,498,335	$ 40,455	1,658,053	$ 44,767
	(wet-tons/yr)	Annual Cost	(wet-tons/yr)	Annual Cost	(wet-tons/yr)	Annual Cost	(wet-tons/yr)	Annual Cost	(wet-tons/yr)	Annual Cost
Land Fill	540	$ 9,178	619	$ 10,525	700	$ 11,896	782	$ 13,291	865	$ 14,708
Cake Land Application (32% EQ Cake: Class A)	9,718	$ 165,203	11,144	$ 189,450	12,596	$ 214,135	14,073	$ 239,237	15,573	$ 264,739
Dried Land Application (90% EQ Granual: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Disposal Costs:		**$ 227,316**		**$ 257,012**		**$ 287,241**		**$ 317,983**		**$ 349,214**

Energy Production ***(Cost Savings)*** $ 0.075 /kWh

Electrical

Equipment	Current (kW*hr/yr)	Current Annual Cost	2010 (kW*hr/yr)	2010 Annual Cost	2015 (kW*hr/yr)	2015 Annual Cost	2020 (kW*hr/yr)	2020 Annual Cost	2025 (kW*hr/yr)	2025 Annual Cost
Generator	5,491,499	$ (411,862)	6,298,212	$ (472,366)	7,119,603	$ (533,970)	7,955,061	$ (596,630)	8,803,977	$ (660,298)
Electrical Cost / (Savings) Subtotal:		$ (411,862)		$ (472,366)		$ (533,970)		$ (596,630)		$ (660,298)

Heat $ - /CCF

Description	Current (mmBTU/yr)	Current Annual Cost	2010 (mmBTU/yr)	2010 Annual Cost	2015 (mmBTU/yr)	2015 Annual Cost	2020 (mmBTU/yr)	2020 Annual Cost	2025 (mmBTU/yr)	2025 Annual Cost
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings):		**$ (411,862)**		**$ (472,366)**		**$ (533,970)**		**$ (596,630)**		**$ (660,298)**

	Current		2010		2015		2020		2025
TOTAL ANNUAL O&M COSTS:	**$ 552,760**		**$ 534,190**		**$ 515,210**		**$ 495,837**		**$ 476,087**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3B: BM-E Integrated with SRMP - Centrifuge Dewatering
Capital Cost

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*		
Digestion System Subtotal:					$	3,996,000
Gas & Generation Systems Subtotal:					$	1,330,000
Liquid Reduction Systems Subtotal:					$	-
Equipment Subtotal					**$**	**5,326,000**
Installation	50%			2,663,000		
Subtotal:					**$**	**7,989,000**
Miscellaneous 15%	15%			1,198,350		
Process Piping and Valves 10%	10%			798,900		
Plumbing at 3%	3%			239,670		
Electrical at 10%	10%			798,900		
Instrumentation and Controls at 6%	6%			479,340		
Subtotal:				3,515,160	**$**	**11,504,160**
Structural Subtotal:				1,334,000		
Subtotal:					**$**	**12,838,160**
Contingencies at 30%	30%			3,851,448		
Contractors Overhead and Profit at 25%	25%			3,209,540		
				7,060,988	**$**	**19,899,148**
TOTAL CAPITAL COST					**$**	**19,899,148**
Annualized Capital Cost (20 YRS @ 5.6%)					$	(1,678,990)
Annualized Capital Cost (20 YRS @ 2.0% SRF)					$	(1,216,967)
Annualized Capital Cost (15 YRS @ 0.0% CREB)					$	(1,326,610)

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3B: BM-E Integrated with SRMP - Centrifuge Dewatering
Digestion System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Digestion System:				
Feed Sequencing Tank (FST): 24 ft. dia. X 20 ft. insul. w/ cover (installed)	ea	1	$ 56,000	$ 56,000
Thermophilic Digester Tank (TD): 45 ft. dia. X 24 ft. insul. w/ fixed cover (i	EA	2	$ 168,000	$ 336,000
Mesophilic Digester Tank (MD): 85 ft. dia. X 29 ft. insul.	EA	2	$ 500,000	$ 1,000,000
Installation (CREDIT to Reduce FST, TD, MD Costs to Equipment/Materials Only)				$ (696,000)
Infilco 2PAD System (including the following):	LS	1	$ 3,300,000	$ 3,300,000
Fixed Cover - Thermophilic Digester	EA	2		
Floating Gas Holder Cover - Mesophilic Digester	EA	2		
Cannon Mixing System - Thermophilic				
Cannon Mixers - 24 inch	EA	6		
Nash Liquid Ring Gas Compressors	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
Cannon Mixing System - Mesophilic				
Cannon Mixers - 30 inch (with Heating Jackets)	EA	12		
Nash Liquid Ring Gas Compressors	EA	4		
Separators	EA	4		
Gas Balancing System	EA	2		
Gas Safety / Control Equipment	EA	2		
2PAD Standard Digester Heating System				
Boiler	EA	1		
Heat Recovery Heat Exchange System (HXs, pumps, controls)	LS	1		
External Recirculation Sludge Heating System	LS	1		
Mesophilic Htg Jacket Pumps & Controls	LS	1		
Gas Safety Handling System & Flare	LS	1		
2PAD System Control Panel with PLC	LS	1		
Sludge Grinder	EA	1		
Sludge Feed Pumps	EA	2		
Sludge Transfer Pumps	EA	9		
Instrumentation				
Pressure / Vacuum Indicator Transmitters	EA	60		
Flow Indicator Transmitters	EA	14		
Temperature Indicator Transmitters	EA	55		
Level Indicator Transmitters	EA	5		
Valves				
Plug Valves	EA	51		
Check Valves	EA	12		
			Digestion System Subtotal:	**$ 3,996,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3B: BM-E Integrated with SRMP - Centrifuge Dewatering
Gas & Generator Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Gas Cleaning				
Unison Solutions - Biogas Scrubber Skid	ea	1	$ 260,000	$ 260,000
Gas Blending System	ea	1	$ 50,000	$ 50,000
Multi-Point Gas Analysis Metering System (CH_4, CO_2, O_2, H_2S)	ea	1	$ 20,000	$ 20,000
Generation				
GE Jenbacher 848	ea	1	$ 550,000	$ 550,000
GE Jenbacher 540	ea	1	$ 380,000	$ 380,000
Switchgear / Electrical Control System	ea	2	$ 35,000	$ 70,000
Heat Dump Radiator	ea		$ -	$ -
			Gas & Generation Systems Subtotal:	**$ 1,330,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3B: BM-E Integrated with SRMP - Centrifuge Dewatering

Liquid Reduction System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Sludge Storage				
Existing Gravity Thickener Tanks (46,182 cf / tank)	ea	2	$ -	$ -
(Note: Equivalent to 4 days storage at 2025 Loading Rates)				
Thickening System				
Gravity Belt Thickener (5 HP, 2 m Belt, 250 gpm/m)	ea	0	$ -	$ -
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System				$ -
Thickened Sludge Storage				
Existing Sludge Storage Tanks (140,000 gal. / tank)	ea	4	$ -	$ -
(Note: Equivalent to 10 days storage at 2025 Loading Rates)				
Dewatering System *(Furnished under SRMP)*				
Centrifuge (250 HP, 225 gpm, 5000 lbs/hr)	ea	3	$ -	$ -
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System				$ -
Dewatered Sludge Storage *(Furnished under SRMP)*				
Bulk Material Live Bottom Bin (52 cy, 40 ton capacity)	ea	8	$ -	$ -
(Note: Equivalent to 7 days dewatered sludge storage at 2025 Loading Rates)				
(Note: Equivalent to 10 days dried sludge storage at 2025 Loading Rates)				
Drying System				
Scott Model 548 AST Drying System	ea	0	$ 550,000	$ -
Dryer Exhaust Heat Recovery System	ea	0	$ 125,000	$ -
			Liquid Reduction Systems Subtotal:	**$ -**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3B: BM-E Integrated with SRMP - Centrifuge Dewatering

Structural

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Building				
Sludge Transfer Pumping	sf	576	$ 100	$ 57,600
Sludge Recirculation Pumping	sf	440	$ 100	$ 44,000
Heat Recovery System (HX, Pumps, Controls)	sf	500	$ 100	$ 50,000
Thermo HXs	sf	500	$ 100	$ 50,000
Meso Water Pumps	sf	500	$ 100	$ 50,000
Thermo Water Pumps	sf	500	$ 100	$ 50,000
Gas Mixing System (Compressors, Safety, Balancing)	sf	500	$ 100	$ 50,000
Gas Scrubber System & Blending System	sf	324	$ 100	$ 32,400
Generator System	sf	1500	$ 100	$ 150,000
Dryer	sf	0	$ 100	$ -
Admin	sf	500	$ 100	$ 50,000
Shop	sf	1000	$ 100	$ 100,000
Lockers	sf	500	$ 100	$ 50,000
Existing Solids Handling Building Renovation				$ -
Demolition of Existing Incinerator Equipment (per floor)	ea	4	$ 50,000	$ 200,000
Rework Floors, Openings	ea	1	$ 400,000	$ 400,000
				$ -
			Structural Subtotal:	**$ 1,334,000**

Ann Arbor WWTP - Feasibility Study

SCENARIO 3A: BM-E System Integrated with SRMP - Centrifuge Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Plant Influent							
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50	(MGD)
BOD	(mg/L)	162	159	156	152	149	(mg/L)
TSS	(mg/L)	195	200	205	210	215	(mg/L)
Primary Sludge							
Hydraulic Flow	(gal./day)	94,977	109,628	124,704	140,197	156,098	(gal./day)
Solids Mass Flow	(lbs/day)	31,684	36,572	41,601	46,770	52,074	(lbs/day)
Volatile Solids	*(lbs/day)*	*22,179*	*25,600*	*29,121*	*32,739*	*36,452*	*(lbs/day)*
WAS							
Hydraulic Flow	(gal./day)	169,695	191,849	213,776	235,448	256,838	(gal./day)
Solids Mass Flow	(lbs/day)	14,458	16,345	18,213	20,060	21,882	(lbs/day)
Volatile Solids	*(lbs/day)*	*9,976*	*11,278*	*12,567*	*13,841*	*15,099*	*(lbs/day)*
Gravity Thickener Loading							
Hydraulic Load							
Combined Sludge	(gal./day)	274,125	312,244	350,568	389,060	427,684	(gal./day)
Solids Load							
Combined Sludge	(lbs/day)	46,142	52,917	59,815	66,830	73,957	(lbs/day)
Combined Sludge	(dt/yr)	8,421	9,657	10,916	12,196	13,497	(dt/yr)
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*	*(%)*
Volatile Solids	*(lbs/day)*	*32,155*	*36,879*	*41,688*	*46,580*	*51,551*	*(lbs/day)*
Gravity Thickened Combined Sludge							
Hydraulic Flow	(gal./day)	114,849	131,713	148,881	166,341	184,081	(gal./day)
Solids Mass Flow	(lbs/day)	35,760	41,011	46,356	51,793	57,316	(lbs/day)
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%	(%)
Volatile Solids	*(lbs/day)*	*24,920*	*28,581*	*32,308*	*36,100*	*39,952*	*(lbs/day)*
2PAD							
Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%	(%)
2PAD Sludge Output							
Hydraulic Flow	(gal./day)	114,849	131,713	148,881	166,341	184,081	(gal./day)
Solids Mass Flow	(lbs/day)	20,808	23,862	26,971	30,133	33,345	(lbs/day)
Solids Mass Flow	(dt/yr)	3,797	4,355	4,922	5,499	6,086	(dt/yr)
% Solids	(%)	2.17%	2.17%	2.17%	2.17%	2.17%	(%)
VS Destroyed	(lbs/day)	14,952	17,149	19,385	21,660	23,971	(lbs/day)
Biogas Production							
	cf/lbs VSS destroyed	17.00	17.00	17.00	17.00	17.00	cf/lbs VSS des
	cf/day	254,185	291,525	329,545	368,216	407,509	cf/day
	cf/hr	10,591	12,147	13,731	15,342	16,980	cf/hr
	BTU/cf	600	600	600	600	600	BTU/cf
	BTU/hr	6,354,618	7,288,126	8,238,618	9,205,388	10,187,731	BTU/hr
	BTU/day	152,510,843	174,915,023	197,726,828	220,929,309	244,505,541	BTU/day
Heat Available from 80% Efficient Boiler							
BTU/hr		5,083,695	5,830,501	6,590,894	7,364,310	8,150,185	BTU/hr
Meso Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	156,448	156,448	156,448	156,448	156,448	BTU/hr
Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,734	22,734	22,734	22,734	22,734	BTU/hr
Total Meso Heat Loss	BTU/hr	45,468	45,468	45,468	45,468	45,468	BTU/hr
Thermo Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	60,788	60,788	60,788	60,788	60,788	BTU/hr
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,719	22,719	22,719	22,719	22,719	BTU/hr
Total Thermo Heat Loss	BTU/hr	45,438	45,438	45,438	45,438	45,438	BTU/hr
Thermo Batch Heating Demand							
BTU/batch		5,128,488	6,382,579	7,659,488	8,958,226	10,277,805	
hrs/batch		3.00	3.00	3.00	3.00	3.00	
Batch BTU/hr		1,709,496	2,127,526	2,553,163	2,986,075	3,425,935	
Worst Case Heat Demand	BTU/hr	2,143,968	2,561,998	2,987,635	3,420,547	3,860,407	
Heat Supply							
Boiler	BTU/hr	-	-	-	-	-	BTU/hr
Generator Exhaust	BTU/hr	2,125,899	2,438,198	2,756,180	3,079,607	3,408,243	BTU/hr
Generator Cooling Jacket	BTU/hr	1,338,489	1,535,115	1,735,320	1,938,953	2,145,866	BTU/hr
Generator 2nd Stage Intercoole	BTU/hr	124,505	142,795	161,418	180,360	199,607	BTU/hr
Dryer Exhaust	BTU/hr	-	-	-	-	-	BTU/hr
Heat Surplus (Deficit)	%	67%	61%	56%	52%	49%	%

Ann Arbor WWTP - Feasibility Study

SCENARIO 3A: BM-E System Integrated with SRMP - Centrifuge Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Transfer Pumping							
Energy Consumption							
Connected HP	(HP)	20	20	20	20	20	(HP)
Operation	(hrs/yr)	4,380	4,380	4,380	4,380	4,380	(hrs/yr)
Electrical Demand	(kW*hr/yr)	65,350	65,350	65,350	65,350	65,350	(kW*hr/yr)
2PAD Sludge Storage							
Number of Tanks							
Total		2	2	2	2	2	
Operating		1	1	2	2	2	
Tank Size							
Diameter (ft)		70	70	70	70	70	
Water Depth (ft)		12	12	12	12	12	
Operating Surface Area (sf)		3,848	3,848	3,848	3,848	3,848	
Operating Volume (cf)		46,182	46,182	46,182	46,182	46,182	
Sludge to Storage							
Sludge Flow (MGD)		114,849	131,713	148,881	166,341	184,081	
Available Holding Time (hours)		72	63	111	100	90	
Gravity Belt Thickening							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Thickened Sludge Output							
Percent Solids	(%)	4.2%	4.2%	4.2%	4.2%	4.2%	(%)
Hydraulic Flow	(gal./day)	56,694	65,015	73,486	82,101	90,852	(gal./day)
Solids Mass Flow	(lbs/day)	19,859	22,773	25,741	28,758	31,824	(lbs/day)
Solids Mass Flow	(tons/year)	3,624	4,156	4,698	5,248	5,808	(tons/year)
Weight Weight (SG 1.02)	(tons/day)	241.1	276.5	312.6	349.2	386.4	(tons/day)
Dry Weight	(tons/day)	9.9	11.4	12.9	14.4	15.9	(tons/day)
Recycle from GBT Operations							
Hydraulic Flow	*(gal./day)*	*60,331*	*69,192*	*78,215*	*87,391*	*96,715*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*1,045*	*1,199*	*1,355*	*1,514*	*1,675*	*(lbs/day)*
Equipment Loading (8 hr / day)							
Belt Width	(m)	2.0	2.0	2.0	2.0	2.0	(m)
Number Operating		1.0	1.0	1.0	1.0	1.0	
Number Standby		1.0	1.0	1.0	1.0	1.0	
Sludge Feed Rate	(gpm)	244	280	316	353	391	(gpm)
Unit Feed Rate	(gpm/m)	122	140	158	177	195	(gpm/m)
GBT Energy Consumption							
Connected HP	(HP)	5	5	5	5	5	(HP)
Operation	(hrs/yr)	2,920	2,920	2,920	2,920	2,920	(hrs/yr)
Electrical Demand	(kW*hr/yr)	10,892	10,892	10,892	10,892	10,892	(kW*hr/yr)
GBT Sludge Storage							
Number of Tanks							
Total Available		4	4	4	4	4	
Operating		4	4	4	4	4	
Tank Size							
Unit Operating Volume	(gal.)	140,000	140,000	140,000	140,000	140,000	(gal.)
Available Holding Time	(hours)	237	207	183	164	148	(hours)
Available Holding Time	(days)	9.9	8.6	7.6	6.8	6.2	(days)
Polymer Consumption							
GBT Polymer Dose	(lbs active/dt)	9.2	9.2	9.2	9.2	9.2	(lbs active/dt)
GBT Polymer Feed	(lbs active / yr)	34,937	40,065	45,285	50,594	55,987	(lbs active / y
Centrifuge Polymer Dose	(lbs active/dt)	7.1	7.1	7.1	7.1	7.1	(lbs active/dt)
Centrifuge Polymer Feed	(lbs active / yr)	25,732	29,509	33,353	37,263	41,236	(lbs active / y
Total Polymer Consumption	(lbs active / yr)	60,669	69,573	78,638	87,857	97,222	(lbs active / y
Centrifuge Dewatering (5 d/wk, 1 shift/day)							
Number of Units Operating		1.0	1.0	1.0	1.0	1.0	
Number of Units Standby		1.0	1.0	1.0	1.0	1.0	
Shifts / Day		1.0	1.0	1.0	1.0	1.0	
Hours in Service / Shift	(hours)	6.5	7.5	8.5	9.5	10.5	(hours)
Hydraulic Loading / Unit	(gal./day)	86,279	98,942	111,834	124,944	138,262	(gal./day)
Mass Loading / Unit	(lbs/day)	27,901	31,996	36,165	40,404	44,711	(lbs/day)
Hydraulic Loading / Unit	(gpm)	221.2	219.9	219.3	219.2	219.5	(gpm)
Mass Loading / Unit	(lbs/hr)	4,292	4,266	4,255	4,253	4,258	(lbs/hr)
Centrifuge Energy Consumption							
Unit HP	(HP)	250	250	250	250	250	(HP)
Operation	(hrs/yr)	1,690	1,950	2,210	2,470	2,730	(hrs/yr)
Electrical Demand	(kW*hr/yr)	315,185	363,675	412,165	460,655	509,145	(kW*hr/yr)
Electrical Cost	($/yr)	$ 23,639	$ 27,276	$ 30,912	$ 34,549	$ 38,186	($/yr)
Dewatered Sludge Output							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Solids Mass Flow	(lbs/day)	18,933	21,712	24,540	27,417	30,340	(lbs/day)
Percent Solids	(%)	32%	32%	32%	32%	32%	(%)
Density	(lbs/cf)	66.8	66.8	66.8	66.8	66.8	(lbs/cf)
Volumetric Flow	(cy/day)	32.8	37.6	42.5	47.5	52.6	(cy/day)
Wet Weight	(tons/day)	29.6	33.9	38.3	42.8	47.4	(tons/day)
Dry Weight	(tons/day)	9.5	10.9	12.3	13.7	15.2	(tons/day)
Annual Totals							
Volume	(cy/year)	11,973	13,731	15,520	17,339	19,187	(cy/year)
Wet Weight	(tons/year)	10,798	12,382	13,996	15,636	17,303	(tons/year)
Dry Weight	(tons/year)	3,455	3,962	4,479	5,004	5,537	(tons/year)

Ann Arbor WWTP - Feasibility Study

SCENARIO 3A: BM-E System Integrated with SRMP - Centrifuge Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Recycle from Centrifuge Operations							
Hydraulic Flow	*(gal./day)*	*49,600*	*56,880*	*64,291*	*71,827*	*79,484*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*926*	*1,062*	*1,200*	*1,341*	*1,484*	*(lbs/day)*
Dewatered Sludge Storage							
Number of Hoppers		8	8	8	8	8	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	416	416	416	416	416	(cy)
Total Storage Capacity	(wet tons)	320	320	320	320	320	(wet tons)
Total Storage Capacity	(days)	10.8	9.4	8.3	7.5	6.8	(days)
Gas Cleaning Skid							
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	35	35	35	35	35	(HP)
Turn-down	(%)	0%	0%	0%	0%	0%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	228,724	228,724	228,724	228,724	228,724	(kW*hr/yr)
Generation							
Energy Output	(kW)	660	757	856	956	1,058	(kW)
Exhaust Air Flow	(lbs/hr)	8,710	9,990	11,293	12,618	13,964	(lbs/hr)
Exhaust Gas Temperature	(F)	991	991	991	991	991	(F)
Exhaust Gas Heat	(BTU/hr)	2,125,899	2,438,198	2,756,180	3,079,607	3,408,243	(BTU/hr)
Cooling Jacket Heat	(BTU/hr)	1,338,489	1,535,115	1,735,320	1,938,953	2,145,866	(BTU/hr)
2nd Stage Intercooler Heat	(BTU/hr)	124,505	142,795	161,418	180,360	199,607	(BTU/hr)
Uptime	(%)	95%	95%	95%	95%	95%	(%)
Downtime	(hrs/yr)	438	438	438	438	438	(hrs/yr)
Electricity Production	(kW*hr/yr)	5,491,499	6,298,212	7,119,603	7,955,061	8,803,977	(kW*hr/yr)

Appendix K Scenario 3C

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3C: BM-E Integrated with SRMP - Belt Filter Press Dewatering
Disposal Costs

Ultimate Disposal - Current Loads to 2PAD CHP

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,034,647	$ 0.027	$ 27,935
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	751	$ 17	$ 12,769
Solids Content: 23%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	13,520	$ 17	$ 229,844
Solids Content: 23%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 295,549**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,186,508	$ 0.027	$ 32,036
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	861	$ 17	$ 14,643
Solids Content: 23%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	15,505	$ 17	$ 263,580
Solids Content: 23%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2010):				**$ 335,259**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,341,103	$ 0.027	$ 36,210
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	974	$ 17	$ 16,551
Solids Content: 23%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	17,525	$ 17	$ 297,923
Solids Content: 23%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2015):				**$ 375,684**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,498,317	$ 0.027	$ 40,455
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	1,088	$ 17	$ 18,492
Solids Content: 23%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	19,579	$ 17	$ 332,847
Solids Content: 23%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2020):				**$ 416,793**

Ultimate Disposal - Year 2025

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (EQ Liquid: Class A)	Gallon	1,658,033	$ 0.027	$ 44,767
Liquid Sludge Solids Content: 4.2%				
Land Fill	Wet Ton	1,204	$ 17	$ 20,463
Solids Content: 23%				
Cake Land Application (EQ Cake: Class A)	Wet Ton	21,666	$ 17	$ 368,328
Solids Content: 23%				
Dried Land Application (90% EQ Granule: Class A)	Wet Ton	-	$ 17	$ -
Total Annual Disposal Costs (Year 2025):				**$ 458,557**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3C: BM-E Integrated with SRMP - Belt Filter Press Dewatering
Operation & Maintenance Cost

Energy Consumption

	Current		2010		2015		2020		2025	
Electrical	$ 0.075 /kWh									
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Digester system / Feed pumps		$ 65,000		$ 65,000		$ 65,000		$ 65,000		$ 65,000
Transfer Pump System	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901	65,350	$ 4,901
Gravity Belt Thickening	10,892	$ 817	10,892	$ 817	10,892	$ 817	10,892	$ 817	10,892	$ 817
BFP Dewatering	61,097	$ 4,582	69,826	$ 5,237	78,554	$ 5,892	87,282	$ 6,546	96,010	$ 7,201
Gas Cleaning System	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154	228,724	$ 17,154
Dryer	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Electrical Subtotal:		$ 92,455		$ 93,109		$ 93,764		$ 94,419		$ 95,073
Natural Gas	$ - /CCF									
Equipment	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Consumption:		**$ 92,455**		**$ 93,109**		**$ 93,764**		**$ 94,419**		**$ 95,073**

Chemical Consumption

Description	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*
Annual Polymer Usage (17.3 lbs. active / dry ton)	60,668	$ 3,640	69,573	$ 4,174	78,637	$ 4,718	87,856	$ 5,271	97,221	$ 5,833
Lime	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 3,640**		**$ 4,174**		**$ 4,718**		**$ 5,271**		**$ 5,833**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
Operation:										
2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
* Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
* BFP Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
Dryer Operations	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
Operations Subtotal:	6,942	$ 416,520	6,942	$ 416,520	6,942	$ 416,520	6,942	$ 416,520	6,942	$ 416,520
Maintenance:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
* Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
* BFP Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
Total Annual Labor:	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**	**9,454**	**$ 567,240**

Generator Maintenance Contract $ 0.01 /kWhr

Description	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator Maintenance Contract ($0.01/kWh)	5,491,433	$ 54,914	6,298,136	$ 62,981	7,119,517	$ 71,195	7,954,965	$ 79,550	8,803,872	$ 88,039
Total Annual Generator Maintenance Contract:		**$ 54,914**		**$ 62,981**		**$ 71,195**		**$ 79,550**		**$ 88,039**

Ultimate Disposal

Description	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*
Liquid Land Application (7% Solids EQ Liquid: Class A)	1,034,647	$ 27,935	1,186,508	$ 32,036	1,341,103	$ 36,210	1,498,317	$ 40,455	1,658,033	$ 44,767
	(wet-tons/yr)	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*
Land Fill	751	$ 12,769	861	$ 14,643	974	$ 16,551	1,088	$ 18,492	1,204	$ 20,463
Cake Land Application (32% EQ Cake: Class A)	13,520	$ 229,844	15,505	$ 263,580	17,525	$ 297,923	19,579	$ 332,847	21,666	$ 368,328
Dried Land Application (90% EQ Granule: Class A)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Disposal Costs:		**$ 295,549**		**$ 335,259**		**$ 375,684**		**$ 416,793**		**$ 458,557**

Energy Production *(Cost Savings)* $ 0.075 /kWh

Electrical										
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator	5,491,433	$ (411,857)	6,298,136	$ (472,360)	7,119,517	$ (533,964)	7,954,965	$ (596,622)	8,803,872	$ (660,290)
Electrical Cost / (Savings) Subtotal:		$ (411,857)		$ (472,360)		$ (533,964)		$ (596,622)		$ (660,290)
Heat	$ - /CCF									
Description	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings):		**$ (411,857)**		**$ (472,360)**		**$ (533,964)**		**$ (596,622)**		**$ (660,290)**

TOTAL ANNUAL O&M COSTS:		**$ 601,940**		**$ 590,404**		**$ 578,637**		**$ 566,651**		**$ 554,452**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3C: BM-E Integrated with SRMP - Belt Filter Press Dewatering
Capital Costs

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*		
Digestion System Subtotal:					$	3,996,000
Gas & Generation Systems Subtotal:					$	1,355,000
Liquid Reduction Systems Subtotal:					$	-
Equipment Subtotal					**$**	**5,351,000**
Installation	50%			2,675,500		
Subtotal:					**$**	**8,026,500**
Miscellaneous 15%	15%			1,203,975		
Process Piping and Valves 10%	10%			802,650		
Plumbing at 3%	3%			240,795		
Electrical at 10%	10%			802,650		
Instrumentation and Controls at 6%	6%			481,590		
Subtotal:				3,531,660	**$**	**11,558,160**
Structural Subtotal:				1,334,000		
Subtotal:					**$**	**12,892,160**
Contingencies at 30%	30%			3,867,648		
Contractors Overhead and Profit at 25%	25%			3,223,040		
				7,090,688	**$**	**19,982,848**
TOTAL CAPITAL COST					**$**	**19,982,848**
Annualized Capital Cost (20 YRS @ 5.6%)					$	(1,686,052)
Annualized Capital Cost (20 YRS @ 2.0% SRF)					$	(1,222,085)
Annualized Capital Cost (15 YRS @ 0.0% CREB)					$	(1,332,190)

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3C: BM-E Integrated with SRMP - Belt Filter Press Dewatering
Digestion System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*		*Extension*	
Digestion System:						
Feed Sequencing Tank (FST): 24 ft. dia. X 20 ft. insul. w/ cover (installed)	ea	1	$	56,000	$	56,000
Thermophilic Digester Tank (TD): 45 ft. dia. X 24 ft. insul. w/ fixed cover (i	EA	2	$	168,000	$	336,000
Mesophilic Digester Tank (MD): 85 ft. dia. X 29 ft. insul.	EA	2	$	500,000	$	1,000,000
Installation (CREDIT to Reduce FST, TD, MD Costs to Equipment/Materials Only)					$	(696,000)
Infilco 2PAD System (including the following):	LS	1	$	3,300,000	$	3,300,000
Fixed Cover - Thermophilic Digester	EA	2				
Floating Gas Holder Cover - Mesophilic Digester	EA	2				
Cannon Mixing System - Thermophilic						
Cannon Mixers - 24 inch	EA	6				
Nash Liquid Ring Gas Compressors	EA	4				
Gas Balancing System	EA	2				
Gas Safety / Control Equipment	EA	2				
Cannon Mixing System - Mesophilic						
Cannon Mixers - 30 inch (with Heating Jackets)	EA	12				
Nash Liquid Ring Gas Compressors	EA	4				
Separators	EA	4				
Gas Balancing System	EA	2				
Gas Safety / Control Equipment	EA	2				
2PAD Standard Digester Heating System						
Boiler	EA	1				
Heat Recovery Heat Exchange System (HXs, pumps, controls)	LS	1				
External Recirculation Sludge Heating System	LS	1				
Mesophilic Htg Jacket Pumps & Controls	LS	1				
Gas Safety Handling System & Flare	LS	1				
2PAD System Control Panel with PLC	LS	1				
Sludge Grinder	EA	1				
Sludge Feed Pumps	EA	2				
Sludge Transfer Pumps	EA	9				
Instrumentation						
Pressure / Vacuum Indicator Transmitters	EA	60				
Flow Indicator Transmitters	EA	14				
Temperature Indicator Transmitters	EA	55				
Level Indicator Transmitters	EA	5				
Valves						
Plug Valves	EA	51				
Check Valves	EA	12				
			Digestion System Subtotal:		**$**	**3,996,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3C: BM-E Integrated with SRMP - Belt Filter Press Dewatering
Gas & Generator Systems

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
Gas Cleaning				
Unison Solutions - Biogas Scrubber Skid	ea	1	$ 260,000	$ 260,000
Gas Blending System	ea	1	$ 50,000	$ 50,000
Multi-Point Gas Analysis Metering System (CH4, CO2, O2, H2S)	ea	1	$ 20,000	$ 20,000
Generation				
GE Jenbacher 848	ea	1	$ 550,000	$ 550,000
GE Jenbacher 540	ea	1	$ 380,000	$ 380,000
Switchgear / Electrical Control System	ea	2	$ 35,000	$ 70,000
Heat Dump Radiator	ea	1	$ 25,000	$ 25,000
			Gas & Generation Systems Subtotal:	**$ 1,355,000**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3C: BM-E Integrated with SRMP - Belt Filter Press Dewatering
Liquid Reduction System

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Sludge Storage				
Existing Gravity Thickener Tanks (46,182 cf / tank)	ea	2	$ -	$ -
(Note: Equivalent to 4 days storage at 2025 Loading Rates)				
Thickening System				
Gravity Belt Thickener (5 HP, 2 m Belt, 250 gpm/m)	ea	0	$ -	$ -
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System				$ -
Thickened Sludge Storage				
Existing Sludge Storage Tanks (140,000 gal. / tank)	ea	4	$ -	$ -
(Note: Equivalent to 10 days storage at 2025 Loading Rates)				
Dewatering System *(Furnished under SRMP)*				
BFP (15 HP, 2 m Belt, 70 gpm/m, 1400 lbs/hr/m)	ea	4	$ -	$ -
Controls				$ -
Piping & Valves				$ -
Pump Systems				$ -
Polymer Storage / Prep / Feed System				$ -
Dewatered Sludge Storage *(Furnished under SRMP)*				
Bulk Material Live Bottom Bin (52 cy, 40 ton capacity)	ea	8	$ -	$ -
(Note: Equivalent to 5 days dewatered sludge storage at 2025 Loading Rates)				
Drying System				
Scott Model 548 AST Drying System	ea	0	$ 550,000	$ -
Dryer Exhaust Heat Recovery System	ea	0	$ 125,000	$ -
			Liquid Reduction Systems Subtotal:	**$ -**

Feasibility Study: Biodigester for Combined Heat and Power at Ann Arbor Wastewater Treatment Plant
HESCO Sustainable Energy, LLC

Scenario 3C: BM-E Integrated with SRMP - Belt Filter Press Dewatering
Structural

Description	*Unit*	*Estimated Quantity*	*Unit Cost*	*Extension*
2PAD Building				
Sludge Transfer Pumping	sf	576	$ 100	$ 57,600
Sludge Recirculation Pumping	sf	440	$ 100	$ 44,000
Heat Recovery System (HX, Pumps, Controls)	sf	500	$ 100	$ 50,000
Thermo HXs	sf	500	$ 100	$ 50,000
Meso Water Pumps	sf	500	$ 100	$ 50,000
Thermo Water Pumps	sf	500	$ 100	$ 50,000
Gas Mixing System (Compressors, Safety, Balancing)	sf	500	$ 100	$ 50,000
Gas Scrubber System & Blending System	sf	324	$ 100	$ 32,400
Generator System	sf	1500	$ 100	$ 150,000
Dryer	sf	0	$ 100	$ -
Admin	sf	500	$ 100	$ 50,000
Shop	sf	1000	$ 100	$ 100,000
Lockers	sf	500	$ 100	$ 50,000
Existing Solids Handling Building Renovation				$ -
Demolition of Existing Incinerator Equipment (per floor)	ea	4	$ 50,000	$ 200,000
Rework Floors, Openings	ea	1	$ 400,000	$ 400,000
				$ -
			Structural Subtotal:	**$ 1,334,000**

Ann Arbor WWTP - Feasibility Study

SCENARIO 3A: BM-E System Integrated with SRMP - Belt Filter Press Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Plant Influent							
Flow	(MGD)	19.20	21.78	24.35	26.93	29.50	(MGD)
BOD	(mg/L)	162	159	156	152	149	(mg/L)
TSS	(mg/L)	195	200	205	210	215	(mg/L)
Primary Sludge							
Hydraulic Flow	(gal./day)	94,977	109,628	124,704	140,197	156,098	(gal./day)
Solids Mass Flow	(lbs/day)	31,684	36,572	41,601	46,770	52,074	(lbs/day)
Volatile Solids	*(lbs/day)*	*22,179*	*25,600*	*29,121*	*32,739*	*36,452*	*(lbs/day)*
WAS							
Hydraulic Flow	(gal./day)	169,689	191,842	213,767	235,438	256,827	(gal./day)
Solids Mass Flow	(lbs/day)	14,457	16,345	18,213	20,059	21,881	(lbs/day)
Volatile Solids	*(lbs/day)*	*9,976*	*11,278*	*12,567*	*13,841*	*15,098*	*(lbs/day)*
Gravity Thickener Loading							
Hydraulic Load							
Combined Sludge	(gal./day)	274,118	312,236	350,559	389,050	427,672	(gal./day)
Solids Load							
Combined Sludge	(lbs/day)	46,142	52,917	59,814	66,829	73,956	(lbs/day)
Combined Sludge	(dt/yr)	8,421	9,657	10,916	12,196	13,497	(dt/yr)
% Volatile	*(%)*	*70%*	*70%*	*70%*	*70%*	*70%*	*(%)*
Volatile Solids	*(lbs/day)*	*32,155*	*36,878*	*41,688*	*46,580*	*51,550*	*(lbs/day)*
Gravity Thickened Combined Sludge							
Hydraulic Flow	(gal./day)	114,848	131,711	148,879	166,339	184,078	(gal./day)
Solids Mass Flow	(lbs/day)	35,760	41,010	46,356	51,792	57,316	(lbs/day)
% Solids	(%)	3.73%	3.73%	3.73%	3.73%	3.73%	(%)
Volatile Solids	*(lbs/day)*	*24,920*	*28,581*	*32,308*	*36,099*	*39,951*	*(lbs/day)*
2PAD							
Volatile Destruction (%)	(%)	60%	60%	60%	60%	60%	(%)
2PAD Sludge Output							
Hydraulic Flow	(gal./day)	114,848	131,711	148,879	166,339	184,078	(gal./day)
Solids Mass Flow	(lbs/day)	20,808	23,862	26,971	30,133	33,345	(lbs/day)
Solids Mass Flow	(dt/yr)	3,797	4,355	4,922	5,499	6,085	(dt/yr)
% Solids	(%)	2.17%	2.17%	2.17%	2.17%	2.17%	(%)
VS Destroyed	(lbs/day)	14,952	17,148	19,385	21,659	23,971	(lbs/day)
Biogas Production							
	cf/lbs VSS destroyed	17.00	17.00	17.00	17.00	17.00	cf/lbs VSS des
	cf/day	254,182	291,522	329,541	368,211	407,504	cf/day
	cf/hr	10,591	12,147	13,731	15,342	16,979	cf/hr
	BTU/cf	600	600	600	600	600	BTU/cf
	BTU/hr	6,354,542	7,288,038	8,238,518	9,205,277	10,187,609	BTU/hr
	BTU/day	152,509,002	174,912,907	197,724,438	220,926,649	244,502,620	BTU/day
Heat Available from 80% Efficient Boiler							
BTU/hr		5,083,633	5,830,430	6,590,815	7,364,222	8,150,087	BTU/hr
Meso Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	156,448	156,448	156,448	156,448	156,448	BTU/hr
Total Meso Heat Loss	BTU/hr	312,896	312,896	312,896	312,896	312,896	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,734	22,734	22,734	22,734	22,734	BTU/hr
Total Meso Heat Loss	BTU/hr	45,468	45,468	45,468	45,468	45,468	BTU/hr
Thermo Ambient Heat Loss Demand							
Winter							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	60,788	60,788	60,788	60,788	60,788	BTU/hr
Total Thermo Heat Loss	BTU/hr	121,576	121,576	121,576	121,576	121,576	BTU/hr
Summer							
Digesters Operating		2	2	2	2	2	
Heat Loss / Digester	BTU/hr	22,719	22,719	22,719	22,719	22,719	BTU/hr
Total Thermo Heat Loss	BTU/hr	45,438	45,438	45,438	45,438	45,438	BTU/hr
Thermo Batch Heating Demand							
BTU/batch		5,128,412	6,382,503	7,659,335	8,958,074	10,277,576	
hrs/batch		3.00	3.00	3.00	3.00	3.00	
Batch BTU/hr		1,709,471	2,127,501	2,553,112	2,986,025	3,425,859	
Worst Case Heat Demand	BTU/hr	2,143,943	2,561,973	2,987,584	3,420,497	3,860,331	BTU/hr
Heat Supply							
Boiler	BTU/hr	-	-	-	-	-	BTU/hr
Generator Exhaust	BTU/hr	2,125,873	2,438,169	2,756,146	3,079,570	3,408,203	BTU/hr
Generator Cooling Jacket	BTU/hr	1,338,472	1,535,097	1,735,299	1,938,930	2,145,841	BTU/hr
Generator 2nd Stage Intercoole	BTU/hr	124,504	142,794	161,416	180,358	199,604	BTU/hr
Dryer Exhaust	BTU/hr	-	-	-	-	-	BTU/hr
Heat Surplus (Deficit)	%	67%	61%	56%	52%	49%	%

Ann Arbor WWTP - Feasibility Study

SCENARIO 3A: BM-E System Integrated with SRMP - Belt Filter Press Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Transfer Pumping							
Energy Consumption							
Connected HP	(HP)	20	20	20	20	20	(HP)
Operation	(hrs/yr)	4,380	4,380	4,380	4,380	4,380	(hrs/yr)
Electrical Demand	(kW*hr/yr)	65,350	65,350	65,350	65,350	65,350	(kW*hr/yr)
2PAD Sludge Storage							
Number of Tanks							
Total		2	2	2	2	2	
Operating		1	1	2	2	2	
Tank Size							
Diameter (ft)		70	70	70	70	70	
Water Depth (ft)		12	12	12	12	12	
Operating Surface Area (sf)		3,848	3,848	3,848	3,848	3,848	
Operating Volume (cf)		46,182	46,182	46,182	46,182	46,182	
Sludge to Storage							
Sludge Flow (MGD)		114,848	131,711	148,879	166,339	184,078	
Available Holding Time (hours)		72	63	111	100	90	
Gravity Belt Thickening							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Thickened Sludge Output							
Percent Solids	(%)	4.2%	4.2%	4.2%	4.2%	4.2%	(%)
Hydraulic Flow	(gal./day)	56,693	65,014	73,485	82,100	90,851	(gal./day)
Solids Mass Flow	(lbs/day)	19,858	22,773	25,740	28,758	31,823	(lbs/day)
Solids Mass Flow	(tons/year)	3,624	4,156	4,698	5,248	5,808	(tons/year)
Weight Weight (SG 1.02)	(tons/day)	241.1	276.5	312.6	349.2	386.4	(tons/day)
Dry Weight	(tons/day)	9.9	11.4	12.9	14.4	15.9	(tons/day)
Recycle from GBT Operations							
Hydraulic Flow	*(gal./day)*	*60,330*	*69,192*	*78,214*	*87,390*	*96,713*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*1,045*	*1,199*	*1,355*	*1,514*	*1,675*	*(lbs/day)*
Equipment Loading (8 hr / day)							
Belt Width	(m)	2.0	2.0	2.0	2.0	2.0	(m)
Number Operating		1.0	1.0	1.0	1.0	1.0	
Number Standby		1.0	1.0	1.0	1.0	1.0	
Sludge Feed Rate	(gpm)	244	280	316	353	391	(gpm)
Unit Feed Rate	(gpm/m)	122	140	158	177	195	(gpm/m)
GBT Energy Consumption							
Connected HP	(HP)	5	5	5	5	5	(HP)
Operation	(hrs/yr)	2,920	2,920	2,920	2,920	2,920	(hrs/yr)
Electrical Demand	(kW*hr/yr)	10,892	10,892	10,892	10,892	10,892	(kW*hr/yr)
GBT Sludge Storage							
Number of Tanks							
Total Available		4	4	4	4	4	
Operating		4	4	4	4	4	
Tank Size							
Unit Operating Volume	(gal.)	140,000	140,000	140,000	140,000	140,000	(gal.)
Available Holding Time	(hours)	237	207	183	164	148	(hours)
Available Holding Time	(days)	9.9	8.6	7.6	6.8	6.2	(days)
Polymer Consumption							
GBT Polymer Dose	(lbs active/dt)	9.2	9.2	9.2	9.2	9.2	(lbs active/dt)
GBT Polymer Feed	(lbs active / yr)	34,936	40,064	45,284	50,593	55,986	(lbs active / y
Centrifuge Polymer Dose	(lbs active/dt)	7.1	7.1	7.1	7.1	7.1	(lbs active/dt)
Centrifuge Polymer Feed	(lbs active / yr)	25,732	29,508	33,353	37,263	41,235	(lbs active / y
Total Polymer Consumption	(lbs active / yr)	60,668	69,573	78,637	87,856	97,221	(lbs active / y
BFP Dewatering (5 d/wk, 1 shift/day)							
Number of Units Operating		3.0	3.0	3.0	3.0	3.0	
Number of Units Standby		1.0	1.0	1.0	1.0	1.0	
Shifts / Day		1.0	1.0	1.0	1.0	1.0	
Hours in Service / Shift	(hours)	7.0	8.0	9.0	10.0	11.0	(hours)
Hydraulic Loading / Unit	(gal./day)	28,759	32,980	37,277	41,647	46,087	(gal./day)
Mass Loading / Unit	(lbs/day)	9,300	10,665	12,055	13,468	14,904	(lbs/day)
Hydraulic Loading / Unit	(gpm)	68.5	68.7	69.0	69.4	69.8	(gpm)
Mass Loading / Unit	(lbs/hr)	1,329	1,333	1,339	1,347	1,355	(lbs/hr)
BFP Energy Consumption							
Unit HP	(HP)	15	15	15	15	15	(HP)
Operation	(hrs/yr)	5,460	6,240	7,020	7,800	8,580	(hrs/yr)
Electrical Demand	(kW*hr/yr)	61,097	69,826	78,554	87,282	96,010	(kW*hr/yr)
Electrical Cost	($/yr)	$ 4,582	$ 5,237	$ 5,892	$ 6,546	$ 7,201	($/yr)
Dewatered Sludge Output							
Solids Capture	(%)	95%	95%	95%	95%	95%	(%)
Solids Mass Flow	(lbs/day)	18,932	21,711	24,540	27,417	30,339	(lbs/day)
Percent Solids	(%)	23%	23%	23%	23%	23%	(%)
Density	(lbs/cf)	66.8	66.8	66.8	66.8	66.8	(lbs/cf)
Volumetric Flow	(cy/day)	45.6	52.3	59.2	66.1	73.1	(cy/day)
Wet Weight	(tons/day)	41.2	47.2	53.3	59.6	66.0	(tons/day)
Dry Weight	(tons/day)	9.5	10.9	12.3	13.7	15.2	(tons/day)
Annual Totals							
Volume	(cy/year)	16,658	19,103	21,592	24,124	26,695	(cy/year)
Wet Weight	(tons/year)	15,022	17,227	19,472	21,755	24,074	(tons/year)
Dry Weight	(tons/year)	3,455	3,962	4,479	5,004	5,537	(tons/year)

Ann Arbor WWTP - Feasibility Study

SCENARIO 3A: BM-E System Integrated with SRMP - Belt Filter Press Dewatering

Mass Balance Summary

For Various Design / Operating Conditions

		Current	2010	2015	2020	2025	
Recycle from Dewatering Operations							
Hydraulic Flow	*(gal./day)*	*46,823*	*53,696*	*60,692*	*67,806*	*75,034*	*(gal./day)*
Solids Mass Flow	*(lbs/day)*	*926*	*1,062*	*1,200*	*1,341*	*1,484*	*(lbs/day)*
Dewatered Sludge Storage							
Number of Hoppers		8	8	8	8	8	
Hopper Volume	(cy)	52	52	52	52	52	(cy)
Hopper Capacity	(wet tons)	40	40	40	40	40	(wet tons)
Total Storage Capacity	(cy)	416	416	416	416	416	(cy)
Total Storage Capacity	(wet tons)	320	320	320	320	320	(wet tons)
Total Storage Capacity	(days)	7.8	6.8	6.0	5.4	4.9	(days)
Gas Cleaning Skid							
Energy Consumption (300 kWh/dt)							
Connected HP	(HP)	35	35	35	35	35	(HP)
Turn-down	(%)	0%	0%	0%	0%	0%	(%)
Operation	(hrs/yr)	8,760	8,760	8,760	8,760	8,760	(hrs/yr)
Electrical Demand	(kW*hr/yr)	228,724	228,724	228,724	228,724	228,724	(kW*hr/yr)
Generation							
Energy Output	(kW)	660	757	856	956	1,058	(kW)
Exhaust Air Flow	(lbs/hr)	8,710	9,990	11,293	12,618	13,964	(lbs/hr)
Exhaust Gas Temperature	(F)	991	991	991	991	991	(F)
Exhaust Gas Heat	(BTU/hr)	2,125,873	2,438,169	2,756,146	3,079,570	3,408,203	(BTU/hr)
Cooling Jacket Heat	(BTU/hr)	1,338,472	1,535,097	1,735,299	1,938,930	2,145,841	(BTU/hr)
2nd Stage Intercooler Heat	(BTU/hr)	124,504	142,794	161,416	180,358	199,604	(BTU/hr)
Uptime	(%)	95%	95%	95%	95%	95%	(%)
Downtime	(hrs/yr)	438	438	438	438	438	(hrs/yr)
Electricity Production	(kW*hr/yr)	5,491,433	6,298,136	7,119,517	7,954,965	8,803,872	(kW*hr/yr)

Appendix L Baseline SRMP

City of Ann Arbor, Michigan
Water Utilities Department
Wastewater Treatment Plant

Baseline
Opinion of Probable Operation & Maintenance Costs

HESCO Sustainable Energy, LLC
March 2007

Energy Consumption

	Current		2010		2015		2020		2025	
Electrical	$ 0.075	/kWh								
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
GBT Feed pumps (1, 15 HP)	131400	$ 9,855	131400	$ 9,855	131400	$ 9,855	131400	$ 9,855	131400	$ 9,855
Transfer Pump System (2, 25HP)	67,886	$ 5,091	77,584	$ 5,819	87,282	$ 6,546	96,980	$ 7,274	111,527	$ 8,365
Gravity Belt Thickening (1, 5HP)	32,675	$ 2,451	32,675	$ 2,451	32,675	$ 2,451	32,675	$ 2,451	32,675	$ 2,451
Centrifuge (2, 250 HP)	678,860	$ 50,915	775,840	$ 58,188	872,820	$ 65,462	969,800	$ 72,735	1,115,270	$ 83,645
Sludge Bin Mixers (4, 75HP)	466,623	$ 34,997	466,623	$ 34,997	466,623	$ 34,997	466,623	$ 34,997	466,623	$ 34,997
Misc (1, 25 HP)	490,122	$ 36,759	490,122	$ 36,759	490,122	$ 36,759	490,122	$ 36,759	490,122	$ 36,759
Electrical Subtotal:		$ 140,067		$ 148,068		$ 156,069		$ 164,070		$ 176,071
Natural Gas	$ 0.60	/CCF								
Equipment	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*	*(CCF/yr)*	*Annual Cost*
Boiler	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Air Handling Units	48,697	$ 29,218	48,697	$ 29,218	48,697	$ 29,218	48,697	$ 29,218	48,697	$ 29,218
Natural Gas Subtotal:		$ 29,218		$ 29,218		$ 29,218		$ 29,218		$ 29,218
Total Annual Energy Consumption:		**$ 169,286**		**$ 177,286**		**$ 185,287**		**$ 193,288**		**$ 205,289**

Chemical Consumption

Description	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*	*(lbs/yr)*	*Annual Cost*
Annual Polymer Usage (17.3 lbs. active / dry ton)	60,669	$ 3,640	69,573	$ 4,174	78,638	$ 4,718	87,857	$ 5,271	97,222	$ 5,833
Lime (see disposal)		$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Chemical Costs:		**$ 3,640**		**$ 4,174**		**$ 4,718**		**$ 5,271**		**$ 5,833**

Labor O&M Labor (5FTE spread across 365 d/yr) $ 60.00 /hr

Operation:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
2PAD Operations Heating & Pumping	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040	2,184	$ 131,040
* Gravity Belt Thickening Operations	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520	1,092	$ 65,520
* Centrifuge Operations	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800	780	$ 46,800
Dryer Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Generator Operations	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
Gas System (Mixing, Cleaning, Storage, Fuel Blend)	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760	546	$ 32,760
On-Call	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280	338	$ 20,280
Supervision / Administration / Reporting	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360	1,456	$ 87,360
Operations Subtotal:	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280	7,488	$ 449,280
Maintenance:										
Description	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*	*(hrs/yr)*	*Annual Cost*
Sludge Pump Maintenance & Rebuilds	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Water Pump Maintenance & Rebuilds	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Heat Exchanger Maintenance	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680	128	$ 7,680
Boiler / Heating System Maintenance	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800	80	$ 4,800
Gas Compressor Maintenance	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840	64	$ 3,840
Instrumentation & Controls Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
Valves & Piping Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
General Facility Maintenance	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200	320	$ 19,200
* Gravity Belt Thickener Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
* Centrifuge Maintenance	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040	384	$ 23,040
Maintenance Subtotal:	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720	2,512	$ 150,720
Total Annual Labor:	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**	**10,000**	**$ 600,000**

Generator Maintenance Contract $ 0.01 /kWhr

Description	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator Maintenance Contract ($0.01/kWh)	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Total Annual Generator Maintenane Contract:		**$ -**		**$ -**		**$ -**		**$ -**		**$ -**

Ultimate Disposal

Description	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*	*Annual Fee*	*Annual Cost*
MDEQ Biosolids Program Fee	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
	(gal./yr)	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*	*(gal./yr)*	*Annual Cost*
Liquid Land Application (7.91% Solids Class B)	16,000,000	$ 432,000	18,300,000	$ 494,100	20,600,000	$ 556,200	23,000,000	$ 621,000	25,400,000	$ 685,800
	(wet-tons/yr)	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*	*(wet-tons/yr)*	*Annual Cost*
Land Fill (28% Cake)	4,116	$ 69,972	4,724	$ 80,308	5,348	$ 90,916	5,992	$ 101,864	6,656	$ 113,152
Cake Land Application (37.4% Cake: Class B)	4,733	$ 80,461	5,433	$ 92,353	6,893	$ 104,584	6,893	$ 117,173	7,654	$ 130,118
Lime	1,533	$ 114,960	1,757	$ 131,760	1,992	$ 149,400	2,227	$ 167,040	2,474	$ 185,520
Total Annual Disposal Costs:		**$ 722,393**		**$ 823,521**		**$ 926,100**		**$ 1,032,077**		**$ 1,139,590**

Energy Production (Cost Savings) $ 0.075 /kWh

Electrical										
Equipment	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*	*(kW*hr/yr)*	*Annual Cost*
Generator	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Electrical Cost / (Savings) Subtotal:		$ -		$ -		$ -		$ -		$ -
Heat	$ -	/CCF								
Description	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*	*(mmBTU/yr)*	*Annual Cost*
Surplus Heat: After Digestion / Drying	-	$ -	-	$ -	-	$ -	-	$ -	-	$ -
Natural Gas Cost / (Savings) Subtotal:		$ -		$ -		$ -		$ -		$ -
Total Annual Energy Cost / (Savings):		**$ -**		**$ -**		**$ -**		**$ -**		**$ -**

TOTAL ANNUAL O&M COSTS:		**$ 1,495,319**		**$ 1,604,981**		**$ 1,716,106**		**$ 1,830,636**		**$ 1,950,713**

City of Ann Arbor, Michigan
Water Utilities Department
Wastewater Treatment Plant

Baseline
Opinion of Probable Solids Disposal Costs

HESCO Sustainable Energy, LLC
August 2006

Ultimate Disposal - Current Loads

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (7.91% Solids Liquid: Class B)	Gallon	16,000,000	$ 0.027	$ 432,000
Land Fill (28% Cake)	Wet Ton	4,116	$ 17	$ 69,972
Cake Land Application (37.4% Cake: Class B)	Wet Ton	4,733	$ 17	$ 80,461
Lime	Ton	1,533	$ 75	$ 114,960
Total Annual Disposal Costs (Estimate for Current Loads):				**$ 722,393**

Ultimate Disposal - Year 2010

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (7.91% Solids Liquid: Class B)	Gallon	18,300,000	$ 0.027	$ 494,100
Land Fill (28% Cake)	Wet Ton	4,724	$ 17	$ 80,308
Cake Land Application (37.4% Cake: Class B)	Wet Ton	5,433	$ 17	$ 92,353
Lime	Ton	1,757	$ 75	$ 131,760
Total Annual Disposal Costs (Year 2010):				**$ 823,521**

Ultimate Disposal - Year 2015

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (7.91% Solids Liquid: Class B)	Gallon	20,600,000	$ 0.027	$ 556,200
Land Fill (28% Cake)	Wet Ton	5,348	$ 17	$ 90,916
Cake Land Application (37.4% Cake: Class B)	Wet Ton	6,152	$ 17	$ 104,584
Lime	Ton	1,992	$ 75	$ 149,400
Total Annual Disposal Costs (Year 2015):				**$ 926,100**

Ultimate Disposal - Year 2020

Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (7.91% Solids Liquid: Class B)	Gallon	23,000,000	$ 0.027	$ 621,000
Land Fill (28% Cake)	Wet Ton	5,992	$ 17	$ 101,864
Cake Land Application (37.4% Cake: Class B)	Wet Ton	6,893	$ 17	$ 117,173
Lime	Ton	2,227	$ 75	$ 167,040
Total Annual Disposal Costs (Year 2020):				**$ 1,032,077**

Ultimate Disposal - Year 2025

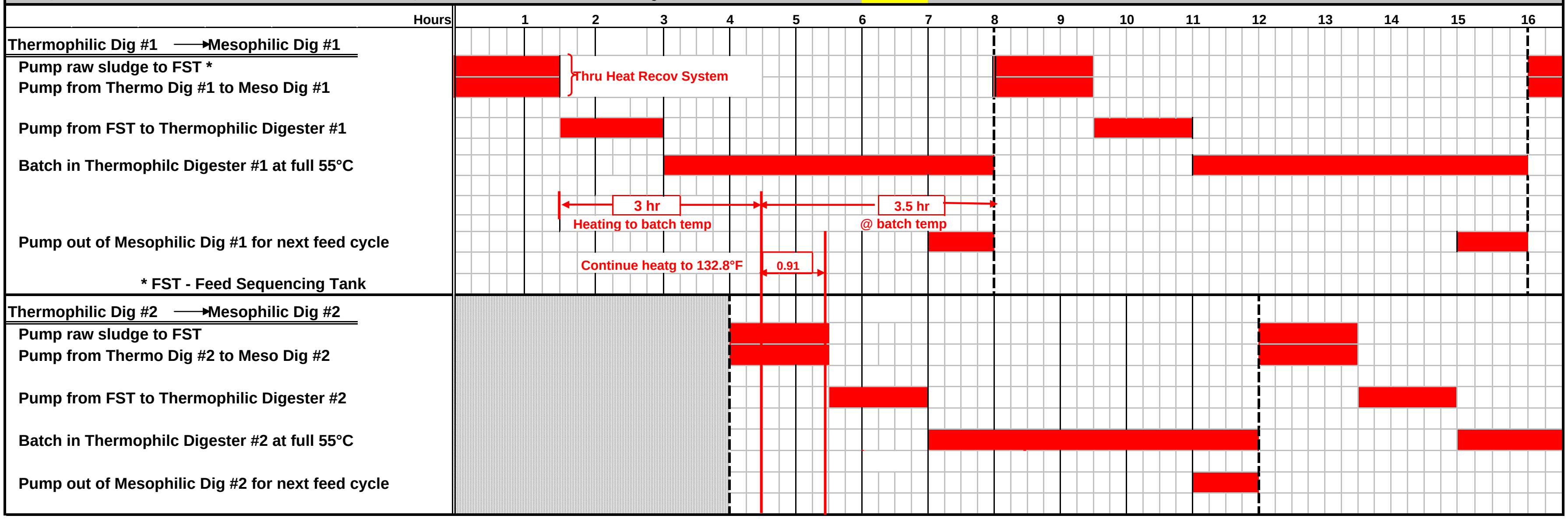
Description	*Unit*	*Estimated Qty*	*Unit Cost*	*Extension*
MDEQ Biosolids Program Fee	Annual	1	$ 25,000	$ 25,000
Liquid Land Application (7.91% Solids Liquid: Class B)	Gallon	25,400,000	$ 0.027	$ 685,800
Land Fill (28% Cake)	Wet Ton	6,656	$ 17	$ 113,152
Cake Land Application (37.4% Cake: Class B)	Wet Ton	7,654	$ 17	$ 130,118
Lime	Ton	2,474	$ 75	$ 185,520
Total Annual Disposal Costs (Year 2025):				**$ 1,139,590**

Appendix M

2PAD Feed Cycles

FEED CYCLES

Project Name: Ann Arbor WWTP **Project Location:** Ann Arbor, Michigan **Date:** 3/6/2007



THERMOPHILIC DIGESTER RECIRCULATION HX __(Chart above and formulas below must be checked for individual applications)__.

Raw Sludge Design Flow	191,046	GPD
Number Feed Cycles / Day / Train	3	
Number Trains	2	
Volume / Train / Feed Cycle	31,841	gal
Thermo Digester Vol / Train	227,173	gal
Min temp to Thermo Dig	78.1	°F **(from "Htg System Summ" sheet)**
Batch temperature (55°C)	131.0	°F
After batch temp reached, heat to	132.8	°F
Blended Thermo temp from feeding	125.13	°F
BTUs to get back to batch temp	11,120,788	BTU
Tank Losses	60,788	BTU/h

Input time to get to batch temp	3.00	hr
Heat required from recirc loop	3,767,718	BTU/h **

__**Staggered per above, so that only one train requires max. heat at a time.**__

** Doesn't include any heating losses in piping.

Appendix N

2PAD Annual Power Estimate

APPROXIMATE POWER COSTS
COMPRESSORS & PUMPS

Ann Arbor WWTP **Ann Arbor, Michigan**

Date: 3/23/2007 **Cost/KWh** $0.075

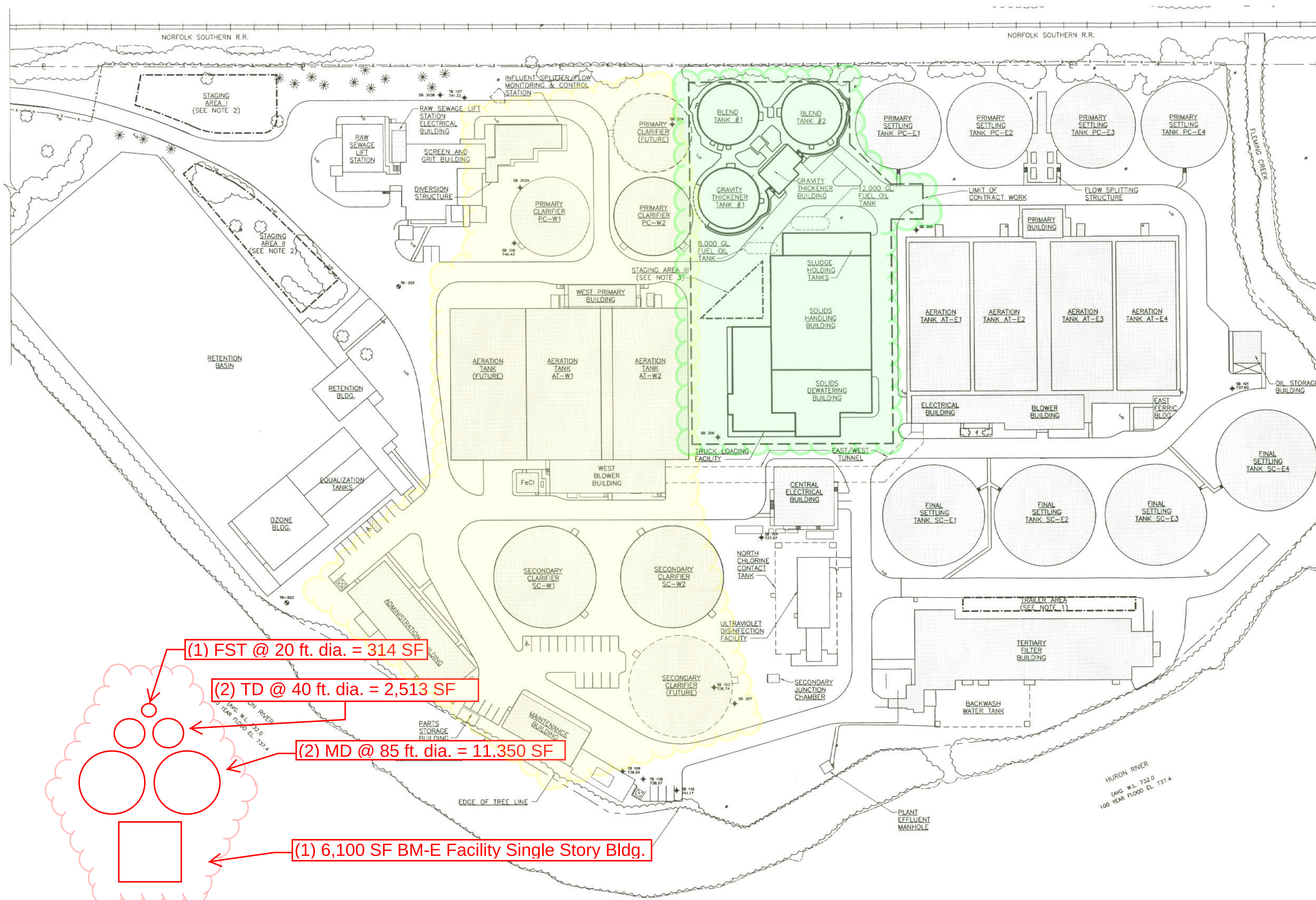
Equipment	Quantity	HP	# hrs/day	Cost/yr
Compressors:				
Thermo Mixing System (max, BHP)	2	9.2	24.0	$9,057
Meso Mixing System (max, BHP)	2	26.3	24.0	$25,752
Sludge Pumps:				
Raw Sludge Feed:	1	10	9.0	$1,838
Sludge Feed from Sequencing Tank	1	10	9.0	$1,838
Sludge Recirculation (Thermo Heating Loop)	2	15	15.6	$9,551
Sludge Transfer to Mesophilic	2	10	9.0	$3,676
Sludge Transfer from Mesophilic (typically not in our scope)	2	15	6.0	$3,676
Hot Water Pumps:				
Recirculation Pump for Heat Recovery Exchanger	1	10	9.0	$1,838
Hot Water Pump forThermo Heat Exchanger	2	7.5	15.6	$4,776
Hot water Pump for Meso Heating Jackets	2	3	6.0	$735
Hot Water Pump for Boiler Recirculation Loop	1		16.0	$0
Grinders:				
Raw Sludge	1	5	9.0	$919
Thermophilic Sludge	1	5	9.0	$919

Grinders

Approximate Power Cost/yr $64,576

Appendix O

Site Plan with BM-E Footprint Overlay



Residuals Handling Project

Planned Plant Upgrades

BM-E System - Scenario 3A

LEGEND

- STAGING AND TRAILER AREAS DESIGNATED FOR THIS PROJECT.
- LIMITS OF CONTRACT WORK
- WORK TO BE PERFORMED AS PART OF THE FACILITIES RENOVATION PROJECT.
- FACILITIES WHERE WORK IS TO BE PERFORMED AS PART OF THIS PROJECT.

NOTES:

1. TRAILER AREA WILL INCLUDE ENGINEER'S TRAILER, SHIFT SUPERVISORS TEMPORARY TRAILER AND CONTRACTOR TRAILER.
2. STAGING AREAS I AND II ARE RESERVED FOR RESIDUAL HANDLING IMPROVEMENTS PROJECT ONLY.
3. THE OLD SOLIDS HANDLING BUILDING CURRENTLY OCCUPIES STAGING AREA III. THIS BUILDING IS TO BE DEMOLISHED AS PART OF THE FACILITIES RENOVATION PROJECT-PHASE I. ONCE DEMOLISHED THIS AREA WILL BE AVAILABLE AS A STAGING AREA FOR THE RESIDUALS HANDLING IMPROVEMENTS PROJECT.

NEW SITE PLAN

SCALE: 1" = 60'

NOTE: Footprint area for Gravity Belt Thickening, Dewatering, Conveyance, and Sludge Storage are included in Proposed Residuals Handling Improvements

GREELEY AND HANSEN 211 WEST FORT STREET, SUITE 710 DETROIT, MICHIGAN 48226-3202	DESIGNED JMG DRAWN AJM CHECKED JMG	APPROVED	NO. DATE APPD REVISION	SCALE 60 0 60 120 FT 1"=60'

CITY OF ANN ARBOR, MICHIGAN
WASTEWATER TREATMENT PLANT
RESIDUALS HANDLING IMPROVEMENTS PROJECT

GENERAL

NEW SITE PLAN

FILE NAME 02141AG07.DWG
DWG AG7
DATE JUNE 2007 REV 0

02141AG01 201AXC01 02141BOR XREFS:
FILE: 02141AG07 1:1 06/14/07 09:14 GH-A

Acknowledgements

- The State of Michigan DLEG / Energy Office running the Michigan Biomass Energy Program
- City of Ann Arbor Energy Office – study management and oversight, central point for coordination & communication between all involved parties
- City of Ann Arbor Wastewater Treatment Plant – source of technical information on plant assets, operations and planning, technical review of feasibility study
- Greeley & Hansen - source of background and technical information on SRMP, technical review of feasibility study
- Mr. Eric Aupperle: Representing the Public Acceptance Committee that participated on the SRMP – review of feasibility study