ATTACHMENTS

III

5.4

Res. No. 46 - 17 - 18. By Alderperson Wolf. July 17, 2017.

A RESOLUTION authorizing the appropriate City Officials to enter into an agreement for a ten foot underground electrical easement at the east side of Optimist Park.

RESOLVED: That the appropriate City Officials are authorized to enter into an agreement with Alliant Energy for a ten foot electrical easement at the east side of Optimist Park.

Pub Wks

____

I HEREBY CERTIFY that the foregoing Resolution was duly passed by the Common Council of the City of Sheboygan, Wisconsin, on the __________ day of _________________________, 20____.

Dated _________________________ 20____. ________________________, City Clerk

Approved ______________________ 20____. ____________________________, Mayor

CITY OF SHEBOYGAN

REQUEST FOR PUBLIC WORKS COMMITTEE CONSIDERATION

ITEM DESCRIPTION: Resolution authorizing the appropriate City Officials to enter into an agreement for an easement for Alliant Energy in Optimist Park.

REPORT PREPARED BY: David H. Biebel, Director of Public Works and Ryan J. Sazama, City Engineer.

REPORT DATE: July 12, 2017 **MEETING DATE:** July 24, 2017

BACKGROUND / ANALYSIS:
A ten foot underground electrical easement at the east end of Optimist Park for the improvement of service to the area.

ACTION REQUESTED:
Recommend approval of resolution.

ATTACHMENTS:
Two

Document No.

EASEMENT UNDERGROUND ELECTRIC

The undersigned **Grantor(s), City of Sheboygan (hereinafter called the "Grantor")**, in consideration of the sum of one dollar ($1.00) and other good and valuable consideration, receipt of which is hereby acknowledged, does hereby grant, convey and warrant unto **Wisconsin Power and Light Company, a Wisconsin corporation, (hereinafter called the "Grantee")**, the Grantee's successors and assigns, the perpetual right and easement to construct, install, maintain, operate, repair, inspect, replace, add, relocate and remove the Designated Facilities, as indicated below, upon, in, over, through and across lands owned by the Grantor **in the City of Sheboygan, County of Sheboygan, State of Wisconsin**, said Easement Area to be **Ten (10)** feet in width and described as follows:

See Exhibit "A" for a legal description of the Easement Area and Exhibit "B" for a depiction of the Easement Area, both which are attached hereto and made a part hereof by reference.

Record this document with the Register of Deeds

Name and Return Address:

Alliant Energy
Attn: Real Estate Department
4902 North Biltmore Lane
P.O. Box 77007
Madison, WI 53707-1007

Parcel Identification Number(s)
59281430847

This Easement is subject to the following conditions:

1. **Designated Facilities:** This easement is for underground electric line facilities, including but not limited to conduit, cables, above ground electric pad-mount transformers, secondary pedestals, riser equipment and other appurtenant equipment associated with underground electric line facilities.

2. **Access:** The Grantee and its agents shall have the right of reasonable ingress and egress to, over and across the Grantor's land adjacent to the Easement Area.

3. **Buildings and Structures: The Grantor agrees within the Easement Area not to** construct or place buildings, structures, or other improvements, or place water, sewer or drainage facilities; all without the express written consent of the Grantee.

4. **Landscaping and Vegetation:** No plantings and landscaping are allowed within the Easement Area that will interfere with the easement rights herein granted. The Grantee has the right to trim or remove trees, bushes and brush within the Easement Area without replacement or compensation hereinafter. The Grantee may treat the stumps of any trees, bushes or brush to prevent re-growth and apply herbicides in accordance with applicable laws, rules and regulations, for tree and brush control.

5. **Elevation:** After the installation of the facilities and final grading of the Easement Area, the Grantor agrees not to alter the elevation of the existing ground surface by more than six (6) inches or place rocks or boulders more than eight (8) inches in diameter, within the Easement Area, without the express written consent of the Grantee.

6. **Restoration and Damages:** The Grantee shall at its option, restore, cause to have restored or pay a reasonable sum for all damages to property, crops, fences, livestock, lawns, roads, fields and field tile (other than trees trimmed or cut down and removed), caused by the construction, maintenance or removal of said facilities.

7. **Rights not granted to the Grantee:** The Grantee shall not have the right to construct or place fences, buildings or any other facilities other than the above Designated Facilities.

8. **Reservation of use by the Grantor:** The right is hereby expressly reserved to the Grantor, the heirs, successors and assigns, of every use and enjoyment of said land within the Easement Area consistent with rights herein granted.

9. **Binding Effect:** This agreement is binding upon the heirs, successors and assigns of the parties hereto, and shall run with the lands described herein.

10. **Easement Brochure:** As provided by PSC 113, the Grantor shall have a minimum period of five days to examine materials approved or provided by the Public Service Commission of Wisconsin describing the Grantor's rights and options in the easement negotiating process. The Grantor hereby voluntarily waives the five day review period or acknowledges that they have had at least five days to review such materials.

WITNESS the signature(s) of the Grantor this ________________ day of ________________, 2017.

______________________________ (SEAL) Signature	______________________________ (SEAL) Signature
______________________________ Printed Name and Title	______________________________ Printed Name and Title
______________________________ (SEAL) Signature	______________________________ (SEAL) Signature
______________________________ Printed Name and Title	______________________________ Printed Name and Title

ACKNOWLEDGEMENT

STATE OF WISCONSIN }
COUNTY OF ________________ } SS

Personally came before me this ____________ day of ________________, 20_____, the above named

____

to me known to be the person(s) who executed the foregoing instrument and acknowledged the same.

____
Signature of Notary

____
Printed Name of Notary

Notary Public, State of Wisconsin

My Commission Expires (is) ________________

ACKNOWLEDGEMENT

STATE OF WISCONSIN }
COUNTY OF ________________ } SS

Personally came before me this ____________ day of ________________, 20_____, the above named

____

to me known to be the person(s) who executed the foregoing instrument and acknowledged the same.

____
Signature of Notary

____
Printed Name of Notary

Notary Public, State of Wisconsin

My Commission Expires (is) ________________

This instrument drafted by

JOSHUA REED – MI-TECH SERVICES

KEVIN STOEVEKEN – MI-TECH SERVICES
Checked by

July 7, 2017

Project Title:	Carmen Ave Pre – 1983 Cable Replacement
ERP Activity ID:	4049558
Tract No.:	6 OF 10
PPN:	

Exhibit A

GRANTOR'S PARCEL:

A part of the North Half (N 1/2) of the Northwest Quarter (NW 1/4) of Section Three (3), Town Fourteen (14) North, Range Twenty-Three (23) East of the 4th principal meridian, Sheboygan County, more particularly described as follows: Commencing at the north quarter corner of said Section Three (3), Town Fourteen (14) North, Range Twenty-Three (23) East; thence south 0°56' east coincident with the east line of the Northwest Quarter (NW 1/4) of said Section Three (3), and the west line of the plat of Parkwood Estates, a distance of 643.98 feet to the point of beginning; Thence, from said beginning south 0°56' east coincident with the aforementioned east line of the Northwest Quarter (NW 1/4) of Section Three (3), a distance of 1085.42 feet; thence south 89°24'27" west, a distance of 684.50 feet, thence north 0°56' west, a distance of 1078.05 feet; thence north 88°48'10" east, a distance of 684.50 feet to the point of beginning, being in the City of Sheboygan, County of Sheboygan, Wisconsin.

EASEMENT AREA:

A Ten (10) foot wide easement beginning at the Northeast corner of the above described parcel and abutting the East property line for the full length of the above described parcel and more particularly described and shown on attached Exhibit B incorporated into and made a part hereof by reference.

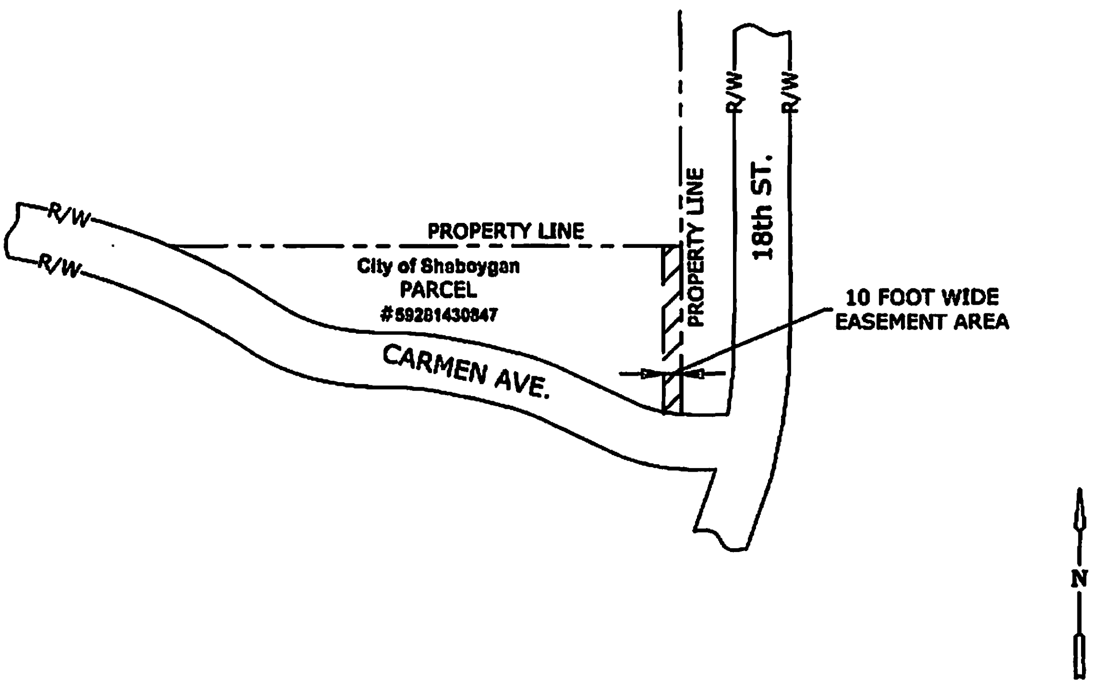
Being a part of the North Half (N 1/2) of the Northwest Quarter (NW 1/4) of Section 3, Township 14 North, Range 23 East, in the City of Sheboygan, County of Sheboygan, Wisconsin.

Grantor's deed recorded on February, 25 1972, as Document No. 944258 in the office of the Register of Deeds for Sheboygan County, Wisconsin.

EXHIBIT "A"

A part of the North Half (N 1/2) of the Northwest Quarter (NW 1/4) of Section Three (3), Town Fourteen (14) North, Range Twenty-Three (23) in the City of Sheboygan, County of Sheboygan, Wisconsin.

A Ten (10) foot wide easement beginning at the Northeast corner of the above described parcel and abutting the East property line for the full length of the above described parcel and more particularly described and shown below.



NOT TO SCALE

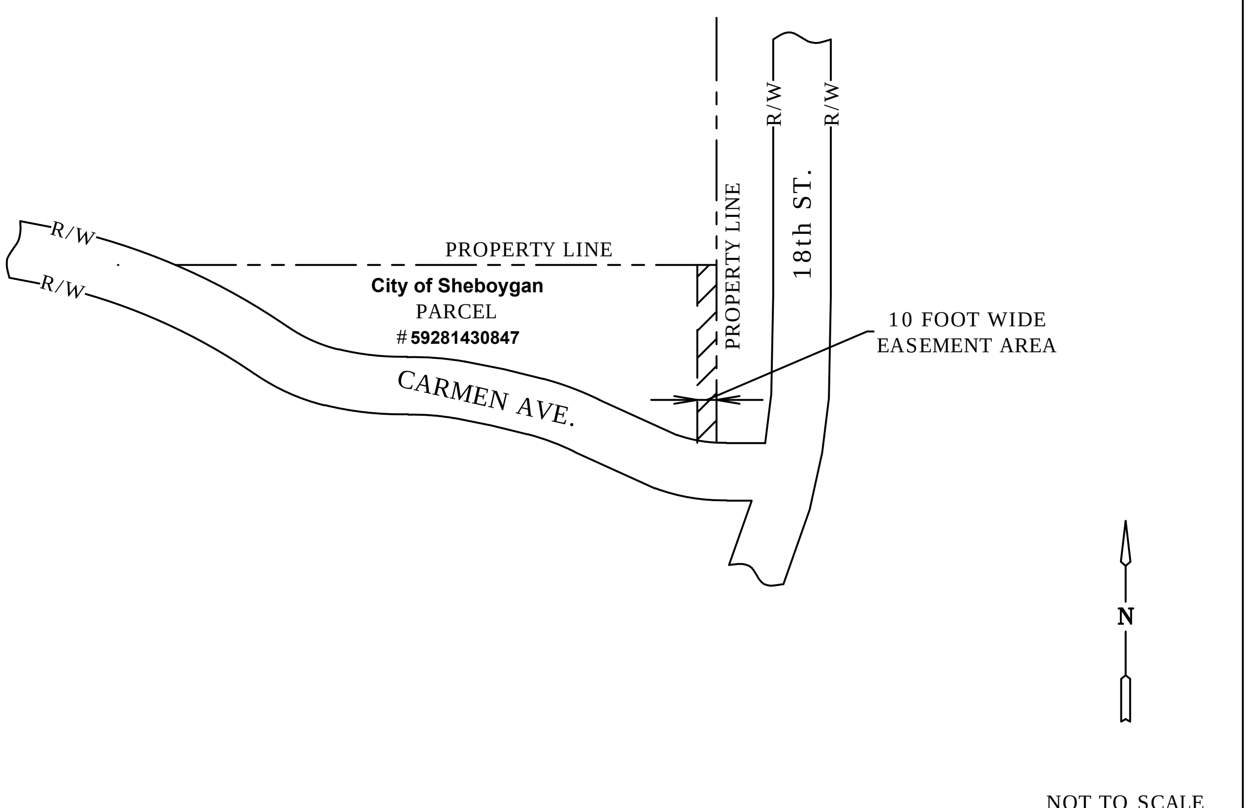
ALLIANT #4049558
4

DRAFTED BY: MI-TECH SERVICES, INC
C.A.S.

EXHIBIT "B"

A part of the North Half (N 1/2) of the Northwest Quarter (NW 1/4) of Section Three (3), Town Fourteen (14) North, Range Twenty-Three (23) in the City of Sheboygan, County of Sheboygan, Wisconsin.

A Ten (10) foot wide easement beginning at the Northeast corner of the above described parcel and abutting the East property line for the full length of the above described parcel and more particularly described and shown below.



NOT TO SCALE

DRAFTED BY: MI-TECH SERVICES, INC
C.A.S.

ALLIANT #4049558
4

III 5.3

Res. No. 47- 17 - 18. By Alderperson Wolf. July 17, 2017.

A RESOLUTION authorizing the Purchasing Agent to enter into contract for the complete replacement of the siding and trim on the Harbor Centre Marina Administration Building and three adjacent accessory structures.

WHEREAS: The Harbor Centre Marina Administration Building has undergone several restoration projects over the past few years intended to repair damage as a result of moisture permeation past the building envelope. The final step in the process is the complete replacement of the original cedar lap siding on the structure(s) which has failed following constant exposure to moisture and sun light since the building was constructed and;

WHEREAS: The Purchasing Agent issued a Request for Bids for the replacement of the natural wood siding with an engineered, pre-finished product(LP SmartSide) which has a superior resistance to moisture penetration, rot, cupping, peeling and cracking along with a strong warranty behind it. Following a review of the bids received, the lowest bid of $ 201,300.00, submitted by Quasius Construction Inc. of Sheboygan has been found to meet all of the specifications.

WHEREAS: In 2016 all of the windows in the building were replaced and the contractor found significant damage to the structure around and under the windows, which was ultimately repaired with costly change orders. Without removing the siding, it is impossible to predict what additional damage will be encountered. It is prudent to repair as much of this concealed moisture damage as possible prior to the application of the new siding. There is $ 350,000.00 available for the project. Due to the aforementioned uncertainty as to the potential existing concealed damage, we are seeking approval of up to $ 350,000.00 to correctly and satisfactorily restore the structure. All additional work found to be needed will be done through formal written change orders and following completion of the project, any unspent funds will be returned to the Finance Director.

RESOLVED: That the Purchasing Agent is hereby authorized to enter into contract with Quasius Construction Inc. of Sheboygan, WI for the complete removal of all of the original natural wood siding and trim on the Harbor Centre Marina Administration Building and three accessory structures and followed by installation of SmartSide® engineered siding and trim which will restore the building envelope and replicate the aesthetic features of the existing siding while creating a much improved resistance to moisture, rot and damage from the sun.

Pub Works

The base contract with Quasius Construction will be in the amount of $ 201,300.00 and the balance of the budgeted amount of $148,700.00 is to be held in reserve as a contingency to allow for proper remediation of probable concealed moisture damage uncovered during the project.

BE IT FURTHER RESOLVED: That the appropriate City Officials are hereby authorized to draw funds on Account # 29037500-621200 in payment of same.

____

I HEREBY CERTIFY that the foregoing Resolution was duly passed by the Common Council of the City of Sheboygan, Wisconsin, on the __________ day of ____________________, 20____.

Dated ______________ 20____. ______________________________, City Clerk

Approved ___________ 20____. ___________________________________, Mayor

CITY OF SHEBOYGAN
REQUEST FOR PUBLIC WORKS COMMITTEE CONSIDERATION

ITEM DESCRIPTION: Resolution by Ald. Wolf authorizing entering into contract for the complete replacement of the siding and trim on the Harbor Centre Marina Administration Building.

REPORT PREPARED BY: Bernard Rammer, Purchasing Agent

REPORT DATE: July 7, 2017

MEETING DATE: July 25, 2017

FISCAL SUMMARY:

Budget Line Item: 29037500-621200
Budget Summary: Harbor Centre Marina Fund
Budgeted Expenditure: $ 350,000.00
Budgeted Revenue: N/A

STATUTORY REFERENCE:

Wisconsin Statutes: N/A
Municipal Code: N/A

BACKGROUND / ANALYSIS:
Over the past number of years, the Harbor Centre Marina Administration Building and adjacent accessory structures have encountered significant damage due primarily to the infiltration of moisture through the building envelope and to a lesser degree damage from the effects of the sun. The natural cedar wood lap siding is rotting, cupping, cracking and warping. Included in the 2017 budget is funding to allow for complete replacement of the natural wood siding with a Diamondkote® pre-finished engineered lap siding (LP SmartSide®)which will provide much improved, long-term protection from the elements, it features a strong warranty and closely replicates the current aesthetic appearance of the structures. A request for bids was issued with the following results:

Quasius Construction Inc...	Sheboygan, WI	$ 201,300.00
A. Chappa Construction Inc.	Sheboygan Falls, WI	$ 225,183.00

Upon review of the bids, it has been determined that the bid submitted by Quasius Construction, Inc. of Sheboygan, WI meets or exceeds all of the specifications.

STAFF COMMENTS:
There is $350,000 in the 2017 budget for this work. Based upon the damage discovered during the window replacement project last year, it is likely that additional moisture damage will be discovered once the old siding has been removed. As such, we are asking that the favorable variance of $148,700 be held in reserve as a contingency. The City will diligently control any additional expense through the use of written change orders and any unspent funds will be returned to the Finance Director following the project completion in the fall of 2017. This will assure that the project is completed in an appropriate manner and that the damaged elements are properly addressed.

ACTION REQUESTED:
Motion to recommend that the Common Council approve the Resolution by Ald. Wolf to authorize the complete replacement of the exterior siding on the Harbor Centre Marina Administration Building and three adjacent accessory structures by Quasius Construction of Sheboygan in the amount of
$ 201,300.00 with a contingency amount of up to $ 148,700.00 to be used to properly repair any concealed moisture damage that may be discovered during the project.

ATTACHMENTS:

I. Res No. ____-17-18

Co-Digestion Evaluation

City of Sheboygan - Wastewater Treatment Plant

Project Number: 60532058

June 27, 2017

Quality information

Prepared by	Checked by	Approved by
Rusty Schroedel	Ralph Eschborn	Tom Holtan

Revision History

Revision	Revision date	Details	Authorized	Name	Position

Distribution List

# Hard Copies	PDF Required	Association / Company Name

Prepared for:

City of Sheboygan - Wastewater Treatment Plant

Prepared by:

AECOM
1555 RiverCenter Drive
Milwaukee, WI 53212

aecom.com

Table of Contents

Figures

Tables

1. Executive Summary

Sheboygan has accepted high strength waste (HSW) for years in order to co-digest with the plant's sludge to increase digester gas production. The use of the increased volume of digester gas, primarily to make electricity, resulted in significant cost savings and occasional production of electricity in excess of the treatment plant's electricity demand. The combination of aging facilities, reduced tipping fees for the HSW, and digester capacity limitations resulted in questions regarding the cost-effectiveness of retaining acceptance of HSW.

A substantial amount of data was received from the Sheboygan wastewater plant regarding sludge production, digester gas production, digester gas utilization, system operations, and operating costs. This data was analyzed for current and future conditions to evaluate three options of continuing to receive current volumes of HSW, eliminate receipt of HSW, or to reduce the volume of HSW received.

The analysis determined that the lowest net present value cost was to eliminate the receipt of HSW. However, several current systems would be underutilized should no HSW be received. Also, current tipping fees are significantly less than those charged previously. Selective receipt of HSW with appropriate tipping fees has the potential to allow continuing to receive HSW worthwhile.

A more detailed analysis of the potential HSW streams, tipping fees, and limited capital improvements along with sensitivity of process performance and unit costs could identify a more cost-effective HSW receiving program.

2. Introduction

The City of Sheboygan wastewater facility has been a leader nationwide in the development of co-digestion and associated energy production. It was one of the first facilities in North America to achieve net zero energy, meaning it was often able to produce more electricity through its microturbine system than required to operate the treatment plant. Recently, more treatment plants have added the ability to accept and co-digest high strength wastes. This has increased competition for the higher quality wastes and lowered tipping fees that treatment plants receive for accepting wastes. Sheboygan has seen a significant drop in tipping fees for high strength wastes (HSW), causing this revenue source to decrease as summarized in **Figure 2-1**. Sheboygan currently receives tipping fees ranging from $0 to $0.04 per gallon.

Several portions of the co-digestion system, such as the digester that is used as a receiving tank and several of the microturbines are in need of repair or replacement. A capital improvements plan has been prepared for the wastewater facility and the co-digestion system. Related to this analysis, the Facility Plan recommended the following capital upgrades (Wastewater Treatment Facilities Plan, Draft Report, January 2017):

- Rehabilitate HSW receiving - $1,814,000
- Conversion of D6 from a secondary digester to a fourth primary digester - $1,548,000
- Replace the 30 kW turbines in 5 years - $1,000,000
- Replace the 200 kW turbine in 10 years - $1,000,000

Figure 2-1: High Strength Waste Volume and Revenue 2010 to 2016

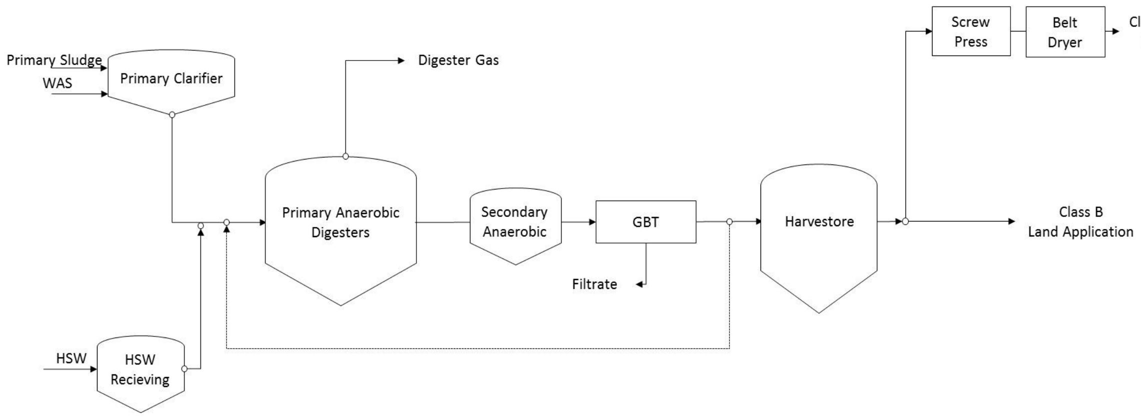
Sheboygan desires an independent review of the co-digestion system economics, including a review of the capital plan, while considering the impacts of reduced revenue from high strength wastes. The City needs to prioritize various capital improvements and determine if it makes financial sense to make significant capital improvements to the high strength waste and co-digestion system.

This report summarizes the review of the alternatives, data analysis, development of a cost model, and provides conclusions and recommendations regarding the future of co-digestion at the Sheboygan Wastewater Treatment Plant.

3. Review of Alternatives

Sheboygan currently co-settles the primary sludge and waste activated sludge (WAS) in the primary clarifiers. HSW is received and stored in old digesters in the West Digestion Complex. The co-settled sludge and HSW are currently digested in three (3) 750,000 gallon primary digesters in the East Digestion Complex before being directed to a secondary digester. The digested sludge is then thickened to approximately 6% total solids (TS) using gravity belt thickeners and a portion of the thickened sludge is recycled to the primary digesters to provide some recuperative thickening. The thickened sludge not recycled is directed to two (2) 2 million gallon Harvestore tanks which provide several months of sludge storage as 180 days of sludge storage is required during wintertime operation when land application is not allowed. Currently about half of the digested sludge is dewatered using screw presses and dried in a belt dryer and the dried biosolids is distributed as a Class A product. The remainder of the biosolids is land applied as a Class B liquid sludge. A process flow diagram of Sheboygan's sludge processing system is provided in **Figure 3-1.**

Figure 3-1: Sheboygan, WI Sludge Process Flow Diagram



Three alternatives were identified during project definition and scoping. They are:

- Baseline or current conditions: Continue to receive high strength wastes at existing volumes and from existing sources. The improvements recommended in the capital improvement plan are included.
- Eliminate high strength waste receiving. This would still allow for production and use of digester gas from municipal wastewater discharged to the plant.
- Continue to receive high strength wastes. Define the appropriate or limited improvements that should be made to the system.

4. Data Analysis

A significant volume of detailed plant records were provided to the team regarding sludge systems performance and operational considerations. Appendix A provides a list of that information. The historical records were used to prepare a mass and energy balance that is the basis for the analysis in this evaluation. Selected spreadsheets used for the analysis are included in Appendix B.

4.1 Historical Loading Data

To set a baseline for the three alternatives, three years of operational data were analyzed from 2014 to 2016. The total sludge and HSW feed to the digesters is summarized in **Table 4-1** and **Figure 4-1**. The data shows fairly consistent feed throughout the three years analyzed. The data also showed that the maximum 30 day peaking factor ranged from 1.2 to 1.4 for this period for both the sludge and HSW (data not shown). The volatile solids (VS) content of the sludge and HSW feed and digested sludge is summarized in **Table 4-2** along with digester gas production. For the HSW, total solids and volatile solids were not measured until 2016. Also digested sludge VS sampling was conducted more regularly in 2016 with 52 samples collected compared to 8 in 2014 and 13 and 2015. The more comprehensive sampling of HSW and digested sludge occurred starting in August 2016. The average annual gas production increased during the three years as noted in **Table 4-2** and **Figure 4-2**. In 2016, gas measured 55% methane which is a little lower than the 60-65% estimated for sludge (M&E 5^{th} Edition) and the difference is likely due to differences in co-digestion feedstocks. Based on the plant records, greater than 90% of the HSW received (by volume) at Sheboygan since 2010 has been dairy waste and in 2014 to 2016, over 97% (by volume) of the HSW was dairy waste.

Table 4-1: Summary of Three Years of Sludge Production

	Primary + WAS		HSW		Total
Units	gal	% TS	gal	% TS	gal
2014 Avg	67,600	3.6	43,800		111,200
2015 Avg	67,200	3.0	45,300		112,500
2016 Avg	58,800	3.3	43,800	8.9	102,600
3-YR Average	**64,500**	3.3	**44,300**		**108,800**

Figure 4-1: Summary of Three Years of Sludge Production

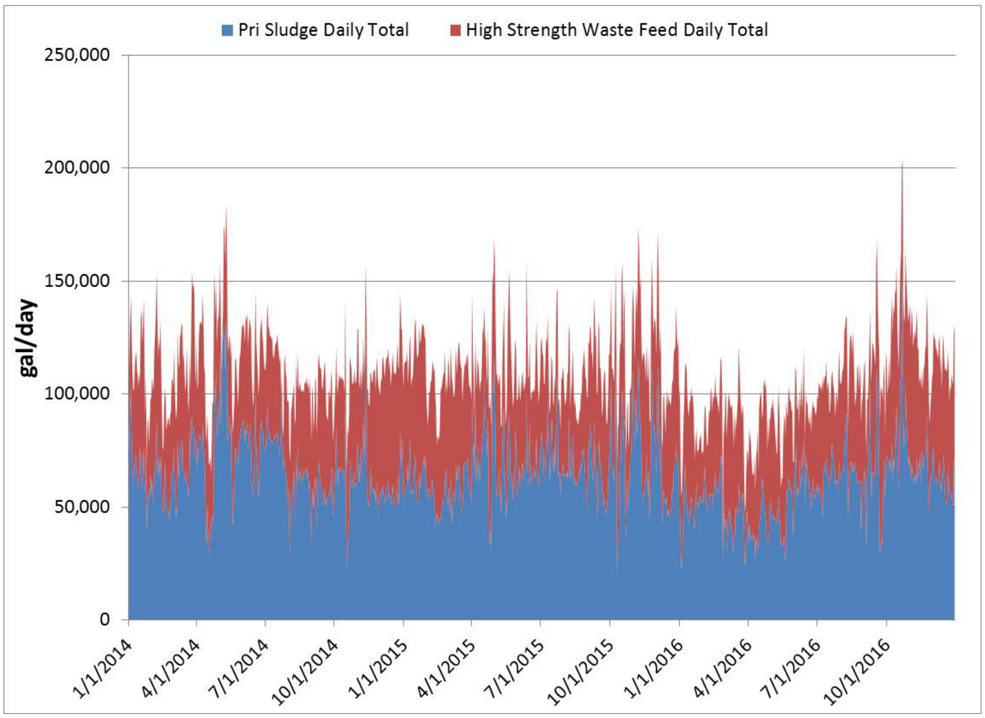
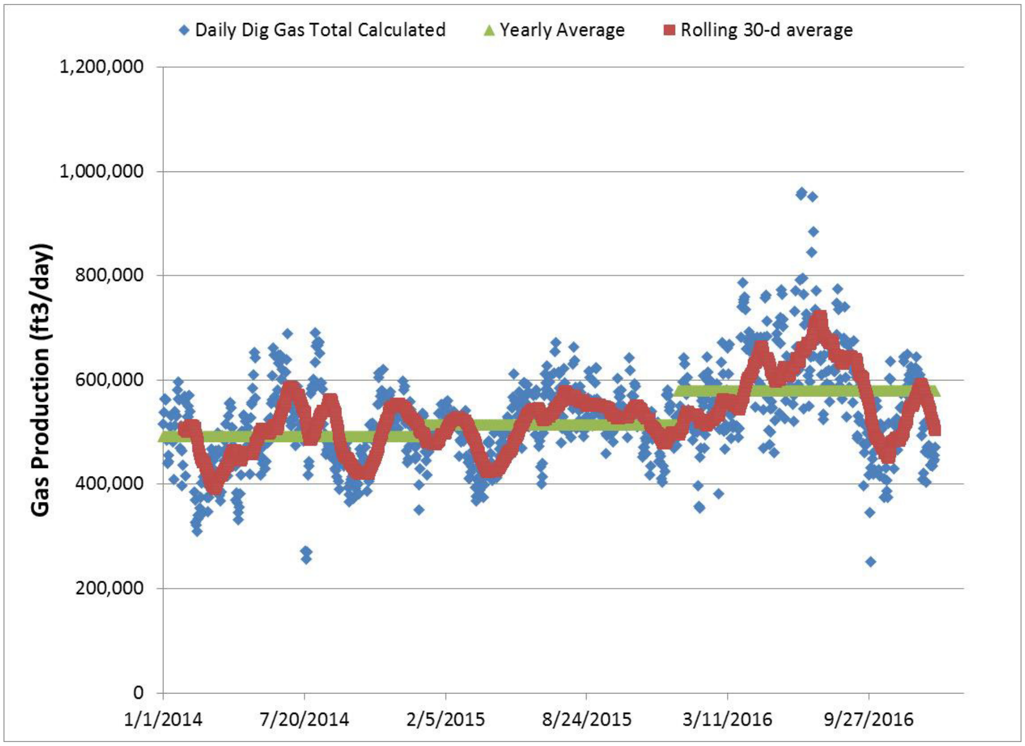


Table 4-2: Summary of Volatile Solids Content and Digester Gas Production

	Primary + WAS (% VS/TS)	HSW (% VS/TS)	Digested (% VS/TS)	Digester Gas (cu ft/d)
2014 Avg	71.8		55.3	492,000
2015 Avg	75.6		62.5	514,700
2016 Avg	73.4	81.0	60.7	579,800
3-YR Average	**73.6**		**60.4**	528,800

Figure 4-2: Summary of Digester Gas Production



Since detailed HSW and digested sludge sampling was not regularly monitored until August 2016, a “snapshot” from August to December 2016 was analyzed to set the basis for current anaerobic digester performance and this data is summarized in **Table 4-3**. The digester volatile solids reduction (VSR) performance was estimated using the Van Kleeck equation.

The data showed that overall VSR in the anaerobic digester averaged around 57%, however, it is expected that the VSR performance of the sludge and HSW fractions would be different. Using the VS feed differences in the sludge and HSW in the Van Kleeck equation, it was estimated that the primary and WAS sludge fraction achieved 45% VSR and the HSW fraction achieved 62% VSR. The actual VSR for the different feed streams could vary more than this and it is possible the addition of HSW provides synergistic or possibly even antagonistic impacts on overall VSR. Either way, the VSR assumptions are carried forward into the analysis for the different ratios of sludge to HSW.

The overall gas production of 20.7 cu ft/lb VSR is also higher than typically expected for sludge which ranges from 13 to 18 cu ft/lb VSR (M&E 5th edition). The differences are likely due to the impact of HSW feed into the anaerobic digester. For the mass balance assumptions in this analysis, it is assumed that digestion of the sludge fraction provides 18 cu ft/lb VSR, which corresponds to the highest value in the range expected. To provide an overall gas production of 20.7 cu ft/lb VSR, as shown in **Table 4-3**, the HSW fraction was calculated to provide 22 cu ft/lb VSR. Additional testing could be performed to further refine the impact of co-digestion. Sampling for chemical oxygen demand (COD) in the feedstocks and digested sludge would allow a COD balance to be performed which may allow for a more accurate digestion mass and energy balance to be developed. Also conducting Biochemical Methane Potential (BMP) tests would be another method that could be used to determine the overall digestibility and specific gas production for the feed stocks.

Table 4-3: August to December 2016 Anaerobic Digester Performance Summary

Parameter	Value	Units
Average Primary Volume	69,300	gal
Primary Total Solids	3.2	% TS
Primary Sludge VS	72.6%	% VS/TS
Average HSW Volume	51,300	gal
HSW Total Solids	8.9	% TS
HSW VS	81.0%	% VS/TS
Digester SRT	18.7	days
Average Primary Mass	18,300	lb/d
Average HSW Mass	38,100	lb/d
Total Digester Feed	56,400	lb/d
Total Digester Feed TS	5.61%	% TS
Total Digester Feed VS	78.3%	% VS/TS
Digested Sludge VS	60.9%	% VS/TS
VSR - Van Kleek	56.8%	%
Gas Production	519,000	cu ft/d
Methane Content	56.7	% CH_4
Specific Gas Production	20.7	cu ft/lb VSR

4.2 Historical Gas Usage and Heat Balance

Sheboygan beneficially uses the majority of the digester gas for heat and electricity production. The gas can be directed to two (2) 200 kW microturbines, ten (10) 30 kW microturbines, two (2) sludge boilers or a digester gas boiler. Gas that is not beneficially used is flared. Historical breakdown of digester gas use for 2014 to 2016 is summarized in **Table 4-4**. The data shows that about 60-70% of the produced digester gas is used for electrical production and **Table 4-5** shows that the turbines are able to provide approximately 570 to 600 kW of electricity on average. Since the dryer was brought online in 2014, the microturbines are able to provide 60-70% of the total plants electrical needs. Prior to having the dryer system installed, the microturbines were able to provide nearly all of the plants required electrical needs.

Although the majority of the gas is used for electrical production, less than 20% is directly used for heating in the sludge boilers and 11 to 18% of the gas has historically been flared. It should be noted that the digester gas boiler was not brought online until 2016 and that boiler can use either digester gas or natural gas as the fuel source. The plant also contains two (2) natural gas fired house boilers.

Table 4-4: Digester Gas Use Summary

Year	Sludge Boiler[1]	200 kW Microturbines[1]	30 kW Microturbines[1]	Flare[1]
2014 Avg	18.1%	39.8%	30.5%	11.5%
2015 Avg	20.1%	36.4%	32.2%	11.2%
2016 Avg	14.9%	33.5%	28.8%	17.6%
3-YR Avg	17.6%	36.4%	30.4%	13.7%

1. Based on annual average data for gas volume usage.

Table 4-5: Historical Microturbine Electricity Production

Year	200 kW Turbines			30 kW Turbines			Total Electrical Production	% of Plant Total
Units	kWh/d[1]	kW	Efficiency[2]	kWh/d[1]	kW	Efficiency[2]		
2014 Avg	8,822	368	28.2%	5,422	226	21.1%	594	84.2
2015 Avg	8,367	349	27.8%	5,614	234	21.1%	583	71.9
2016 Avg	8,188	341	26.7%	5,560	232	20.6%	573	63.9
3-YR Avg	8,459	352	27.6%	5,534	231	20.9%		

1. Based on annual average data
2. Estimated based on electrical production and volume of gas estimates using heat value of digester gas was 550 Btu/ft^3

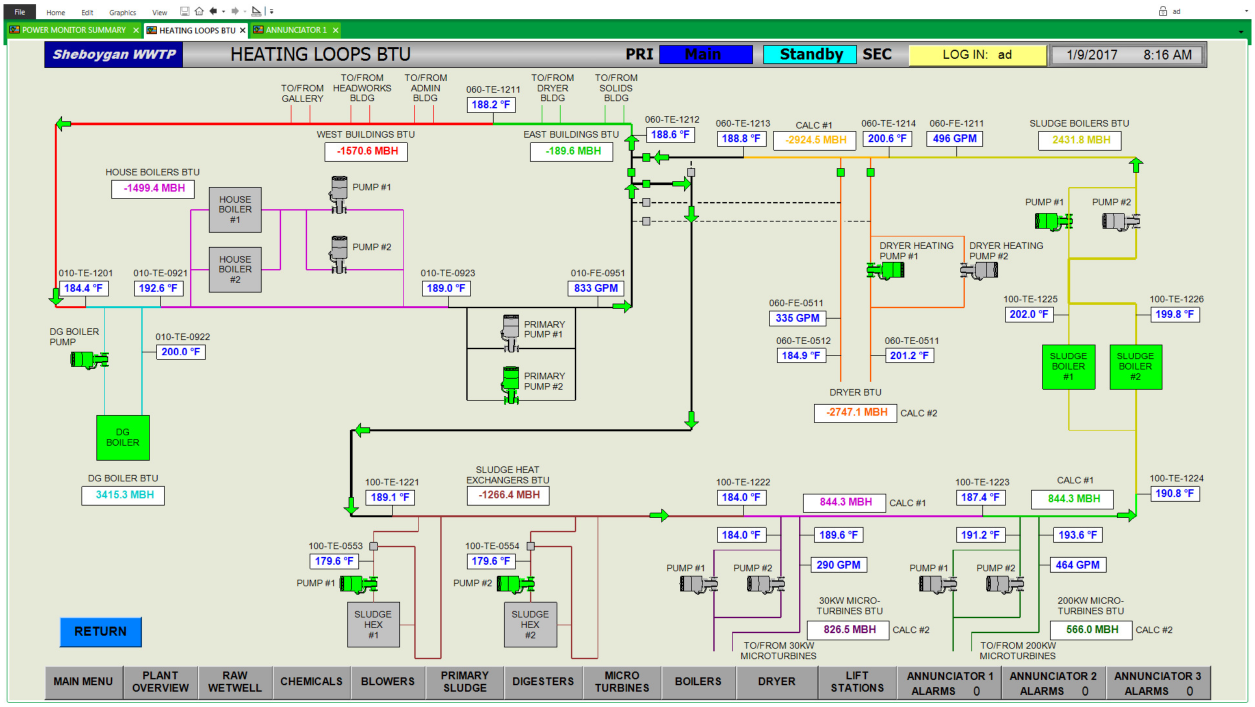
A sophisticated heating loop, shown in **Figure 4-3**, is utilized to meet the plants heating demands for the digester, belt dryer and other plant heating needs (building, tunnels, plant potable hot water, etc.). The heat inputs to the loop come from energy recovery from the microturbines (MT), as well as input from the digester gas fired sludge boilers, natural gas or digester gas fired digester boiler or natural gas fired house boilers. **Table 4-6** provides a summary of the heat inputs into the heating loop from the microturbines and boilers. The total heat input estimated is used to set the total heating baseline for the plant.

Table 4-6: Summary of Heat Inputs into Sludge Heating Loop (Therms/yr)

Year	30 kW MT[1]	200 kW MT[1]	Sludge Boiler[2]	Dig Boiler[1]	House Boiler[3]	Total
2014	18,339	41,249	143,037		28,379	231,004
2015	23,163	23,837	166,507		83,573	297,080
2016	22,244	21,505	135,312	52,565		231,626

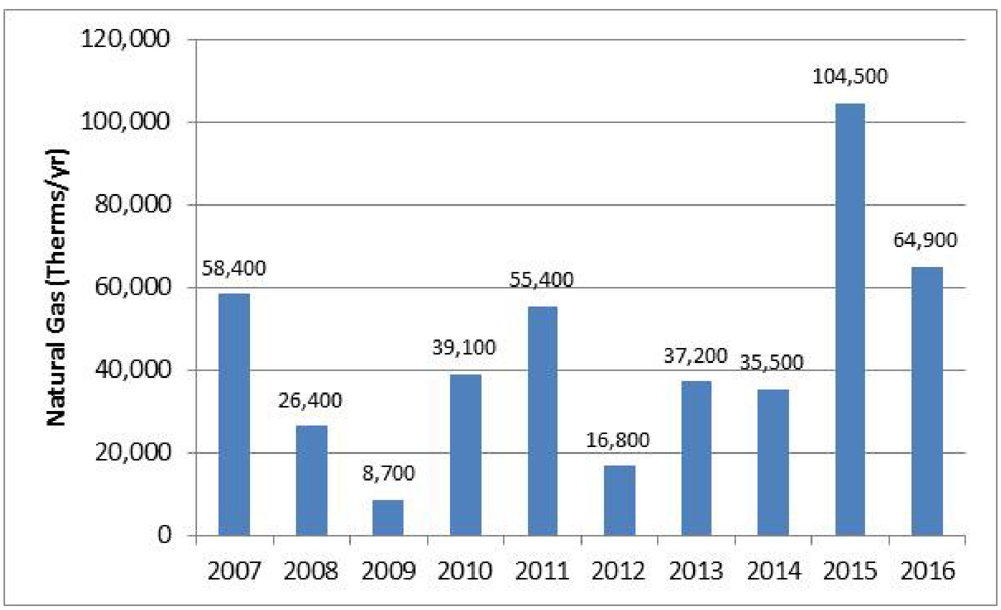
1. Based on annual average data provided
2. Estimated based on average volume of digester gas to boiler assuming a digester gas heat value of 550 Btu/ft^3 and an 80% boiler efficiency
3. Estimated based on natural gas consumption records assuming a 80% boiler efficiency

Figure 4-3: Schematic of the Sheboygan Heating Loop



The total annual natural gas consumption increased after the belt dryer was brought online at the end of 2014 which is evident from the natural gas summary in **Figure 4-4**. In 2014, the natural gas consumption ranged from 64,900 Therms/yr in 2016 up to 104,500 Therms/yr in 2015.

Figure 4-4: Summary of Natural Gas Consumption at Sheboygan



4.3 Basis of Design

The basis of design used for planning was set based on the historical loadings presented in **Table 4-1** and the maximum month conditions were estimated assuming a 1.4 peaking factor for both the sludge and HSW. The facility planning report estimated that the sludge volume in year 2040 would be 6.8% higher than the current production.

4.3.1 Basis of Design – Baseline Condition

The mass and volume load estimates for the baseline conditions (for continuing HSW receiving at the current rate) are presented in **Table 4-7**. The table also assumes that the HSW load would increase proportionally with the plants sludge. **Table 4-7** also presents the digester hydraulic retention time (HRT) estimates with the existing 3 primary digesters and with the 4 total digesters. The Facility Plan recommended converting digester D6 from a secondary digester to a primary digester to increase digestion capacity since their evaluation showed that it was more economical than adding additional mechanical thickening for the primary and WAS feed.

Table 4-7: Basis of Design – Baseline Condition

	Current		2040		
	Average	Max Month	Average	Max Month	
Primary + WAS	17,800	25,100	19,000	26,900	lb/d
	64,500	91,000	68,900	97,200	gpd
HSW	32,900	45,500	35,150	48,600	lb/d
	44,300	61,200	47,300	65,400	gpd
Total	**50,700**	**70,600**	**54,150**	**75,500**	**lb/d**
	108,800	**152,200**	**116,200**	**162,600**	**gpd**
HRT – 3 digesters	20.7	14.8	19.4	13.8	**days**
HRT – 4 digesters	27.6	19.7	25.8	18.5	**days**

It should be noted that with recuperative thickening employed, the SRT would not match the HRT. Historically 18 to 23 million gallons per year of water have been removed by recuperative thickening (3/2/17 e-mail from Sharon Thieszen) so historical average SRT was estimated to be closer to 22 days.

4.3.2 Basis of Design – Eliminate HSW Receiving

One option to consider is eliminating HSW receiving all together. Doing so would allow the existing three primary digesters to have enough capacity throughout the planning period while also providing digester redundancy meaning that two digesters would provide greater than 15 days HRT throughout the planning period with one digester out of service. The design conditions for this option are presented in **Table 4-8.**

Table 4-8 Basis of Design – Eliminate HSW

	Current		2040		
	Average	Max Month	Average	Max Month	
Primary + WAS	17,800	25,100	19,000	26,900	lb/d
	64,500	91,000	68,900	97,200	gpd
HRT – 3 digesters	34.9	24.7	32.7	23.1	**days**
HRT – 2 digesters	23.3	16.5	21.8	15.4	**days**

4.3.3 Basis of Design – Refined HSW Receiving

Another option, which may be more cost effective for Sheboygan, in terms of capital expenditures, would be to reduce the amount of HSW received to the point that would defer or eliminate the need to convert the D6 digester to a primary digester. For this analysis, it was assumed that the amount of HSW received would be reduced by 50%. **Table 4-9** summarizes the design criteria for this which shows that if HSW receiving is cut in half, greater than 17 days of HRT can be maintained in the existing three primary digesters. This condition may not provide full redundancy to provide greater than 15 days of HRT at maximum month conditions if one of the primary digesters was out of service, however, with increased recuperative thickening, the SRT could be maintained at or above 15 days SRT.

Table 4-9: Basis of Design – Reduce HSW Receiving by 50%

	Current		2040		
	Average	Max Month	Average	Max Month	
Primary + WAS	17,800	25,100	19,000	26,900	lb/d
	64,500	91,000	68,900	97,200	gpd
HSW	16,500	22,700	17,600	24,300	lb/d
	22,150	30,600	23,700	32,700	gpd
Total	**34,300**	**47,800**	**36,600**	**51,100**	**lb/d**
	86,650	121,600	92,600	129,900	**gpd**
HRT – 3 digesters	26.0	18.5	24.3	17.3	**days**
HRT – 2 digesters	17.3	12.3	16.2	11.5	**days**

4.4 Alternatives Analysis

Mass and energy balances were prepared for the three different scenarios at current conditions. The outputs from the mass and energy balances were used as the inputs in the cost model discussed in Section 5. **Table 4-10** provides a summary of the digestion, thickening, dewatering and drying mass balances used in this study. From the mass balance, the estimated feed rates to the thickening, dewatering and drying systems were estimated for each scenario. For the purpose of this analysis, it was assumed that 50% of all of the sludge would continue to be thermally dried. However, eliminating or reducing the HSW would provide additional storage capacity in the Harvestore tanks so the need for thermal drying could be reduced or possibly eliminated if HSW receiving is discontinued.

Table 4-10: Sheboygan Alternatives Mass Balance

		Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Primary + WAS	Mass Load	17,800	17,800	17,800	lb/d
	Volatile Solids	74%	74%	74%	VS/TS
	Total Solids	3.3%	3.3%	3.3%	TS
	Volumetric Loading	64,400	64,400	64,400	gpd
HSW	Mass Load	32,900	--	16,450	lb/d
	Volatile Solids	81%	--	81%	VS/TS
	Total Solids	8.9%	--	8.9%	TS
	Volumetric Loading	44,300	--	22,100	gpd

		Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Digester Feed	Mass Load	50,700	17,800	34,250	lb/d
	Volatile Solids	78%	74%	77%	VS/TS
	Total Solids	5.6%	3.3%	4.7%	TS
	Volumetric Loading	108,700	64,400	86,600	gpd
Digester Performance Primary + WAS	VSR	45%	45%	45%	
	Gas Production	18	18	18	cu ft/lb VSR
Digester Performance HSW	VSR	62%	62%	62%	
	Gas Production	22	22	22	cu ft/lb VSR
Total Digester Performance	Total Volatiles Removed	22,420	5,890	14,150	lb VS/d
	Total VSR	56%	45%	54%	
	Total Gas Production	470,000	106,000	288,000	cu ft/day
Thickening	Mass to Thickener[1]	30,100	17,800	24,000	lb/d
	Thickened Solids[2]	6.2%	6.2%	6.2%	TS
	Solids Recovery	91%	91%	91%	
	Active Polymer[3]	4.4	4.4	4.4	lb/DT
	Active Polymer	66.2	39.2	52.8	lb/d
Digested Sludge to Aqua store	Mass Load	25,600	10,300	18,000	lb/d
	Volatile Solids	61%	61%	61%	
	Volumetric Loading	49,500	19,900	34,800	gpd
	Harvestore Volume	4	4	4	MG
	Storage Days	81	201	115	days
Sludge to Dewatering and Drying	Ratio to DW/dry	50%	50%	50%	
	To Dewatering	12,800	5,200	9,000	lb/d
	To Dewatering	2,300	900	1,600	DT/yr
	Dewatered Solids[4]	22%	22%	22%	
	Solids Recovery	95%	95%	95%	
	Active Polymer[3]	38	38	38	lb/DT
	Active Polymer	43.7	17.1	30.4	lb/d
	Dry Solid Content	92%	92%	92%	
	Evaporative Load	7,600	3,000	5,300	ton/y

DT = Dry Ton, MG = Million Gallon

1. Accounts for recuperative thickening estimated based on amounts of water removed. For alternative scenarios, the amount of water removed is assumed to be proportional to the digester feed.
2. Based on historical records.
3. Polymer estimates provided by city staff.
4. Targeted TS with new screw presses.

The mass balance was also used to estimate total gas production for each scenario and the use of the gas is presented in **Table 4-11**. For the baseline scenario, it was assumed that the gas would continue to be used to produce electricity and heat similar to what is summarized in **Table 4-5** and **Table 4-6**. For the case where the HSW is eliminated, the gas production is significantly decreased and it is estimated that only one 200 kW microturbine will be in service for this scenario. For the refined HSW receiving scenario where the HSW input is reduced by 50%, the two 200 kW microturbines and two of the ten 30 kW microturbines are estimated to be in service. For the mass balances presented, the total gas production estimated was less than shown by the historical records, however, the gas uses were still estimated to be the same in terms of electrical and heat production. Using the calculated gas production and historical energy uses lowered the amount of gas being flared down to 5% of the total gas which is reasonable to achieve and reducing flaring would further optimize the system energy balance.

Table 4-11: Digester Gas Use Estimates

	Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Energy Content in Biogas	943,500	212,800	578,200	Therms/yr
Electricity from 200 kW MT	8,400	3,600	8,400	kWh/d
200 kW Electrical Efficiency	28%	28%	28%	
Gas to 200 kW MTs	373,800	160,200	373,800	Therms/yr
% of Total Biogas to 200 kW MT	39.6%	75.3%	64.6%	
Electricity from 30 kW MT	5,500		1,200	kWh/d
30 kW Electrical Efficiency	21%		21%	
Gas to 30 kW MTs	326,400		71,200	Therms/yr
% of Total Biogas to 30 kW MT	34.6%		12.3%	
Total Biogas to MTs	74.2%	75.3%	77.0%	
Sludge Boiler	160,000	34,200	85,400	Therms/yr
Sludge Boiler Efficiency	80.0%	80.0%	80.0%	
Gas to Boiler	200,000	42,800	106,700	Therms/yr
Gas Flared	43,300	9,800	26,500	Therms/yr
% Gas Flared	5%	5%	5%	

The thermal energy requirements at the plant are tied into a sophisticated loop as presented in **Figure 4-3**. The total annual plant heating requirements for the baseline case is based on the information provided in **Table 4-6**. Estimating the heat requirements directly for each scenario would be complicated since the heating needs for the digester and building heating is seasonal and would vary annually. In order to simply this, the savings with respect to the drop in digester heating and reduction in thermal drying were estimated for the two alternative scenarios and it was assumed that the digester heat loss, building and other plant heating needs would be the same for each scenario. The thermal energy requirements are summarized in **Table 4-12**.

Table 4-12: Heat Demand Estimates

	Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Energy Input Baseline	275,000	275,000	275,000	Therms/yr
Digester Heating Savings		-40,400	-20,200	Therms/yr
Dryer Heating Savings		-128,800	-64,400	Therms/yr
Total Energy Input	275,000	105,800	190,400	Therms/yr

As shown in **Figure 4-3**, the heat is supplied to the loop from the microturbines waste heat and the various boilers provided. For the baseline case, it was assumed that the input would be similar to the historical records summarized in **Table 4-6** and that a portion of the heating demand is met with the microturbine waste heat and the digester gas sludge boiler. The remaining heat demands would then be met using natural gas either with the digester gas boiler or house boilers (labeled supplemental boiler input). For the alternative cases, the heat inputs from the microturbine and digester gas fired sludge boilers were estimated based on the gas usages in **Table 4-12**. The shortfall for heating requirements were then calculated to determine how much natural gas would be required for each scenario and the natural gas input is estimated in **Table 4-13**.

Table 4-13: Supply of Heat Demand

	Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Heat from 200 kW MTs	24,300	10,400	24,300	Therms/yr
Heat from 30 kW MTs	20,200	0	4,400	Therms/yr
Heat from Sludge Boiler	160,000	34,200	85,400	Therms/yr
Supplemental Boiler Input	70,500	61,200	76,300	Therms/yr
Boiler Efficiency	85%	85%	85%	
Natural Gas Input	82,900	72,000	89,800	Therms/yr

5. Cost Model

A cost model was prepared that compares the capital costs, operation and maintenance expenses, and the net present value of the three alternatives. The cost model, which uses an Excel spreadsheet for the calculations, is provided in Appendix C.

There are three major sections to the model:

- Process Impacts
- Cost Impacts
- Cost Model Common Inputs

The process impacts section includes major process related variables for the three alternatives such as electrical production, natural gas use, polymer use, and solids quantities. The electrical consumption estimates are based on both historical records, where available, and estimates used for similar equipment from other projects. The solid quantities, polymer, and natural gas quantities provided are based on the analysis discussed in **Section 4.4.** The process variables are used in the cost impacts section to calculate annual expenses for various line item costs such as electrical production. The cost impacts section shows revenues as negative values. There are three revenue generating line items: electrical production from microturbines, HSW tipping fees, and Class A dried biosolids application. The third major section is cost model common impacts. These items are common variables that are used in all alternatives such as interest rate, electrical unit costs, and polymer costs. Interest rate is the City's cost of borrowing money.

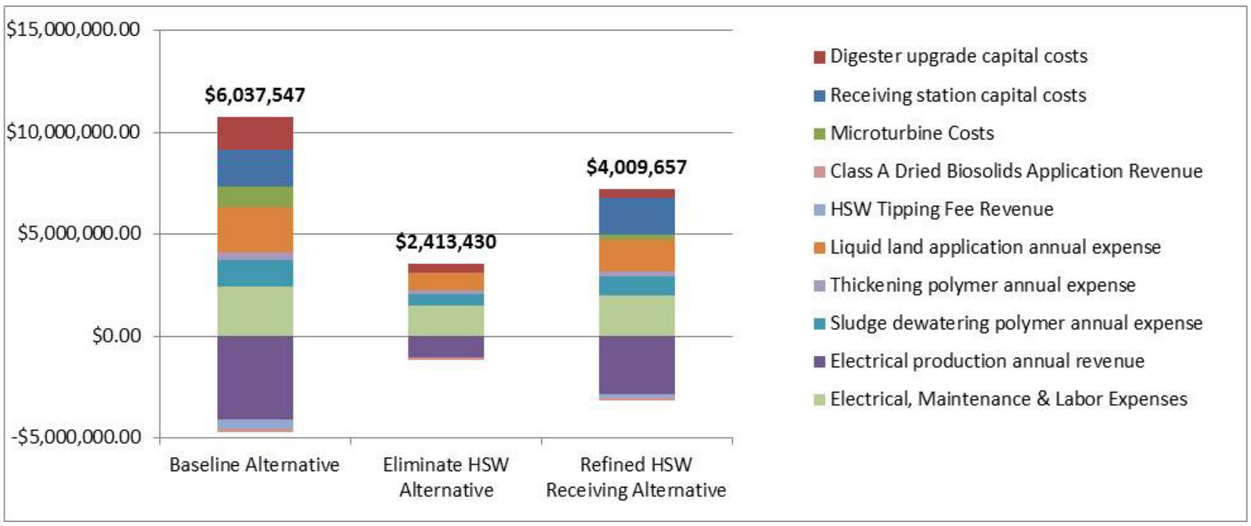
In the cost impacts section, the capital costs are listed as total costs and the analysis includes only the HSW receiving upgrades and digester upgrades. For the scenarios that avoid the conversion of digester D6, the cost amount only includes replacing the digester cover and does not include adding a heating or mixing system. In the cost impacts section, operation and maintenance expenses for the various line items are presented as annual amounts. The annual expenses are summed and the net present value factor is applied to the sum to get a net present value for the annual expenses. This net present value is then added to capital costs to calculate a total net present value for each alternative. Values for some cost line items such as maintenance labor were not included. It is difficult to estimate an accurate value for annual maintenance and the value would be small when compared to the large cost items.

The five largest cost items are highlighted in blue and include:

- Receiving station capital costs
- Digester upgrade capital costs
- Electrical production annual revenue
- Sludge dewatering polymer annual expense
- Liquid land application annual expense

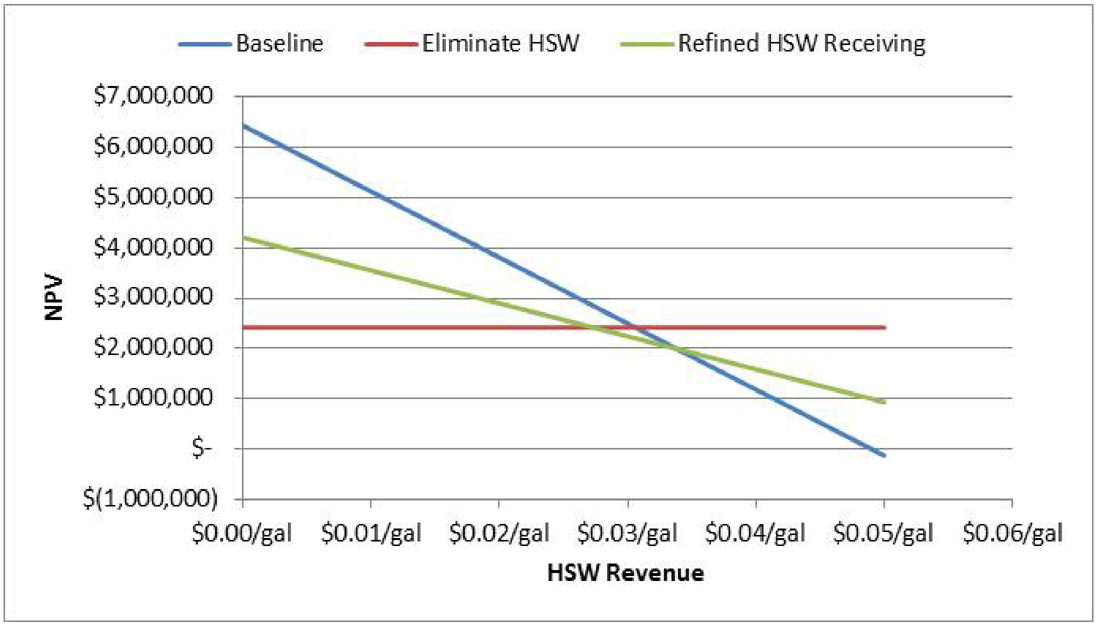
These five items essentially control the outcome of the net present value analysis. Other cost items have a minor impact. A graphical summary of the net present value evaluation is provided in **Figure 5-1**. The "eliminate HSW alternative" has the lowest net present value based on the assumptions used in this analysis.

Figure 5-1: Summary of Net Present Value



As illustrated in **Figure 5-1**, receiving HSW provides the largest ability for Sheboygan to generate revenue; however, the additional revenue does not outweigh the additional capital and operating expenditures associated with receiving HSW. One potential possibility to further increase revenue is to increase the tipping fees for receiving the HSW. As shown in **Figure 2-1**, the revenue from receiving HSW has dropped dramatically over the past several years. In order to better evaluate the impact of receiving HSW, a sensitivity analysis was conducted on the tipping fee revenue on a per gallon received basis and a graphical presentation of this data is provided in **Figure 5-2**.

Figure 5-2: Sensitivity of HSW Receiving Costs



The data presented in **Figure 5-2** shows that if greater than $0.03/gal of revenue can be obtained for receiving HSW (similar to the revenue generated in 2011) then the options with HSW Receiving start becoming favorable from an NPV stand point. Revenue from HSW would need to be about $0.031/gal to make the Baseline Alternative break even with the Eliminate HSW Alternative. Revenue would need to be about $0.0274/gal to make the Refined HSW Receiving Alternative break even with the Eliminate HSW Alternative. It should be noted, however, that if the cost estimates for the digester and HSW system rehabilitation was lower than what is currently listed in the facility plan, the breakeven numbers for HSW revenue would be further reduced.

Future studies could be conducted to look at the sensitivity of other process variables and unit costs on the overall lifecycle cost.

6. Prioritization of Capital Projects

6.1 Facility Plan Report

A report prepared for the City of Sheboygan (Wastewater Treatment Facilities Plan, Draft Report, January 2017) analyzed existing conditions, identified future conditions, evaluated alternatives, and developed a recommended plan. It is beyond the scope of this report to review, analyze, and critique every item recommended in the draft Facilities Plan. The items in the plan that relate to the hauled waste receiving, anaerobic digesters, and digester gas utilization systems and their approximate total project costs are:

- High strength waste receiving and storage improvements – $1,814,000
- Conversion of Digester D6 to a primary digester – $1,548,000
- Replacement of the 30 kW microturbines or increased capacity for these units – Future project – $1,000,000
- Replacement of the 65 kW microturbines – Future project – $1,000,000

6.2 Identify Priorities

A common approach to prioritize wastewater treatment plant improvements and upgrades is to first and foremost emphasize permit compliance and personnel safety. Additional review and analysis of the recommendations in the Facilities Plan is recommended to prioritize the identified capital improvements.

Based on the analysis in this report, other projects can take priority over the above listed improvements. By accepting the option of modifying the existing HSW acceptance program to that which eliminates the need for conversion of Digester D6 to a primary digester and reduces the cost for the high strength waste system improvements to those that relate only to the receiving improvements, can result in a cost savings of approximately $1,200,000.

7. Conclusions

The conclusions of this evaluation are:

1. Elimination of the receipt of high strength waste has the lowest Net Present Value for the identified 10 year period based on the assumptions and performance criteria derived from the historical data.
2. Elimination of the receipt of high strength waste may result in underutilization of several pieces of major equipment.
3. Digester gas utilization may be further optimized. Analysis based on current electrical and natural gas costs may result in more cost-effective gas utilization. For example, it may make economic sense to add additional CHP capacity so that all of the digester gas produced is used for electrical production. It may also be desirable to evaluate future use of a dual fueling option with natural gas to generate electricity. The natural gas could be blended to keep the microturbines operating at the peak operating rate and be used to “fill in the valleys” with respect to gas production.
4. Large capital cost items have the greatest impact on the net present value analysis. Identification of lower cost alternatives may result in improved savings by acceptance of HSW.
5. Newer larger screw presses are planned for the site which is expected to improve dewaterability. The impact of dewatering in terms of total dewatered cake solids and polymer consumption have a large impact on the economics of this system operation. It should also be noted that there is ongoing research and technology developments into processes that decrease polymer consumption and improve dewatered solids concentrations. These developments could be of interest to Sheboygan if polymer consumption remains high and dewatered solids remain below the targeted value of 22% TS with the new screw presses.
6. Adjusting the revenue associated tipping fees will significantly impact the net present value analysis. If the revenue from HSW receiving is increased to greater than $0.03/gal, similar to 2011 levels, the economics of HSW co-digestion become more favorable.

8. References

"Sheboygan Regional Wastewater Treatment Facility – Wastewater Treatment Facility Plan", DRAFT, January 2017

"Wastewater Engineering", Metcalf & Eddy|AECOM, 5th Edition, 2013

Appendix A Data from Wastewater Plant

Numerous files were provided by Sheboygan to review in this analysis. The table below summarizes the files received, relevant information and how the information was used in the analysis. A few select pdf's of some of these files is provided in this appendix following the table.

File Provided by Sheboygan	Relevant information	How it was used in the analysis
2014 to 2016 Co-Dig Eval & HSW Lab Data.zip	Included spreadsheets "co-dig eval" on sludge and HSW loading, concentration, VS contents, digester gas production and use, electrical production and use for years 2014 to 2016. Also included lab data on HSW "HSW Lab Data Report".	Loading data was used to set the historical mass loading and to develop mass balances for the facility using annual average loadings. The information for digester gas usage allowed the proportions of gas split to be determined on an annual basis.
2014 to 2016 Sludge Analysis.zip	Included spreadsheet on the "dried biosolids analysis" for 2015 and 2016 and on the "liquid sludge analysis" for 2014 to 2016. Information mainly included concentrations of metals, nutrients, solids and pathogens.	Provides total solids data for thickened and dried biosolids.
2014 to 2016 Biosolids Loadout.zip	Included spreadsheets on the "dried biosolids loadout" for 2014 to 2016 which included the mass of dried sludge hauled offsite and "land application" for 2014 to 2016 which included the volume of digested thickened solids that were hauled and land applied offsite.	Used for validation in mass balance and to better understand the flow split for thickened sludge land application and dewatering / drying.
2014-2016 Receiving Stations.zip	Included spreadsheets for the "Receiving Station" for wastes received onsite and feed to the headworks.	Not used in this analysis.

Sheboygan WWTP Energy Charges 2014 – 2016.xls	Summarizes monthly and annual electricity consumption for all of Sheboygan's facility.	Used to determine total plant electricity consumption and ratio of electricity produced onsite to total electrical consumption.
HauledWasteRates 2014-2016	Unit cost tipping fees for the HSW received onsite.	Not directly used in the analysis
Copy of WWTP 12 month Avg cost per KWH 2007 – 2016.xlsx	Provides historical electrical unit costs ($/kWh)	Used for electrical unit cost assumptions.
Copy of WWTP KWH-summary DHB.xlsx	Provides the electrical consumption and total costs for electricity consumption at Sheboygan's facilities.	Used to determine total plant electricity consumption and ratio of electricity produced onsite to total electrical consumption.
Copy of WWTP THRMS-summary DHB.xlsx	Provides natural gas consumption (in Therms) and natural gas costs.	Used to calibrate heat balance to determine how much import natural gas was needed. Also used to estimate unit costs for natural gas ($/therm).
Copy of Wastewater_2008_2016 DHB.xlsx	Provides O&M costs for Sheboygan's facilities.	Not directly used in analysis.
HSW go or no go.xls (2 versions provided)	Provides O&M costs for the existing microturbines.	Used the more detailed version for the O&M estimates in the operating and lifecycle cost analysis.
HSW Analysis 2013-2015.xlsx	Provides some data on HSW characterization.	Not directly use in this analysis.
Sheb BTU-Digester Gas 2014-2016	Provides daily heat outputs (in BTU) from the 30 kW microturbines, 200 kW microturbines and digester gas boiler.	Used to establish baseline for energy inputs into the plant heating loop.
Polymer Cost 2014-2016.xlsx	Provides annual polymer consumption and costs for 2014 to 2016.	Not directly used in analysis since polymer unit consumption ratios (lb sludge per DT active polymer dosage) and unit polymer costs were provided separately.

High Strength Waste 2010-2016.xlsx	Provides the breakdown by volume and cost for HSW received at Sheboygan.	Used to develop current average HSW receiving fee and to understand the ratio of HSW sources.
Dryer PM 2015-2017 Steve Corrected 170316.xls	Provides corrected electrical consumption records for the dewatering and drying building.	Used to estimate dryer electrical energy consumption factor (kW/lb H2O evap).

Appendix B Data Analysis

		Baseline HSW Receiving	Eliminate HSW Receiving	Cost Effective HSW Receiving	Units	
Primary + WAS	Mass Load	17,800	17,800	17,800	lb/d	
	Volatile Solids	74%	74%	74%	VS/TS	
	Total Solids	3.3%	3.3%	3.3%	TS	
	Volumetric Loading	64,400	64,400	64,400	gpd	
HSW	Mass Load	32,900		16,450	lb/d	
	Volatile Solids	81%		81%	VS/TS	
	Total Solids	8.9%		8.9%	TS	
	Volumetric Loading	44,300		22,100	gpd	
Digester Feed	Mass Load	50,700	17,800	34,250	lb/d	
	Volatile Solids	78%	74%	77%	VS/TS	
	Total Solids	5.6%	3.3%	4.7%	TS	
	Volumetric Loading	108,700	64,400	86,600	gpd	
Digester Performance	Primary+WAS VSR	45%	45%	45%		
	Primary+WAS Gas Production	18	18	18	ft^3/lb VSR	
	HSW VSR	62%	62%	62%		
	HSW Gas Production	22	22	22	ft^3/lb VSR	
	Total Volatiles Removed	22,420	5,890	14,150	lb VS/d	
	Total VSR	56%	45%	54%		
	Total Gas Production	470,000	106,000	288,000	ft^3/day	
Thickening	Mass to Thickener	30,100	17,800	24,000	lb/d	Accounts for recuperative thickening
	Thickened Solids	6.2%	6.2%	6.2%	TS	Based on Historical Records
	Thickening Capture Rate	91%	91%	91%		
	Polymer Consumption	4.4	4.4	4.4	lb/DT active	
	Active Polymer Consumption	66.2	39.2	52.8	lb/d	
Digested Sludge to Aquastore	Mass Load	25,600	10,300	18,000	lb/d	Accounts for recuperative thickening and 91% recovery
	Volatile Solids	61%	61%	61%		
	Volumetric Loading	49,500	19,900	34,800	gpd	
	Aquastore Volume	4	4	4	million gal	
	Storage Days	81	201	115	days	
Sludge to Dewatering and Drying	Amount to Dewatering/Drying	50%	50%	50%		
	To Dewatering	12,800	5,200	9,000	lb/d	
		2,300	900	1,600	DT/yr	
	To Dewatering	2,300	900	1,600	DT/yr	
	Dewatered Solids	22%	22%	22%		Target with new screw press
	Dewatering Capture Rate	95%	95%	95%		
	Polymer Consumption	38	38	38	lb/DT active	
	Active Polymer Consumption	43.7	17.1	30.4	lb/d	
	Dry Solid Content	92%	92%	92%		
	Evaporative Load	7,600	3,000	5,300	ton H2O/yr	

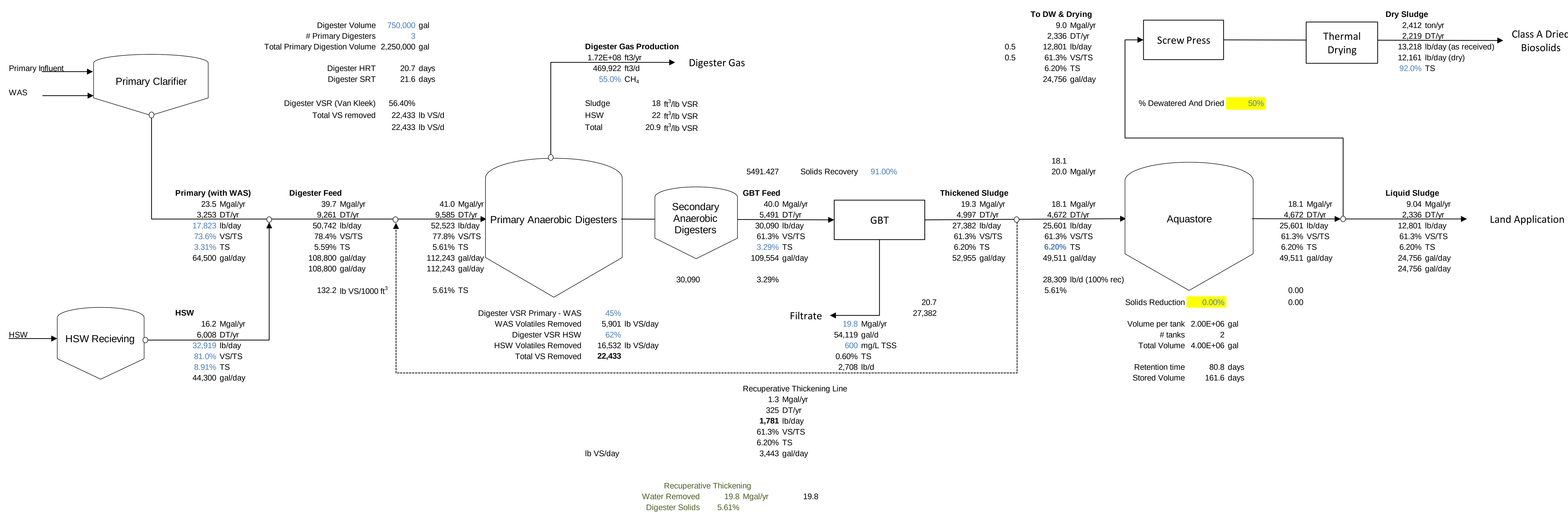
	Baseline HSW Receiving	Eliminate HSW Receiving	Cost Effective HSW Receiving		
Energy Content in Biogas	943,500	212,800	578,200	Therms/yr	
Electricty from 200 kW MT	8400	3600	8400	kWh/d	3,414 Btu/kWh conversion
200 kW Electrical Efficiency	28%	28%	28%		
Gas to 200 kW MTs	373,800	160,200	373,800	Therms/yr	
% of Total Biogas to 200 kW M	39.6%	75.3%	64.6%		
Electricty from 30 kW MT	5500		1200	kWh/d	
30 kW Electrical Efficiency	21%		21%		
Gas to 30 kW MTs	326,400		71,200	Therms/yr	
% of Total Biogas to 30 kW MT	34.6%		12.3%		
Total Biogas to MTs	74.2%	75.3%	77.0%		
Sludge Boiler	160,000	34,200	85,400	Therms/yr	
Sludge Boiler Efficiency	80.0%	80.0%	80.0%		
Gas to Boiler	200,000	42,800	106,700	Therms/yr	
Gas Flared	43,300	9,800	26,500	Therms/yr	
% Gas Flared	5%	5%	5%		
Energy Input Baseline	275,000	275,000	275,000	Therms/yr	
Digester Heating Savings		-40,400	-20,200	Therms/yr	Savings from not heating HSW
Dryer Heating Savings		-128,800	-64,400	Therms/yr	
Total Energy Input	275,000	105,800	190,400	Therms/yr	
200 MT Heat Efficiency	6.5%	6.5%	6.5%		Based on Plant Records
30 MT Heat Efficiency	6.2%	6.2%	6.2%		Based on Plant Records
Heat from 200 kW MTs	24,300	10,400	24,300	Therms/yr	
Heat from 30 kW MTs	20,200	0	4,400	Therms/yr	
Heat from Sludge Boiler	160,000	34,200	85,400	Therms/yr	
Digester Boiler Input	70,500	61,200	76,300	Therms/yr	
Digester Boiler Efficiency	85%	85%	85%		
Natural Gas Input	82,900	72,000	89,800	Therms/yr	

Alternative 1 (Keep same level of HSW) Mass Balance at Average Conditions

SRT equation from M&E

$$\text{SRT} = \frac{VX}{(Q - Q_w)X_e + Q_w X_R}$$

Solids Recovery (Estimated) 95%



From Email from Sharon

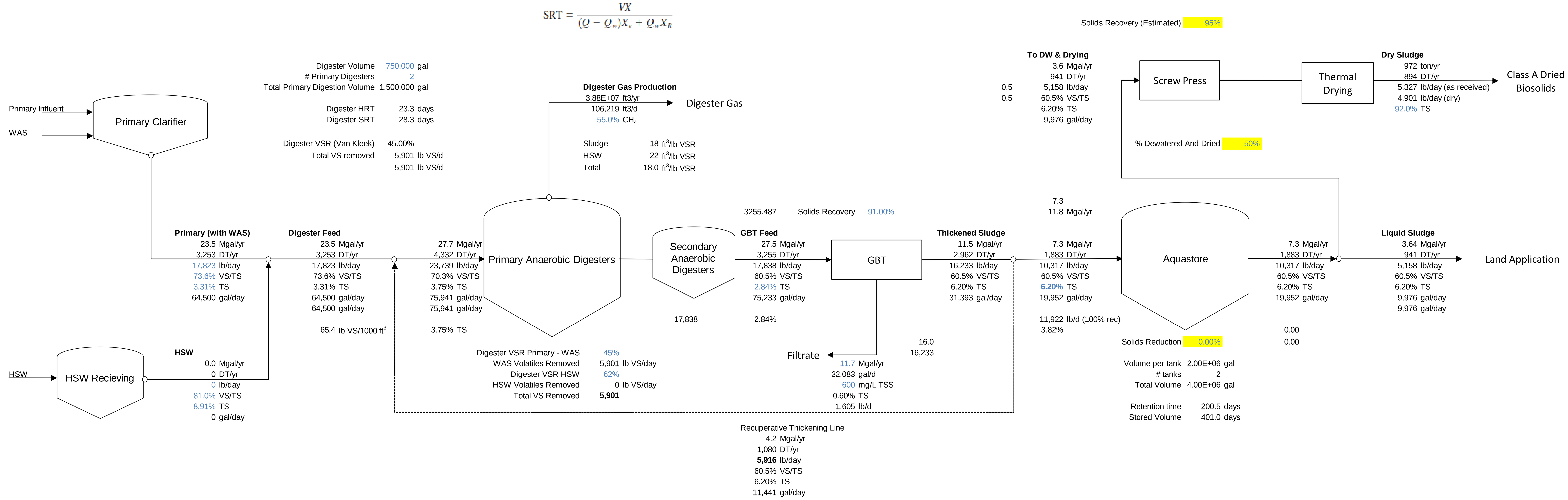
- Recuperative Thickening: The total annual volume of water removed via recuperative thickening is below.
  - 2014 18.0MG
  - 2015 22.65MG
  - 2016 18.61MG

18	Mgal
22.65	Mgal
18.61	Mgal
19.8	

Alternative 2 (No HSW) Mass Balance at Average Conditions

SRT equation from M&E

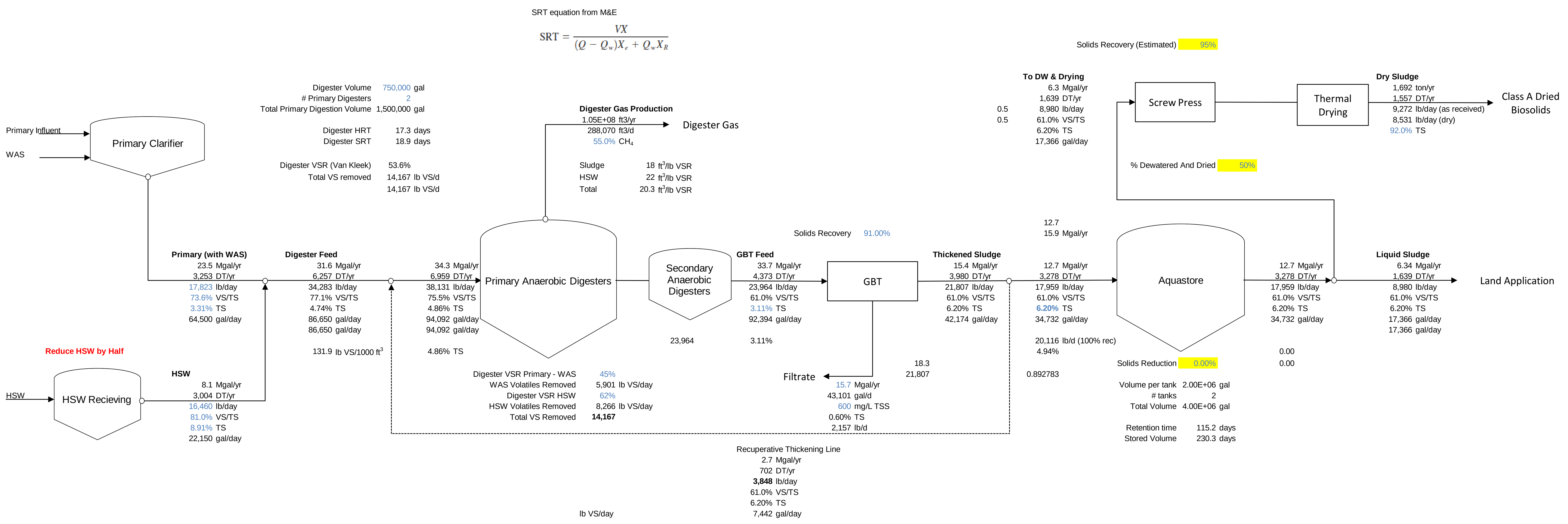
$$\text{SRT} = \frac{VX}{(Q - Q_w)X_e + Q_w X_R}$$



From Email from Sharon

- Recuperative Thickening: The total annual volume of water removed via recuperative thickening is below.
  - 2014 18.0MG
  - 2015 22.65MG
  - 2016 18.61MG

Alternative 3 (Cost Effective: Reduce HSW to avoid a new digester) Mass Balance at Average Conditions



From Email from Sharon

- Recuperative Thickening: The total annual volume of water removed via recuperative thickening is below.
  - 2014 18.0MG
  - 2015 22.65MG
  - 2016 18.61MG

Appendix C Cost Model

Appendix C
Cost Model

Process Impacts									
	Baseline Alternative			**Eliminate HSW Alternative**			**Refined HSW Receiving Alternative**		
HSW Load	44,300 gal/day			0 gal/day			22,100 gal/day		
Digester VSR and Digester Gas Production	56%		470,000 CF/d	45%		106,000 CF/d	54%		288,000 CF/d
200 kW Microturbine Electrical Production	8400	kWh/d		3600	kWh/d		8400	kWh/d	
30 kW Microturbine Electrical Production	5500	kWh/d					1200	kWh/d	
Digester Heating Requirements	1.3	MMBtu/h	Sludge & HSW	0.8	MMBtu/h	Sludge Only	1.1	MMBtu/h	Sludge & HSW
Digester Electrical Requirement	20.7	kWh/Mgal	Est. from other projects	20.7	kWh/Mgal	Est. from other projects	20.7	kWh/Mgal	Est. from other projects
Digester Volume per Digester	0.75	Mgal		0.75	Mgal		0.75	Mgal	
Active Digesters in Service	4			3			3		
Natural Gas Used	82,900	Therms/yr		72,000	Therms/yr		89,800	Therms/yr	
Solids to Thickening	30,100	lb/d	w/ recup thickening	17,800	lb/d	w/ recup thickening	24,000	lb/d	w/ recup thickening
Thickening Energy Consumption	1.0	kW/DT	estimated	1.0	kW/DT	estimated	1.0	kW/DT	estimated
Polymer Required for Thickening	4.4	lb/DT active	44% Active	4.4	lb/DT active	44% Active	4.4	lb/DT active	44% Active
Solids to Aquastore	50,000	gpd		20,000	gpd		35,000	gpd	
Aquastore Tank Capacity	4 Mgal		80.0 days	4 Mgal		200.0 days	4 Mgal		114.3 days
Solids to LA vs. Dewatering & Drying	50%			50%			50%		
Solids to Dewatering & Drying	12,800	lb/d		5,200	lb/d		9,000	lb/d	
Polymer Required for Dewatering	38.0	lb/DT active	44% Active	38.0	lb/DT active	44% Active	38.0	lb/DT active	44% Active
Dewatering Energy Consumption	10.0	kW/DT	Huber Factor	10.0	kW/DT	Huber Factor	10.0	kW/DT	Huber Factor
Dewatered Total Solids	22%	TS		22%	TS		22%	TS	
Dry Total Solids	92%	TS		92%	TS		92%	TS	
Evaporative Load	7,600	ton/yr		3,000	ton/yr		5,300	ton/yr	
Dryer Electrical Energy Efficiency	0.037	kW/lb H2O evap	Est. from Historical Data	0.037	kW/lb H2O evap	Est. from Historical Data	0.037	kW/lb H2O evap	Est. from Historical Data
Class B liquid biosolids to land application	25,000	gpd		10,000	gpd		17,500	gpd	
Class A Biosolids beneficially used	2,412	ton/yr		980	ton/yr		1,696	ton/yr	

Cost Impacts									
	Baseline Alternative			**Eliminate HSW Alternative**			**Refined HSW Receiving Alternative**		
	Capital Costs	Annual O&M Expenses		Capital Costs	Annual O&M Expenses		Capital Costs	Annual O&M Expenses	
		hr/wk	$/year		hr/wk	$/year		hr/wk	$/year
Receiving Station	$1,800,000			$0			$1,800,000		
Operating Labor Expenses		7	$15,142		0	$0		7	$15,142
Maintenance Labor Expenses		1	$2,163		0	$0		1	$2,163
Electrical Expenses									
Digester Upgrades	$1,600,000			$430,000			$430,000		
Operating Labor Expenses			$0			$0			$0
Maintenance Labor Expenses			$0			$0			$0
Electrical Expenses			$54,400			$40,800			$40,800
Thickening	$0			$0			$0		
Operating Labor Expenses		7	$15,142		4.1	$8,955		5.6	$12,074
Maintenance Labor Expenses			$0			$0			$0
Electrical Expenses			$549			$325			$438
Polymer			$44,451			$26,287			$35,443
Microturbines	$1,000,000			$0			$200,000		
Total Expenses			$47,748			$47,748			$47,748
Oil & Media - 30kW			$10,092						$2,018
Maintenance Labor Expenses - 30kW		3	$6,573						$1,315
Oil & Media - 200kW			$9,426			$9,426			$9,426
Maintenance Labor Expenses - 200kW		3	$5,450		3	$5,450		3	$5,450
Electrical Production(negative cost)			**($507,350)**			**($131,400)**			**($350,400)**
Natural Gas Requirements			$37,305			$32,400			$40,410
Sludge Dewatering	$0			$0			$0		
Operating Labor Expenses		7	$15,142		2.8	$6,152		4.9	$10,647
Maintenance Labor Expenses			$0			$0			$0
Electrical Expenses			$2,336			$949			$1,643
Polymer			$163,251			$66,321			$114,786
Sludge Drying	$0			$0			$0		
Operating Labor Expenses		10.5	$22,714		4.3	$9,227		7.4	$15,971
Maintenance Labor Expenses			$0			$0			$0
Electrical Expenses			$56,240			$22,200			$39,220
HSW Tipping Fee Revenue (negative cost)			**($48,509)**			**$0**			**($24,200)**
Class B Liquid Land Application Expense			$273,750			$109,500			$191,625
Class A Dried Biosolids Application Revenue			**($24,122)**			**($9,799)**			**($16,961)**
TOTAL	$4,400,000	38	$201,895	$430,000	14	$244,539	$2,430,000	28	$194,757
Net Present Value	$4,400,000		$1,637,547	$430,000		$1,983,430	$2,430,000		$1,579,657
Total Net Present Value (capital & operating)	**$6,037,547**			**$2,413,430**			**$4,009,657**		

Cost Model Common Inputs

Life of projects (years)	10	
Interest Rate (as decimal)	0.04	
Net Present Value Factor for Annual Costs	8.1109	
Electrical cost ($/kw-hr)	$0.10	Based on 2016 plant records
Natural gas cost ($/therm)	$0.45	Based on 2016 plant records
Polymer cost ($/lb)	$0.80	Per Sharon 03-23-17
Labor cost ($/hr)	$42	Per Sharon 02-27-17, raw labor is $26/hr. 60% added in to cover benefits.
HSW tipping fee revenue ($/gal)	$0.0030	
Liquid land application cost ($/gal)	$0.03	per Sharon 02-27-17 email
Dried biosolids application revenue ($/dry ton)	$10	per Sharon 02-27-17 email, revenue starts in 3rd year

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CITY OF SHEBOYGAN

REQUEST FOR PUBLIC WORKS COMMITTEE CONSIDERATION

ITEM DESCRIPTION: Report of Officer by Director of Public Works. Referencing the Report on the Co-Digestion Evaluation at the Wastewater Treatment Plant. Sheboygan has accepted high strength waste (HSW) for years in order to co-digest with the plant's sludge to increase digester gas production. The use of the increased volume of digester gas, primarily to make electricity, resulted in significant cost savings and occasional production of electricity in excess of the treatment plant's electricity demand. The combination of aging facilities, reduced tipping fees for the HSW, and digester capacity limitations resulted in questions regarding the cost-effectiveness of retaining acceptance of HSW

REPORT PREPARED BY: David H. Biebel, Director of Public Works

REPORT DATE: July 20, 2017 **MEETING DATE:** July 25, 2017

FISCAL SUMMARY:

Budget Line Item: 60138300

Budget Summary: N/A
Budgeted Expenditure: N/A
Budgeted Revenue: N/A

STATUTORY REFERENCE:

Wisconsin Statutes: N/A
Municipal Code: N/A

BACKGROUND / ANALYSIS:

A substantial amount of data was received from the Sheboygan wastewater plant regarding sludge production, digester gas production, digester gas utilization, system operations, and operating costs. This data was analyzed for current and future conditions to evaluate three options of continuing to receive current volumes of HSW, eliminate receipt of HSW, or to reduce the volume of HSW received.

The analysis determined that the lowest net present value cost was to eliminate the receipt of HSW. However, several current systems would be underutilized should no HSW be received. Also, current tipping fees are significantly less than those charged previously. Selective receipt of HSW with appropriate tipping fees has the potential to allow continuing to receive HSW worthwhile.

A more detailed analysis of the potential HSW streams, tipping fees, and limited capital improvements along with sensitivity of process performance and unit costs could identify a more cost-effective HSW receiving program.

STAFF COMMENTS:

The purpose of the evaluation was to determine the overall cost effectiveness of the current co-digestion (high strength waste) program. The WWTP has several capital improvements projects on the horizon along with the high strength waste program requirements. In order to determine the priority of capital improvements at the WWTP this evaluation was necessary to determine the future continuance of the program.

The City of Sheboygan wastewater facility has been a leader nationwide in the development of co-digestion and associated energy production. It was one of the first facilities in North America to achieve net zero energy, meaning it was often able to produce more electricity through its micro turbine system than required to operate the treatment plant. Recently, more treatment plants have added the ability to accept and co-digest high strength wastes. This has increased competition for the higher quality wastes and lowered tipping fees that treatment plants receive for accepting wastes. Sheboygan has seen a significant drop in tipping fees for high strength wastes (HSW), causing this revenue source to decrease.

The City of Sheboygan and the WWTP was fortunate to have existing abandoned infrastructure to be repurposed for Co-Digestion and received over $1 million in equipment to start-up. This allowed the City to receive many benefits of lower energy costs but unfortunately resulted in some major side effects. In order, for the City to continue with the program significant capital improvements over $2 million within the next few years. Given other critical capital improvement needs it is the department's recommendation to suspend the program for now, and consider refining the program when financing terms become more favorable.

ACTION REQUESTED:
Motion to Accept and Adopt the Report Findings to eliminate the Co-Digestion (High Strength Waste) Program.

ATTACHMENTS:

I. Co-Digestion Evaluation.

II

4.10

R. O. No. 99 - 17 - 18. By DIRECTOR OF PUBLIC WORKS. July 17, 2017.

Submitting the Co-Digestion Evaluation for the City of Sheboygan Wastewater Treatment Plant, Project Number 60532058, dated June 27, 2017.

Pub Wks.

Director of Public Works

AECOM

Co-Digestion Evaluation

City of Sheboygan - Wastewater Treatment Plant

Project Number: 60532058

June 27, 2017

Quality information

Prepared by	Checked by	Approved by
Rusty Schroedel	Ralph Eschborn	Tom Holtan

Revision History

Revision	Revision date	Details	Authorized	Name	Position

Distribution List

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Prepared for:

City of Sheboygan - Wastewater Treatment Plant

Prepared by:

AECOM
1555 RiverCenter Drive
Milwaukee, WI 53212

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Figures

Tables

1. Executive Summary

Sheboygan has accepted high strength waste (HSW) for years in order to co-digest with the plant's sludge to increase digester gas production. The use of the increased volume of digester gas, primarily to make electricity, resulted in significant cost savings and occasional production of electricity in excess of the treatment plant's electricity demand. The combination of aging facilities, reduced tipping fees for the HSW, and digester capacity limitations resulted in questions regarding the cost-effectiveness of retaining acceptance of HSW.

A substantial amount of data was received from the Sheboygan wastewater plant regarding sludge production, digester gas production, digester gas utilization, system operations, and operating costs. This data was analyzed for current and future conditions to evaluate three options of continuing to receive current volumes of HSW, eliminate receipt of HSW, or to reduce the volume of HSW received.

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A more detailed analysis of the potential HSW streams, tipping fees, and limited capital improvements along with sensitivity of process performance and unit costs could identify a more cost-effective HSW receiving program.

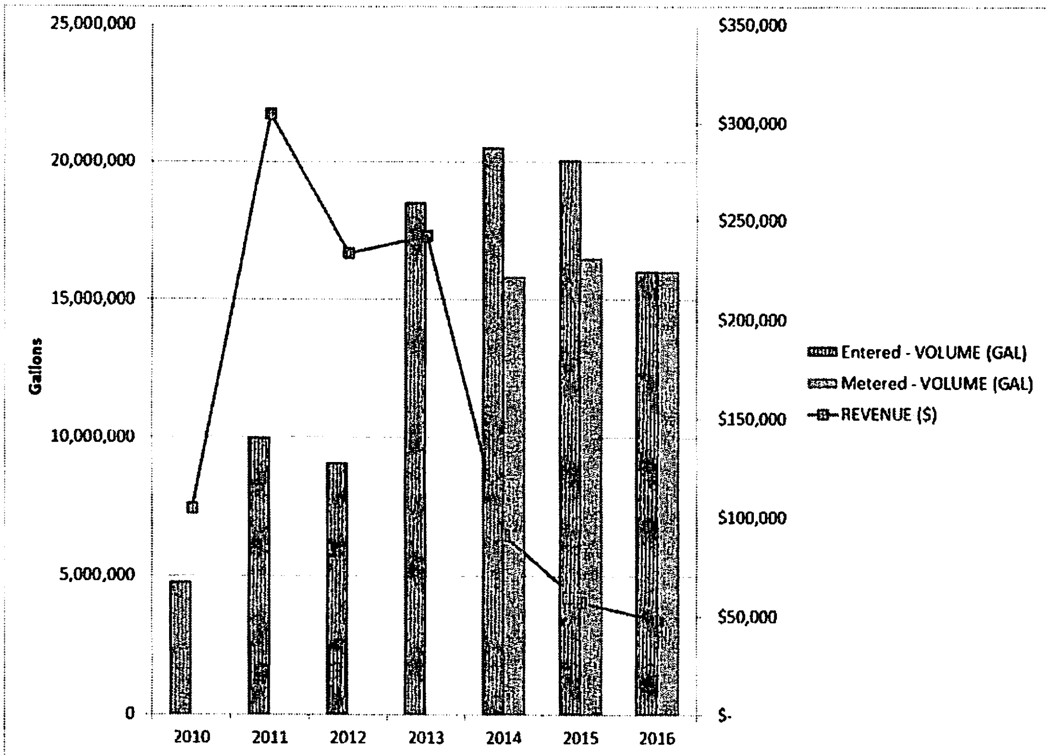
2. Introduction

The City of Sheboygan wastewater facility has been a leader nationwide in the development of co-digestion and associated energy production. It was one of the first facilities in North America to achieve net zero energy, meaning it was often able to produce more electricity through its microturbine system than required to operate the treatment plant. Recently, more treatment plants have added the ability to accept and co-digest high strength wastes. This has increased competition for the higher quality wastes and lowered tipping fees that treatment plants receive for accepting wastes. Sheboygan has seen a significant drop in tipping fees for high strength wastes (HSW), causing this revenue source to decrease as summarized in **Figure 2-1**. Sheboygan currently receives tipping fees ranging from $0 to $0.04 per gallon.

Several portions of the co-digestion system, such as the digester that is used as a receiving tank and several of the microturbines are in need of repair or replacement. A capital improvements plan has been prepared for the wastewater facility and the co-digestion system. Related to this analysis, the Facility Plan recommended the following capital upgrades (Wastewater Treatment Facilities Plan, Draft Report, January 2017):

- Rehabilitate HSW receiving - $1,814,000
- Conversion of D6 from a secondary digester to a fourth primary digester - $1,548,000
- Replace the 30 kW turbines in 5 years - $1,000,000
- Replace the 200 kW turbine in 10 years - $1,000,000

Figure 2-1: High Strength Waste Volume and Revenue 2010 to 2016



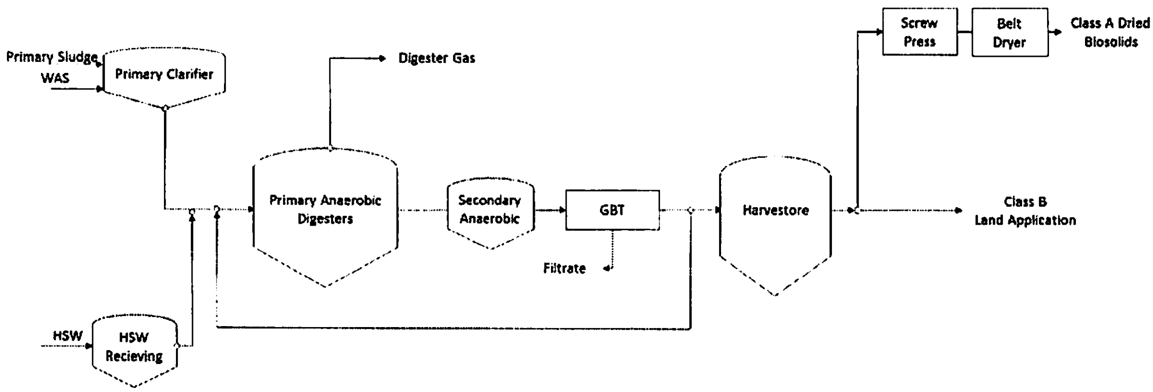
Sheboygan desires an independent review of the co-digestion system economics, including a review of the capital plan, while considering the impacts of reduced revenue from high strength wastes. The City needs to prioritize various capital improvements and determine if it makes financial sense to make significant capital improvements to the high strength waste and co-digestion system.

This report summarizes the review of the alternatives, data analysis, development of a cost model, and provides conclusions and recommendations regarding the future of co-digestion at the Sheboygan Wastewater Treatment Plant.

3. Review of Alternatives

Sheboygan currently co-settles the primary sludge and waste activated sludge (WAS) in the primary clarifiers. HSW is received and stored in old digesters in the West Digestion Complex. The co-settled sludge and HSW are currently digested in three (3) 750,000 gallon primary digesters in the East Digestion Complex before being directed to a secondary digester. The digested sludge is then thickened to approximately 6% total solids (TS) using gravity belt thickeners and a portion of the thickened sludge is recycled to the primary digesters to provide some recuperative thickening. The thickened sludge not recycled is directed to two (2) 2 million gallon Harvestore tanks which provide several months of sludge storage as 180 days of sludge storage is required during wintertime operation when land application is not allowed. Currently about half of the digested sludge is dewatered using screw presses and dried in a belt dryer and the dried biosolids is distributed as a Class A product. The remainder of the biosolids is land applied as a Class B liquid sludge. A process flow diagram of Sheboygan's sludge processing system is provided in **Figure 3-1.**

Figure 3-1: Sheboygan, WI Sludge Process Flow Diagram



Three alternatives were identified during project definition and scoping. They are:

- Baseline or current conditions: Continue to receive high strength wastes at existing volumes and from existing sources. The improvements recommended in the capital improvement plan are included.
- Eliminate high strength waste receiving. This would still allow for production and use of digester gas from municipal wastewater discharged to the plant.
- Continue to receive high strength wastes. Define the appropriate or limited improvements that should be made to the system.

4. Data Analysis

A significant volume of detailed plant records were provided to the team regarding sludge systems performance and operational considerations. Appendix A provides a list of that information. The historical records were used to prepare a mass and energy balance that is the basis for the analysis in this evaluation. Selected spreadsheets used for the analysis are included in Appendix B.

4.1 Historical Loading Data

To set a baseline for the three alternatives, three years of operational data were analyzed from 2014 to 2016. The total sludge and HSW feed to the digesters is summarized in **Table 4-1** and **Figure 4-1**. The data shows fairly consistent feed throughout the three years analyzed. The data also showed that the maximum 30 day peaking factor ranged from 1.2 to 1.4 for this period for both the sludge and HSW (data not shown). The volatile solids (VS) content of the sludge and HSW feed and digested sludge is summarized in **Table 4-2** along with digester gas production. For the HSW, total solids and volatile solids were not measured until 2016. Also digested sludge VS sampling was conducted more regularly in 2016 with 52 samples collected compared to 8 in 2014 and 13 and 2015. The more comprehensive sampling of HSW and digested sludge occurred starting in August 2016. The average annual gas production increased during the three years as noted in **Table 4-2** and **Figure 4-2**. In 2016, gas measured 55% methane which is a little lower than the 60-65% estimated for sludge (M&E 5th Edition) and the difference is likely due to differences in co-digestion feedstocks. Based on the plant records, greater than 90% of the HSW received (by volume) at Sheboygan since 2010 has been dairy waste and in 2014 to 2016, over 97% (by volume) of the HSW was dairy waste.

Table 4-1: Summary of Three Years of Sludge Production

	Primary + WAS		HSW		Total
Units	gal	% TS	gal	% TS	gal
2014 Avg	67,600	3.6	43,800		111,200
2015 Avg	67,200	3.0	45,300		112,500
2016 Avg	58,800	3.3	43,800	8.9	102,600
3-YR Average	**64,500**	3.3	**44,300**		**108,800**

Figure 4-1: Summary of Three Years of Sludge Production

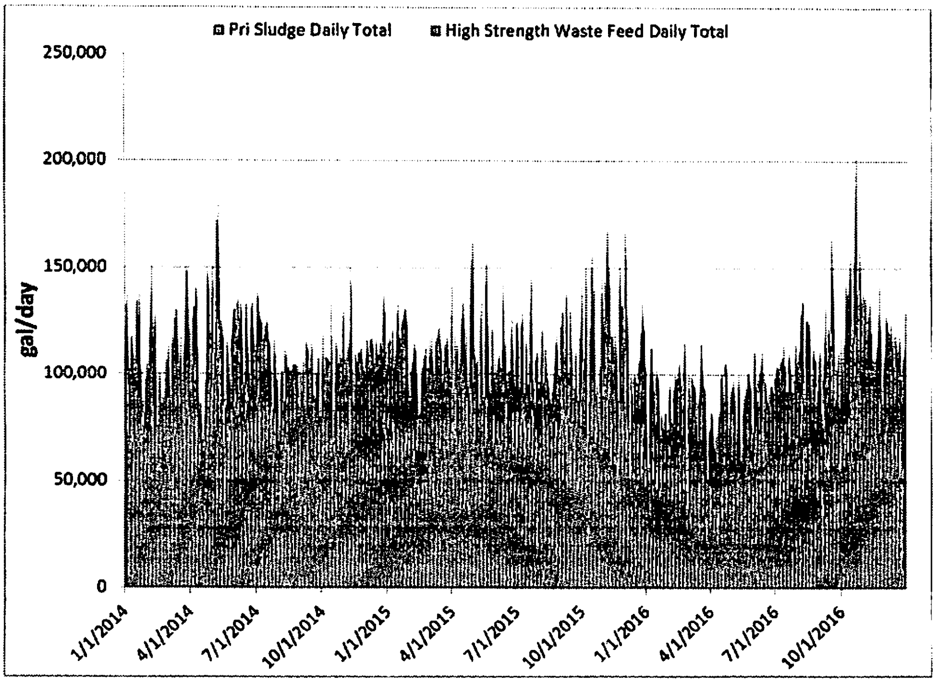
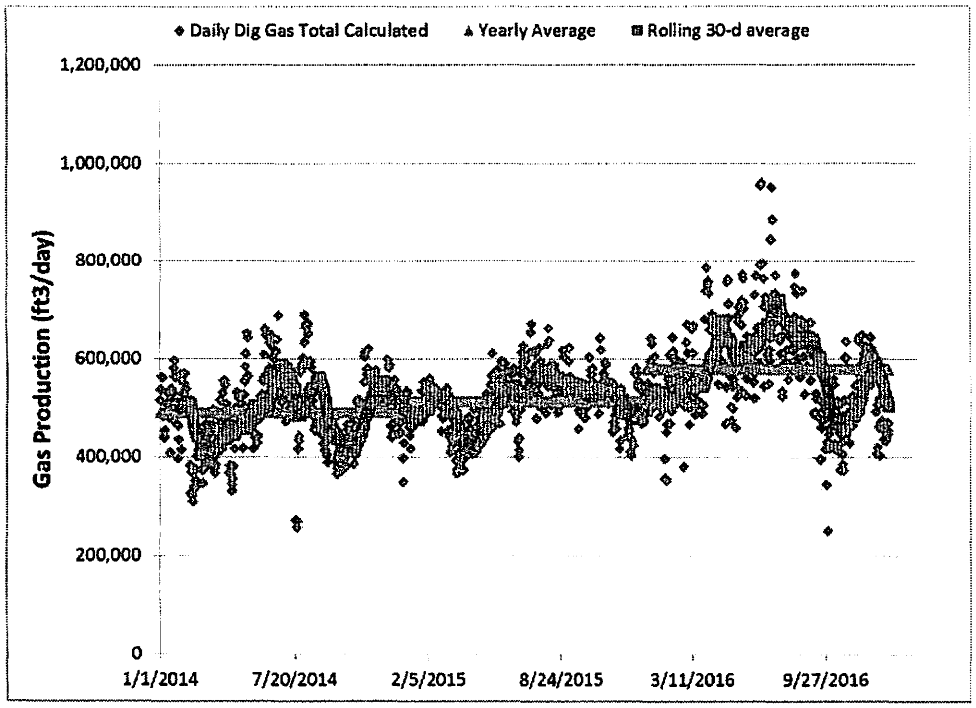


Table 4-2: Summary of Volatile Solids Content and Digester Gas Production

	Primary + WAS (% VS/TS)	HSW (% VS/TS)	Digested (% VS/TS)	**Digester Gas (cu ft/d)**
2014 Avg	71.8		55.3	492,000
2015 Avg	75.6		62.5	514,700
2016 Avg	73.4	81.0	60.7	579,800
3-YR Average	**73.6**		**60.4**	528,800

Figure 4-2: Summary of Digester Gas Production



Since detailed HSW and digested sludge sampling was not regularly monitored until August 2016, a "snapshot" from August to December 2016 was analyzed to set the basis for current anaerobic digester performance and this data is summarized in **Table 4-3**. The digester volatile solids reduction (VSR) performance was estimated using the Van Kleeck equation.

The data showed that overall VSR in the anaerobic digester averaged around 57%, however, it is expected that the VSR performance of the sludge and HSW fractions would be different. Using the VS feed differences in the sludge and HSW in the Van Kleeck equation, it was estimated that the primary and WAS sludge fraction achieved 45% VSR and the HSW fraction achieved 62% VSR. The actual VSR for the different feed streams could vary more than this and it is possible the addition of HSW provides synergistic or possibly even antagonistic impacts on overall VSR. Either way, the VSR assumptions are carried forward into the analysis for the different ratios of sludge to HSW.

The overall gas production of 20.7 cu ft/lb VSR is also higher than typically expected for sludge which ranges from 13 to 18 cu ft/lb VSR (M&E 5th edition). The differences are likely due to the impact of HSW feed into the anaerobic digester. For the mass balance assumptions in this analysis, it is assumed that digestion of the sludge fraction provides 18 cu ft/lb VSR, which corresponds to the highest value in the range expected. To provide an overall gas production of 20.7 cu ft/lb VSR, as shown in **Table 4-3**, the HSW fraction was calculated to provide 22 cu ft/lb VSR. Additional testing could be performed to further refine the impact of co-digestion. Sampling for chemical oxygen demand (COD) in the feedstocks and digested sludge would allow a COD balance to be performed which may allow for a more accurate digestion mass and energy balance to be developed. Also conducting Biochemical Methane Potential (BMP) tests would be another method that could be used to determine the overall digestibility and specific gas production for the feed stocks.

Table 4-3: August to December 2016 Anaerobic Digester Performance Summary

Parameter	Value	Units
Average Primary Volume	69,300	gal
Primary Total Solids	3.2	% TS
Primary Sludge VS	72.6%	% VS/TS
Average HSW Volume	51,300	gal
HSW Total Solids	8.9	% TS
HSW VS	81.0%	% VS/TS
Digester SRT	18.7	days
Average Primary Mass	18,300	lb/d
Average HSW Mass	38,100	lb/d
Total Digester Feed	56,400	lb/d
Total Digester Feed TS	5.61%	% TS
Total Digester Feed VS	78.3%	% VS/TS
Digested Sludge VS	60.9%	% VS/TS
VSR - Van Kleek	56.8%	%
Gas Production	519,000	cu ft/d
Methane Content	56.7	% CH_4
Specific Gas Production	20.7	cu ft/lb VSR

4.2 Historical Gas Usage and Heat Balance

Sheboygan beneficially uses the majority of the digester gas for heat and electricity production. The gas can be directed to two (2) 200 kW microturbines, ten (10) 30 kW microturbines, two (2) sludge boilers or a digester gas boiler. Gas that is not beneficially used is flared. Historical breakdown of digester gas use for 2014 to 2016 is summarized in **Table 4-4**. The data shows that about 60-70% of the produced digester gas is used for electrical production and **Table 4-5** shows that the turbines are able to provide approximately 570 to 600 kW of electricity on average. Since the dryer was brought online in 2014, the microturbines are able to provide 60-70% of the total plants electrical needs. Prior to having the dryer system installed, the microturbines were able to provide nearly all of the plants required electrical needs.

Although the majority of the gas is used for electrical production, less than 20% is directly used for heating in the sludge boilers and 11 to 18% of the gas has historically been flared. It should be noted that the digester gas boiler was not brought online until 2016 and that boiler can use either digester gas or natural gas as the fuel source. The plant also contains two (2) natural gas fired house boilers.

Table 4-4: Digester Gas Use Summary

Year	Sludge Boiler[1]	200 kW Microturbines[1]	30 kW Microturbines[1]	Flare[1]
2014 Avg	18.1%	39.8%	30.5%	11.5%
2015 Avg	20.1%	36.4%	32.2%	11.2%
2016 Avg	14.9%	33.5%	28.8%	17.6%
3-YR Avg	17.6%	36.4%	30.4%	13.7%

1. Based on annual average data for gas volume usage.

Table 4-5: Historical Microturbine Electricity Production

Year	200 kW Turbines			30 kW Turbines			Total Electrical Production	% of Plant Total
Units	kWh/d[1]	kW	Efficiency[2]	kWh/d[1]	kW	Efficiency[2]		
2014 Avg	8,822	368	28.2%	5,422	226	21.1%	594	84.2
2015 Avg	8,367	349	27.8%	5,614	234	21.1%	583	71.9
2016 Avg	8,188	341	26.7%	5,560	232	20.6%	573	63.9
3-YR Avg	8,459	352	27.6%	5,534	231	20.9%		

1. Based on annual average data
2. Estimated based on electrical production and volume of gas estimates using heat value of digester gas was 550 Btu/ft^3

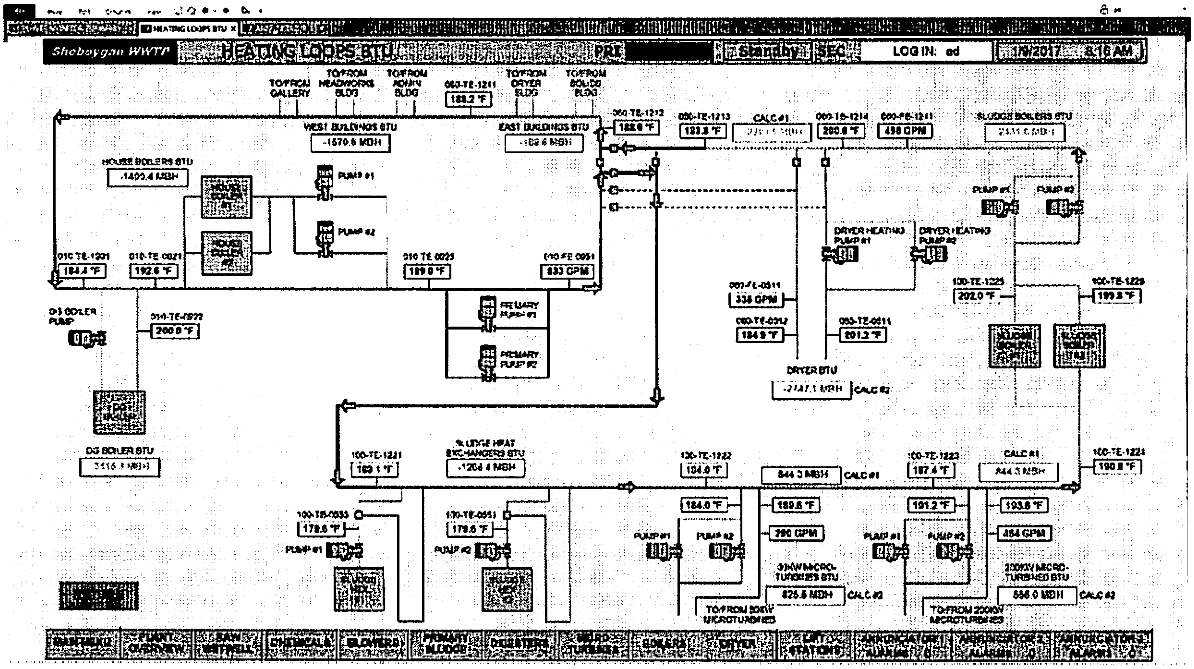
A sophisticated heating loop, shown in **Figure 4-3**, is utilized to meet the plants heating demands for the digester, belt dryer and other plant heating needs (building, tunnels, plant potable hot water, etc.). The heat inputs to the loop come from energy recovery from the microturbines (MT), as well as input from the digester gas fired sludge boilers, natural gas or digester gas fired digester boiler or natural gas fired house boilers. **Table 4-6** provides a summary of the heat inputs into the heating loop from the microturbines and boilers. The total heat input estimated is used to set the total heating baseline for the plant.

Table 4-6: Summary of Heat Inputs into Sludge Heating Loop (Therms/yr)

Year	30 kW MT[1]	200 kW MT[1]	Sludge Boiler[2]	Dig Boiler[1]	House Boiler[3]	Total
2014	18,339	41,249	143,037		28,379	231,004
2015	23,163	23,837	166,507		83,573	297,080
2016	22,244	21,505	135,312	52,565		231,626

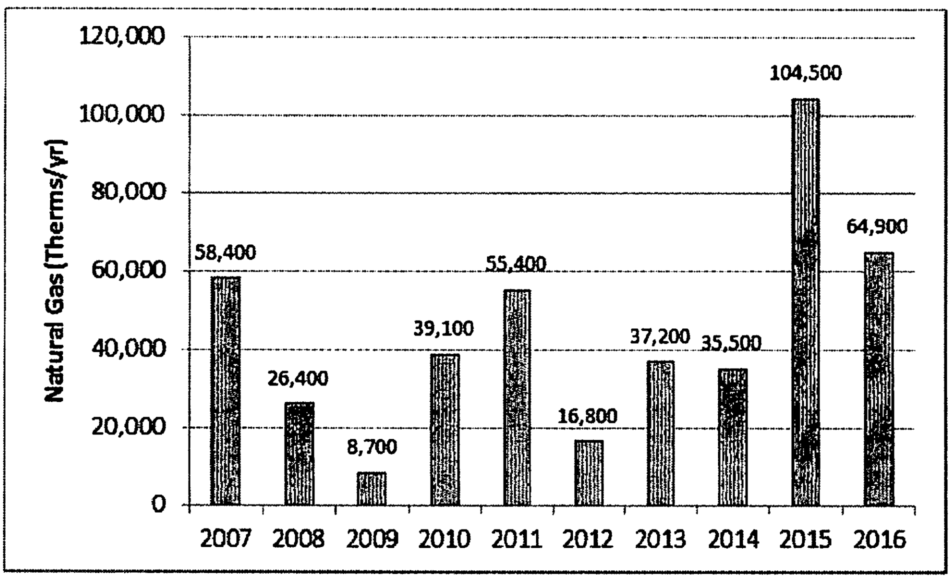
1. Based on annual average data provided
2. Estimated based on average volume of digester gas to boiler assuming a digester gas heat value of 550 Btu/ft^3 and an 80% boiler efficiency
3. Estimated based on natural gas consumption records assuming a 80% boiler efficiency

Figure 4-3: Schematic of the Sheboygan Heating Loop



The total annual natural gas consumption increased after the belt dryer was brought online at the end of 2014 which is evident from the natural gas summary in **Figure 4-4**. In 2014, the natural gas consumption ranged from 64,900 Therms/yr in 2016 up to 104,500 Therms/yr in 2015.

Figure 4-4: Summary of Natural Gas Consumption at Sheboygan



4.3 Basis of Design

The basis of design used for planning was set based on the historical loadings presented in **Table 4-1** and the maximum month conditions were estimated assuming a 1.4 peaking factor for both the sludge and HSW. The facility planning report estimated that the sludge volume in year 2040 would be 6.8% higher than the current production.

4.3.1 Basis of Design – Baseline Condition

The mass and volume load estimates for the baseline conditions (for continuing HSW receiving at the current rate) are presented in **Table 4-7**. The table also assumes that the HSW load would increase proportionally with the plants sludge. **Table 4-7** also presents the digester hydraulic retention time (HRT) estimates with the existing 3 primary digesters and with the 4 total digesters. The Facility Plan recommended converting digester D6 from a secondary digester to a primary digester to increase digestion capacity since their evaluation showed that it was more economical than adding additional mechanical thickening for the primary and WAS feed.

Table 4-7: Basis of Design – Baseline Condition

	Current		2040		
	Average	Max Month	Average	Max Month	
Primary + WAS	17,800	25,100	19,000	26,900	lb/d
	64,500	91,000	68,900	97,200	gpd
HSW	32,900	45,500	35,150	48,600	lb/d
	44,300	61,200	47,300	65,400	gpd
Total	**50,700**	**70,600**	**54,150**	**75,500**	**lb/d**
	108,800	**152,200**	**116,200**	**162,600**	**gpd**
HRT – 3 digesters	20.7	14.8	19.4	13.8	**days**
HRT – 4 digesters	27.6	19.7	25.8	18.5	**days**

It should be noted that with recuperative thickening employed, the SRT would not match the HRT. Historically 18 to 23 million gallons per year of water have been removed by recuperative thickening (3/2/17 e-mail from Sharon Thieszen) so historical average SRT was estimated to be closer to 22 days.

4.3.2 Basis of Design – Eliminate HSW Receiving

One option to consider is eliminating HSW receiving all together. Doing so would allow the existing three primary digesters to have enough capacity throughout the planning period while also providing digester redundancy meaning that two digesters would provide greater than 15 days HRT throughout the planning period with one digester out of service. The design conditions for this option are presented in **Table 4-8.**

Table 4-8 Basis of Design – Eliminate HSW

	Current		2040		
	Average	Max Month	Average	Max Month	
Primary + WAS	17,800	25,100	19,000	26,900	lb/d
	64,500	91,000	68,900	97,200	gpd
HRT – 3 digesters	34.9	24.7	32.7	23.1	**days**
HRT – 2 digesters	23.3	16.5	21.8	15.4	**days**

4.3.3 Basis of Design – Refined HSW Receiving

Another option, which may be more cost effective for Sheboygan, in terms of capital expenditures, would be to reduce the amount of HSW received to the point that would defer or eliminate the need to convert the D6 digester to a primary digester. For this analysis, it was assumed that the amount of HSW received would be reduced by 50%. **Table 4-9** summarizes the design criteria for this which shows that if HSW receiving is cut in half, greater than 17 days of HRT can be maintained in the existing three primary digesters. This condition may not provide full redundancy to provide greater than 15 days of HRT at maximum month conditions if one of the primary digesters was out of service, however, with increased recuperative thickening, the SRT could be maintained at or above 15 days SRT.

Table 4-9: Basis of Design – Reduce HSW Receiving by 50%

	Current		2040		
	Average	Max Month	Average	Max Month	
Primary + WAS	17,800	25,100	19,000	26,900	lb/d
	64,500	91,000	68,900	97,200	gpd
HSW	16,500	22,700	17,600	24,300	lb/d
	22,150	30,600	23,700	32,700	gpd
Total	**34,300**	**47,800**	**36,600**	**51,100**	**lb/d**
	86,650	121,600	92,600	129,900	**gpd**
HRT – 3 digesters	26.0	18.5	24.3	17.3	**days**
HRT – 2 digesters	17.3	12.3	16.2	11.5	**days**

4.4 Alternatives Analysis

Mass and energy balances were prepared for the three different scenarios at current conditions. The outputs from the mass and energy balances were used as the inputs in the cost model discussed in Section 5. **Table 4-10** provides a summary of the digestion, thickening, dewatering and drying mass balances used in this study. From the mass balance, the estimated feed rates to the thickening, dewatering and drying systems were estimated for each scenario. For the purpose of this analysis, it was assumed that 50% of all of the sludge would continue to be thermally dried. However, eliminating or reducing the HSW would provide additional storage capacity in the Harvestore tanks so the need for thermal drying could be reduced or possibly eliminated if HSW receiving is discontinued.

Table 4-10: Sheboygan Alternatives Mass Balance

		Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Primary + WAS	Mass Load	17,800	17,800	17,800	lb/d
	Volatile Solids	74%	74%	74%	VS/TS
	Total Solids	3.3%	3.3%	3.3%	TS
	Volumetric Loading	64,400	64,400	64,400	gpd
HSW	Mass Load	32,900	--	16,450	lb/d
	Volatile Solids	81%	--	81%	VS/TS
	Total Solids	8.9%	--	8.9%	TS
	Volumetric Loading	44,300	--	22,100	gpd

		Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Digester Feed	Mass Load	50,700	17,800	34,250	lb/d
	Volatile Solids	78%	74%	77%	VS/TS
	Total Solids	5.6%	3.3%	4.7%	TS
	Volumetric Loading	108,700	64,400	86,600	gpd
Digester Performance Primary + WAS	VSR	45%	45%	45%	
	Gas Production	18	18	18	cu ft/lb VSR
Digester Performance HSW	VSR	62%	62%	62%	
	Gas Production	22	22	22	cu ft/lb VSR
Total Digester Performance	Total Volatiles Removed	22,420	5,890	14,150	lb VS/d
	Total VSR	56%	45%	54%	
	Total Gas Production	470,000	106,000	288,000	cu ft/day
Thickening	Mass to Thickener[1]	30,100	17,800	24,000	lb/d
	Thickened Solids[2]	6.2%	6.2%	6.2%	TS
	Solids Recovery	91%	91%	91%	
	Active Polymer[3]	4.4	4.4	4.4	lb/DT
	Active Polymer	66.2	39.2	52.8	lb/d
Digested Sludge to Aqua store	Mass Load	25,600	10,300	18,000	lb/d
	Volatile Solids	61%	61%	61%	
	Volumetric Loading	49,500	19,900	34,800	gpd
	Harvestore Volume	4	4	4	MG
	Storage Days	81	201	115	days
Sludge to Dewatering and Drying	Ratio to DW/dry	50%	50%	50%	
	To Dewatering	12,800	5,200	9,000	lb/d
	To Dewatering	2,300	900	1,600	DT/yr
	Dewatered Solids[4]	22%	22%	22%	
	Solids Recovery	95%	95%	95%	
	Active Polymer[3]	38	38	38	lb/DT
	Active Polymer	43.7	17.1	30.4	lb/d
	Dry Solid Content	92%	92%	92%	
	Evaporative Load	7,600	3,000	5,300	ton/y

DT = Dry Ton, MG = Million Gallon

1. Accounts for recuperative thickening estimated based on amounts of water removed. For alternative scenarios, the amount of water removed is assumed to be proportional to the digester feed.
2. Based on historical records.
3. Polymer estimates provided by city staff.
4. Targeted TS with new screw presses.

The mass balance was also used to estimate total gas production for each scenario and the use of the gas is presented in **Table 4-11**. For the baseline scenario, it was assumed that the gas would continue to be used to produce electricity and heat similar to what is summarized in **Table 4-5** and **Table 4-6**. For the case where the HSW is eliminated, the gas production is significantly decreased and it is estimated that only one 200 kW microturbine will be in service for this scenario. For the refined HSW receiving scenario where the HSW input is reduced by 50%, the two 200 kW microturbines and two of the ten 30 kW microturbines are estimated to be in service. For the mass balances presented, the total gas production estimated was less than shown by the historical records, however, the gas uses were still estimated to be the same in terms of electrical and heat production. Using the calculated gas production and historical energy uses lowered the amount of gas being flared down to 5% of the total gas which is reasonable to achieve and reducing flaring would further optimize the system energy balance.

Table 4-11: Digester Gas Use Estimates

	Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Energy Content in Biogas	943,500	212,800	578,200	Therms/yr
Electricity from 200 kW MT	8,400	3,600	8,400	kWh/d
200 kW Electrical Efficiency	28%	28%	28%	
Gas to 200 kW MTs	373,800	160,200	373,800	Therms/yr
% of Total Biogas to 200 kW MT	39.6%	75.3%	64.6%	
Electricity from 30 kW MT	5,500		1,200	kWh/d
30 kW Electrical Efficiency	21%		21%	
Gas to 30 kW MTs	326,400		71,200	Therms/yr
% of Total Biogas to 30 kW MT	34.6%		12.3%	
Total Biogas to MTs	74.2%	75.3%	77.0%	
Sludge Boiler	160,000	34,200	85,400	Therms/yr
Sludge Boiler Efficiency	80.0%	80.0%	80.0%	
Gas to Boiler	200,000	42,800	106,700	Therms/yr
Gas Flared	43,300	9,800	26,500	Therms/yr
% Gas Flared	5%	5%	5%	

The thermal energy requirements at the plant are tied into a sophisticated loop as presented in **Figure 4-3**. The total annual plant heating requirements for the baseline case is based on the information provided in **Table 4-6.** Estimating the heat requirements directly for each scenario would be complicated since the heating needs for the digester and building heating is seasonal and would vary annually. In order to simply this, the savings with respect to the drop in digester heating and reduction in thermal drying were estimated for the two alternative scenarios and it was assumed that the digester heat loss, building and other plant heating needs would be the same for each scenario. The thermal energy requirements are summarized in **Table 4-12.**

Table 4-12: Heat Demand Estimates

	Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Energy Input Baseline	275,000	275,000	275,000	Therms/yr
Digester Heating Savings		-40,400	-20,200	Therms/yr
Dryer Heating Savings		-128,800	-64,400	Therms/yr
Total Energy Input	275,000	105,800	190,400	Therms/yr

As shown in **Figure 4-3**, the heat is supplied to the loop from the microturbines waste heat and the various boilers provided. For the baseline case, it was assumed that the input would be similar to the historical records summarized in **Table 4-6** and that a portion of the heating demand is met with the microturbine waste heat and the digester gas sludge boiler. The remaining heat demands would then be met using natural gas either with the digester gas boiler or house boilers (labeled supplemental boiler input). For the alternative cases, the heat inputs from the microturbine and digester gas fired sludge boilers were estimated based on the gas usages in **Table 4-12**. The shortfall for heating requirements were then calculated to determine how much natural gas would be required for each scenario and the natural gas input is estimated in **Table 4-13**.

Table 4-13: Supply of Heat Demand

	Baseline HSW Receiving	Eliminate HSW Receiving	Refined HSW Receiving	Units
Heat from 200 kW MTs	24,300	10,400	24,300	Therms/yr
Heat from 30 kW MTs	20,200	0	4,400	Therms/yr
Heat from Sludge Boiler	160,000	34,200	85,400	Therms/yr
Supplemental Boiler Input	70,500	61,200	76,300	Therms/yr
Boiler Efficiency	85%	85%	85%	
Natural Gas Input	82,900	72,000	89,800	Therms/yr

5. Cost Model

A cost model was prepared that compares the capital costs, operation and maintenance expenses, and the net present value of the three alternatives. The cost model, which uses an Excel spreadsheet for the calculations, is provided in Appendix C.

There are three major sections to the model:

- Process Impacts
- Cost Impacts
- Cost Model Common Inputs

The process impacts section includes major process related variables for the three alternatives such as electrical production, natural gas use, polymer use, and solids quantities. The electrical consumption estimates are based on both historical records, where available, and estimates used for similar equipment from other projects. The solid quantities, polymer, and natural gas quantities provided are based on the analysis discussed in **Section 4.4.** The process variables are used in the cost impacts section to calculate annual expenses for various line item costs such as electrical production. The cost impacts section shows revenues as negative values. There are three revenue generating line items: electrical production from microturbines, HSW tipping fees, and Class A dried biosolids application. The third major section is cost model common impacts. These items are common variables that are used in all alternatives such as interest rate, electrical unit costs, and polymer costs. Interest rate is the City's cost of borrowing money.

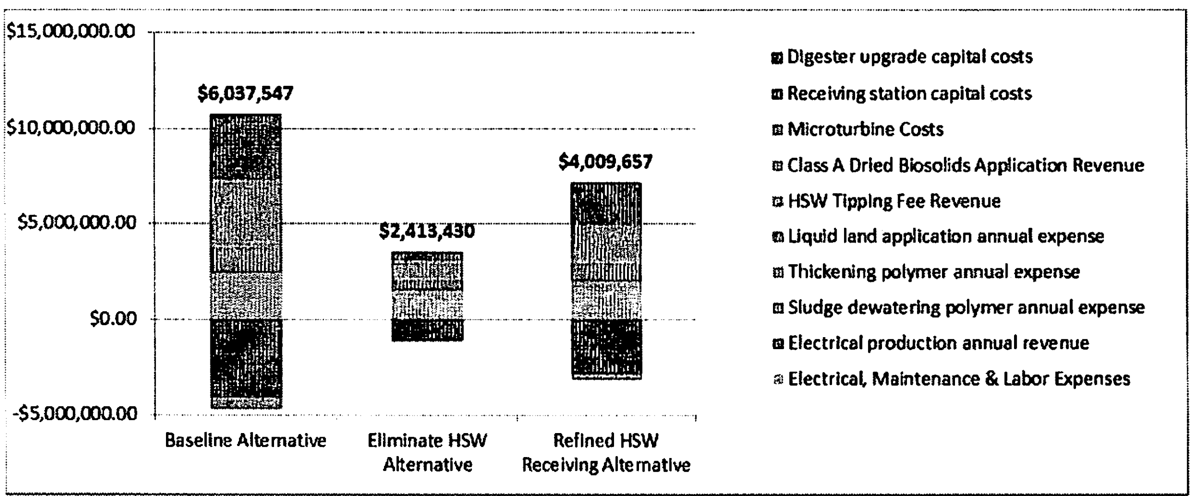
In the cost impacts section, the capital costs are listed as total costs and the analysis includes only the HSW receiving upgrades and digester upgrades. For the scenarios that avoid the conversion of digester D6, the cost amount only includes replacing the digester cover and does not include adding a heating or mixing system. In the cost impacts section, operation and maintenance expenses for the various line items are presented as annual amounts. The annual expenses are summed and the net present value factor is applied to the sum to get a net present value for the annual expenses. This net present value is then added to capital costs to calculate a total net present value for each alternative. Values for some cost line items such as maintenance labor were not included. It is difficult to estimate an accurate value for annual maintenance and the value would be small when compared to the large cost items.

The five largest cost items are highlighted in blue and include:

- Receiving station capital costs
- Digester upgrade capital costs
- Electrical production annual revenue
- Sludge dewatering polymer annual expense
- Liquid land application annual expense

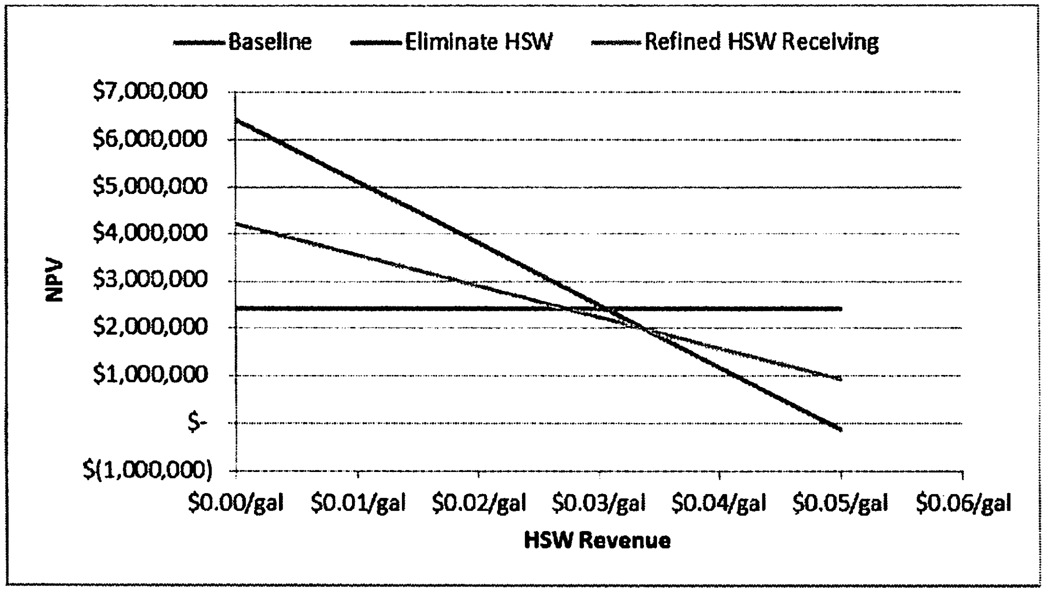
These five items essentially control the outcome of the net present value analysis. Other cost items have a minor impact. A graphical summary of the net present value evaluation is provided in **Figure 5-1**. The "eliminate HSW alternative" has the lowest net present value based on the assumptions used in this analysis.

Figure 5-1: Summary of Net Present Value



As illustrated in **Figure 5-1**, receiving HSW provides the largest ability for Sheboygan to generate revenue; however, the additional revenue does not outweigh the additional capital and operating expenditures associated with receiving HSW. One potential possibility to further increase revenue is to increase the tipping fees for receiving the HSW. As shown in **Figure 2-1**, the revenue from receiving HSW has dropped dramatically over the past several years. In order to better evaluate the impact of receiving HSW, a sensitivity analysis was conducted on the tipping fee revenue on a per gallon received basis and a graphical presentation of this data is provided in **Figure 5-2**.

Figure 5-2: Sensitivity of HSW Receiving Costs



The data presented in **Figure 5-2** shows that if greater than $0.03/gal of revenue can be obtained for receiving HSW (similar to the revenue generated in 2011) then the options with HSW Receiving start becoming favorable from an NPV stand point. Revenue from HSW would need to be about $0.031/gal to make the Baseline Alternative break even with the Eliminate HSW Alternative. Revenue would need to be about $0.0274/gal to make the Refined HSW Receiving Alternative break even with the Eliminate HSW Alternative. It should be noted, however, that if the cost estimates for the digester and HSW system rehabilitation was lower than what is currently listed in the facility plan, the breakeven numbers for HSW revenue would be further reduced.

Future studies could be conducted to look at the sensitivity of other process variables and unit costs on the overall lifecycle cost.

6. Prioritization of Capital Projects

6.1 Facility Plan Report

A report prepared for the City of Sheboygan (Wastewater Treatment Facilities Plan, Draft Report, January 2017) analyzed existing conditions, identified future conditions, evaluated alternatives, and developed a recommended plan. It is beyond the scope of this report to review, analyze, and critique every item recommended in the draft Facilities Plan. The items in the plan that relate to the hauled waste receiving, anaerobic digesters, and digester gas utilization systems and their approximate total project costs are:

- High strength waste receiving and storage improvements – $1,814,000
- Conversion of Digester D6 to a primary digester – $1,548,000
- Replacement of the 30 kW microturbines or increased capacity for these units – Future project – $1,000,000
- Replacement of the 65 kW microturbines – Future project – $1,000,000

6.2 Identify Priorities

A common approach to prioritize wastewater treatment plant improvements and upgrades is to first and foremost emphasize permit compliance and personnel safety. Additional review and analysis of the recommendations in the Facilities Plan is recommended to prioritize the identified capital improvements.

Based on the analysis in this report, other projects can take priority over the above listed improvements. By accepting the option of modifying the existing HSW acceptance program to that which eliminates the need for conversion of Digester D6 to a primary digester and reduces the cost for the high strength waste system improvements to those that relate only to the receiving improvements, can result in a cost savings of approximately $1,200,000.

7. Conclusions

The conclusions of this evaluation are:

1. Elimination of the receipt of high strength waste has the lowest Net Present Value for the identified 10 year period based on the assumptions and performance criteria derived from the historical data.
2. Elimination of the receipt of high strength waste may result in underutilization of several pieces of major equipment.
3. Digester gas utilization may be further optimized. Analysis based on current electrical and natural gas costs may result in more cost-effective gas utilization. For example, it may make economic sense to add additional CHP capacity so that all of the digester gas produced is used for electrical production. It may also be desirable to evaluate future use of a dual fueling option with natural gas to generate electricity. The natural gas could be blended to keep the microturbines operating at the peak operating rate and be used to "fill in the valleys" with respect to gas production.
4. Large capital cost items have the greatest impact on the net present value analysis. Identification of lower cost alternatives may result in improved savings by acceptance of HSW.
5. Newer larger screw presses are planned for the site which is expected to improve dewaterability. The impact of dewatering in terms of total dewatered cake solids and polymer consumption have a large impact on the economics of this system operation. It should also be noted that there is ongoing research and technology developments into processes that decrease polymer consumption and improve dewatered solids concentrations. These developments could be of interest to Sheboygan if polymer consumption remains high and dewatered solids remain below the targeted value of 22% TS with the new screw presses.
6. Adjusting the revenue associated tipping fees will significantly impact the net present value analysis. If the revenue from HSW receiving is increased to greater than $0.03/gal, similar to 2011 levels, the economics of HSW co-digestion become more favorable.

8. References

"Sheboygan Regional Wastewater Treatment Facility – Wastewater Treatment Facility Plan", DRAFT, January 2017

"Wastewater Engineering", Metcalf & Eddy|AECOM, 5th Edition, 2013

Appendix A Data from Wastewater Plant

Numerous files were provided by Sheboygan to review in this analysis. The table below summarizes the files received, relevant information and how the information was used in the analysis. A few select pdf's of some of these files is provided in this appendix following the table.

File Provided by Sheboygan	Relevant information	How it was used in the analysis
2014 to 2016 Co-Dig Eval & HSW Lab Data.zip	Included spreadsheets "co-dig eval" on sludge and HSW loading, concentration, VS contents, digester gas production and use, electrical production and use for years 2014 to 2016. Also included lab data on HSW "HSW Lab Data Report".	Loading data was used to set the historical mass loading and to develop mass balances for the facility using annual average loadings. The information for digester gas usage allowed the proportions of gas split to be determined on an annual basis.
2014 to 2016 Sludge Analysis.zip	Included spreadsheet on the "dried biosolids analysis" for 2015 and 2016 and on the "liquid sludge analysis" for 2014 to 2016. Information mainly included concentrations of metals, nutrients, solids and pathogens.	Provides total solids data for thickened and dried biosolids.
2014 to 2016 Biosolids Loadout.zip	Included spreadsheets on the "dried biosolids loadout" for 2014 to 2016 which included the mass of dried sludge hauled offsite and "land application" for 2014 to 2016 which included the volume of digested thickened solids that were hauled and land applied offsite.	Used for validation in mass balance and to better understand the flow split for thickened sludge land application and dewatering / drying.
2014-2016 Receiving Stations.zip	Included spreadsheets for the "Receiving Station" for wastes received onsite and feed to the headworks.	Not used in this analysis.

Sheboygan WWTP Energy Charges 2014 – 2016.xls	Summarizes monthly and annual electricity consumption for all of Sheboygan's facility.	Used to determine total plant electricity consumption and ratio of electricity produced onsite to total electrical consumption.
HauledWasteRates 2014-2016	Unit cost tipping fees for the HSW received onsite.	Not directly used in the analysis
Copy of WWTP 12 month Avg cost per KWH 2007 – 2016.xlsx	Provides historical electrical unit costs ($/kWh)	Used for electrical unit cost assumptions.
Copy of WWTP KWH-summary DHB.xlsx	Provides the electrical consumption and total costs for electricity consumption at Sheboygan's facilities.	Used to determine total plant electricity consumption and ratio of electricity produced onsite to total electrical consumption.
Copy of WWTP THRMS-summary DHB.xlsx	Provides natural gas consumption (in Therms) and natural gas costs.	Used to calibrate heat balance to determine how much import natural gas was needed. Also used to estimate unit costs for natural gas ($/therm).
Copy of Wastewater_2008_2016 DHB.xlsx	Provides O&M costs for Sheboygan's facilities.	Not directly used in analysis.
HSW go or no go.xls (2 versions provided)	Provides O&M costs for the existing microturbines.	Used the more detailed version for the O&M estimates in the operating and lifecycle cost analysis.
HSW Analysis 2013-2015.xlsx	Provides some data on HSW characterization.	Not directly use in this analysis.
Sheb BTU-Digester Gas 2014-2016	Provides daily heat outputs (in BTU) from the 30 kW microturbines, 200 kW microturbines and digester gas boiler.	Used to establish baseline for energy inputs into the plant heating loop.
Polymer Cost 2014-2016.xlsx	Provides annual polymer consumption and costs for 2014 to 2016.	Not directly used in analysis since polymer unit consumption ratios (lb sludge per DT active polymer dosage) and unit polymer costs were provided separately.

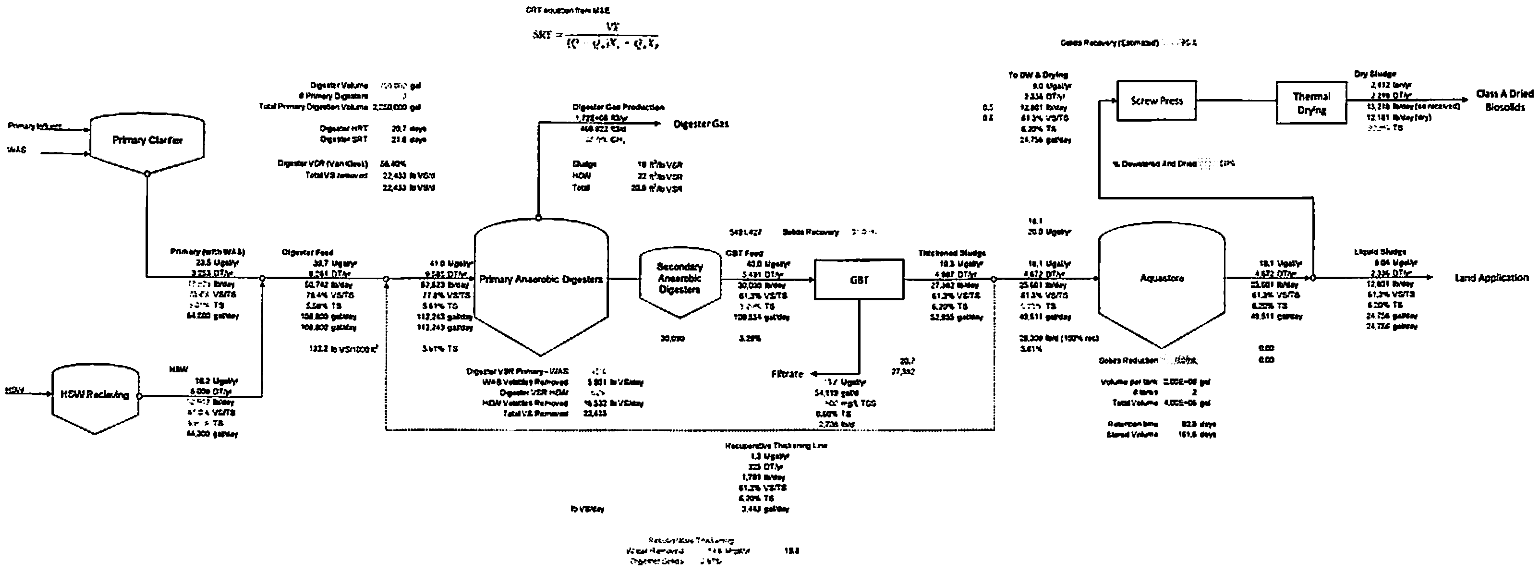
High Strength Waste 2010-2016.xlsx	Provides the breakdown by volume and cost for HSW received at Sheboygan.	Used to develop current average HSW receiving fee and to understand the ratio of HSW sources.
Dryer PM 2015-2017 Steve Corrected 170316.xls	Provides corrected electrical consumption records for the dewatering and drying building.	Used to estimate dryer electrical energy consumption factor (kW/lb H2O evap).

Appendix B Data Analysis

		Baseline HSW Receiving	Eliminate HSW Receiving	Cost Effective HSW Receiving	Units	
Primary + WAS	Mass Load	17,800	17,800	17,800	lb/d	
	Volatile Solids	74%	74%	74%	VS/TS	
	Total Solids	3.3%	3.3%	3.3%	TS	
	Volumetric Loading	64,400	64,400	64,400	gpd	
HSW	Mass Load	32,900		16,450	lb/d	
	Volatile Solids	81%		81%	VS/TS	
	Total Solids	8.9%		8.9%	TS	
	Volumetric Loading	44,300		22,100	gpd	
Digester Feed	Mass Load	50,700	17,800	34,250	lb/d	
	Volatile Solids	78%	74%	77%	VS/TS	
	Total Solids	5.6%	3.3%	4.7%	TS	
	Volumetric Loading	108,700	64,400	86,600	gpd	
Digester Performance	Primary+WAS VSR	45%	45%	45%		
	Primary+WAS Gas Production	18	18	18	ft^3/lb VSR	
	HSW VSR	62%	62%	62%		
	HSW Gas Production	22	22	22	ft^3/lb VSR	
	Total Volatiles Removed	22,420	5,890	14,150	lb VS/d	
	Total VSR	56%	45%	54%		
	Total Gas Production	470,000	108,000	288,000	ft^3/day	
Thickening	Mass to Thickener	30,100	17,800	24,000	lb/d	Accounts for recuperative thickening
	Thickened Solids	6.2%	6.2%	6.2%	TS	Based on Historical Records
	Thickening Capture Rate	91%	91%	91%		
	Polymer Consumption	4.4	4.4	4.4	lb/DT active	
	Active Polymer Consumption	66.2	39.2	52.8	lb/d	
Digested Sludge to Aquastore	Mass Load	25,600	10,300	18,000	lb/d	Accounts for recuperative thickening and 91% recovery
	Volatile Solids	61%	61%	61%		
	Volumetric Loading	49,500	19,900	34,800	gpd	
	Aquastore Volume	4	4	4	million gal	
	Storage Days	81	201	115	days	
Sludge to Dewatering and Drying	Amount to Dewatering/Drying	50%	50%	50%		
	To Dewatering	12,800	5,200	9,000	lb/d	
		2,300	900	1,600	DT/yr	
	To Dewatering	2,300	900	1,600	DT/yr	
	Dewatered Solids	22%	22%	22%		Target with new screw press
	Dewatering Capture Rate	95%	95%	95%		
	Polymer Consumption	38	38	38	lb/DT active	
	Active Polymer Consumption	43.7	17.1	30.4	lb/d	
	Dry Solid Content	92%	92%	92%		
	Evaporative Load	7,600	3,000	5,300	ton H2O/yr	

	Baseline HSW Receiving	Eliminate HSW Receiving	Cost Effective HSW Receiving			
Energy Content in Biogas	943,500	212,800	578,200	Therms/yr		
Electricty from 200 kW MT	8400	3600	8400	kWh/d	3,414	Btu/kWh conversion
200 kW Electrical Efficiency	28%	28%	28%			
Gas to 200 kW MTs	373,800	160,200	373,800	Therms/yr		
% of Total Biogas to 200 kW MT	39.6%	75.3%	64.6%			
Electricty from 30 kW MT	5500		1200	kWh/d		
30 kW Electrical Efficiency	21%		21%			
Gas to 30 kW MTs	326,400		71,200	Therms/yr		
% of Total Biogas to 30 kW MT	34.6%		12.3%			
Total Biogas to MTs	74.2%	75.3%	77.0%			
Sludge Boiler	160,000	34,200	85,400	Therms/yr		
Sludge Boiler Efficiency	80.0%	80.0%	80.0%			
Gas to Boiler	200,000	42,800	106,700	Therms/yr		
Gas Flared	43,300	9,800	26,500	Therms/yr		
% Gas Flared	5%	5%	5%			
Energy Input Baseline	275,000	275,000	275,000	Therms/yr		
Digester Heating Savings		-40,400	-20,200	Therms/yr	Savings from not heating HSW	
Dryer Heating Savings		-128,800	-64,400	Therms/yr		
Total Energy Input	275,000	105,800	190,400	Therms/yr		
200 MT Heat Efficiency	6.5%	6.5%	6.5%		Based on Plant Records	
30 MT Heat Efficiency	6.2%	6.2%	6.2%		Based on Plant Records	
Heat from 200 kW MTs	24,300	10,400	24,300	Therms/yr		
Heat from 30 kW MTs	20,200	0	4,400	Therms/yr		
Heat from Sludge Boiler	160,000	34,200	85,400	Therms/yr		
Digester Boiler Input	70,500	61,200	78,300	Therms/yr		
Digester Boiler Efficiency	85%	85%	85%			
Natural Gas Input	82,900	72,000	89,800	Therms/yr		

Alternative 1 (Keep same level of HSW) Mass Balance at Average Conditions

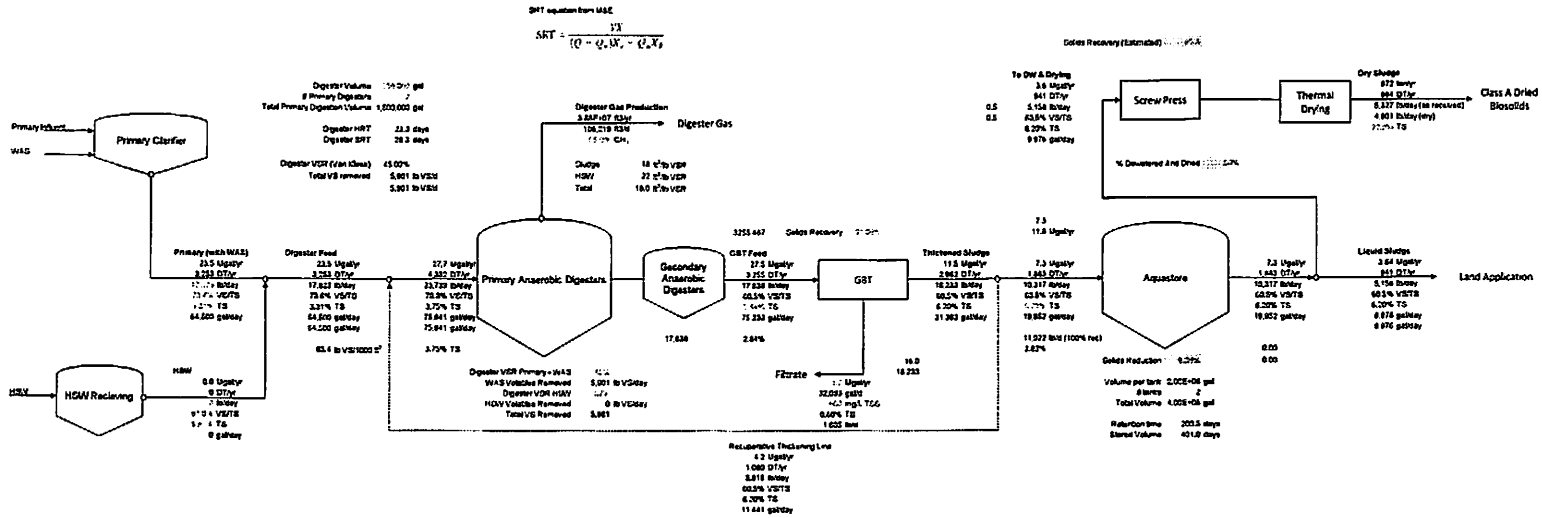


From Email from Sharon

- Recuperative Thickening: The total annual volume of water removed via recuperative thickening is below.
  - 2014 18.0MG — 18 Mgal
  - 2015 22.65MG — 22.65 Mgal
  - 2016 18.61MG — 18.61 Mgal

  19.8

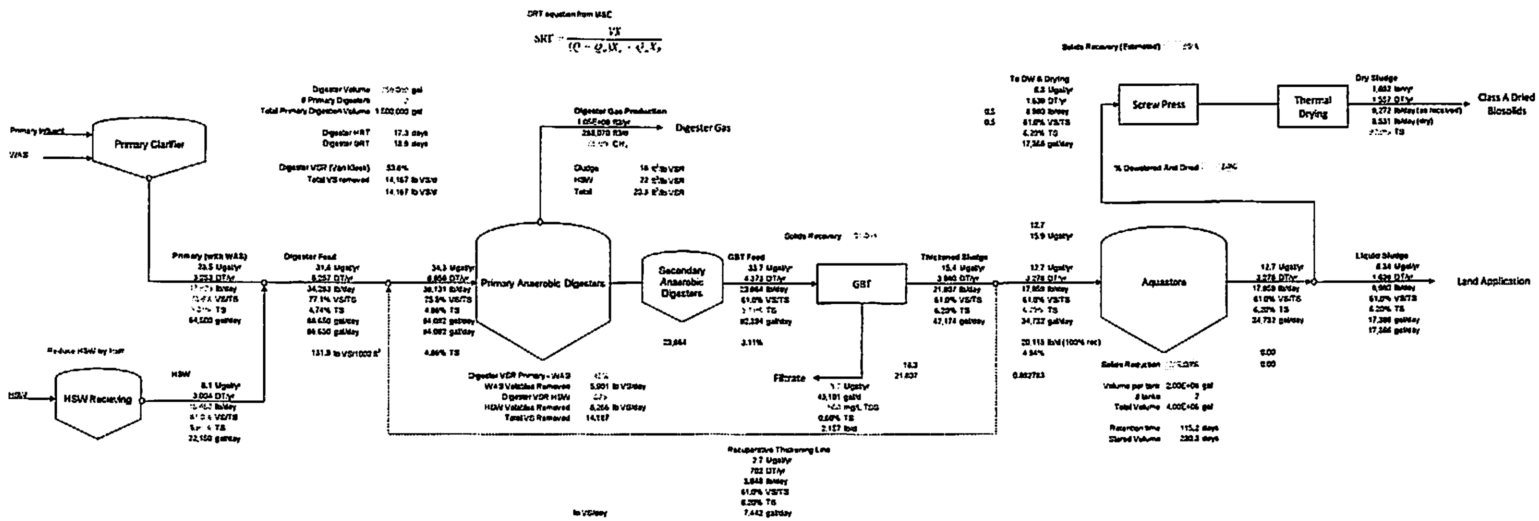
Alternative 2 (No HSW) Mass Balance at Average Conditions



From Email from Sharon

- Recuperative Thickening: The total annual volume of water removed via recuperative thickening is below.
  - 2014 18.0MG
  - 2015 22.65MG
  - 2016 18.61MG

Alternative 3 (Cost Effective: Reduce HSW to avoid a new digester) Mass Balance at Average Conditions



From Email from Sharon

- Recuperative Thickening: The total annual volume of water removed via recuperative thickening is below.
  - 2014 18.0MG
  - 2015 22.65MG
  - 2016 18.61MG

Appendix C Cost Model

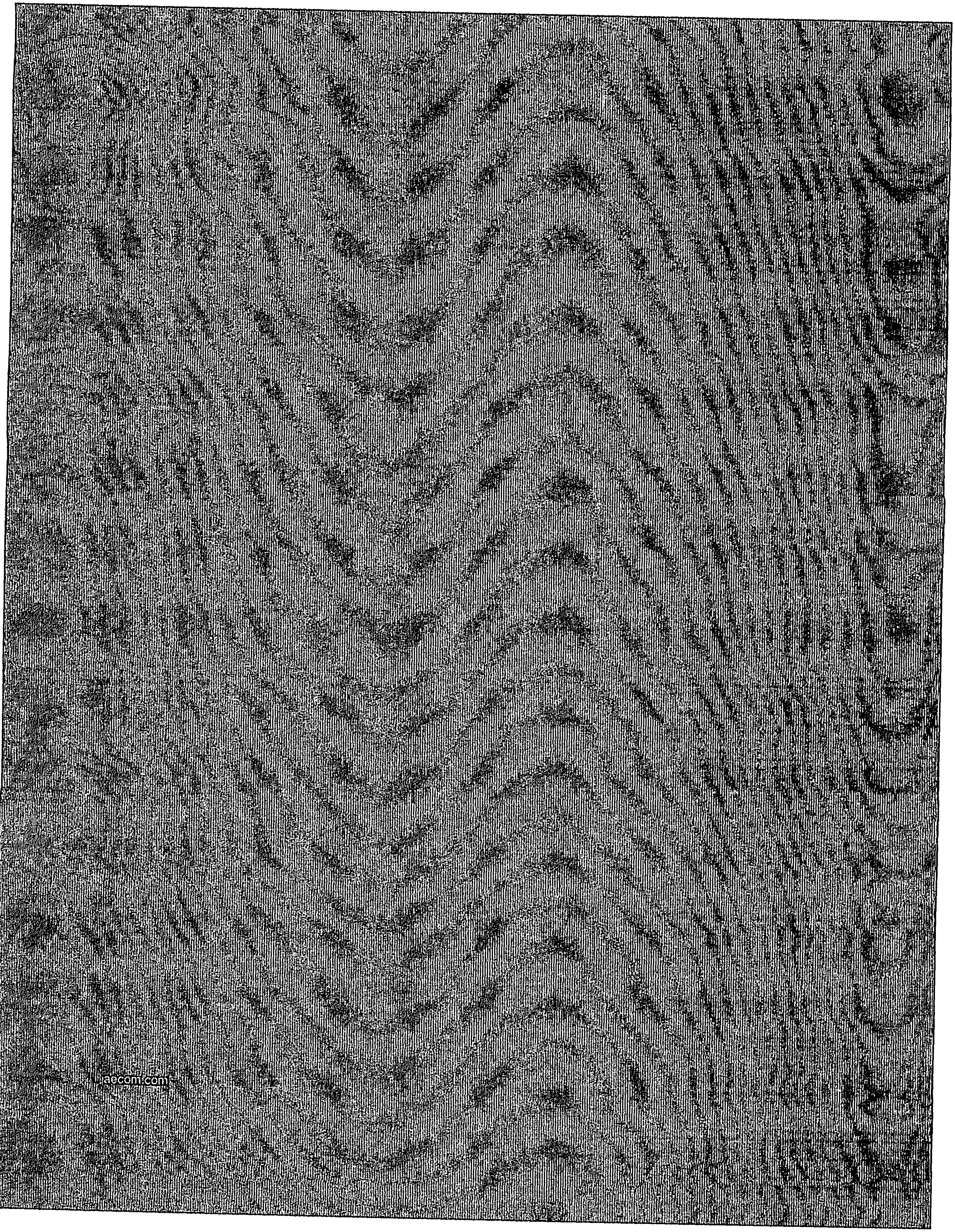
Appendix C
Cost Model

Process Impacts									
	Baseline Alternative			Eliminate HSW Alternative			Refined HSW Receiving Alternative		
HSW Load	44,300 gal/day			0 gal/day			22,100 gal/day		
Digester VSR and Digester Gas Production	56%		470,000 CF/d	45%		106,000 CF/d	54%		288,000 CF/d
200 kW Microturbine Electrical Production	8400	kWh/d		3600	kWh/d		8400	kWh/d	
30 kW Microturbine Electrical Production	5500	kWh/d					1200	kWh/d	
Digester Heating Requirements	1.3	MMBtu/h	Sludge & HSW	0.8	MMBtu/h	Sludge Only	1.1	MMBtu/h	Sludge & HSW
Digester Electrical Requirement	20.7	kWh/Mgal	Est. from other projects	20 7	kWh/Mgal	Est. from other projects	20 7	kWh/Mgal	Est. from other projects
Digester Volume per Digester	0.75	Mgal		0.75	Mgal		0.75	Mgal	
Active Digesters in Service	4			3			3		
Natural Gas Used	82,900	Therms/yr		72,000	Therms/yr		89,800	Therms/yr	
Solids to Thickening	30,100	lb/d	w/ recup thickening	17,800	lb/d	w/ recup thickening	24,000	lb/d	w/ recup thickening
Thickening Energy Consumption	1.0	kW/DT	estimated	1.0	kW/DT	estimated	1.0	kW/DT	estimated
Polymer Required for Thickening	4.4	lb/DT active	44% Active	4 4	lb/DT active	44% Active	4.4	lb/DT active	44% Active
Solids to Aquastore	50,000	gpd		20,000	gpd		35,000	gpd	
Aquastore Tank Capacity	4 Mgal		80.0 days	4 Mgal		200.0 days	4 Mgal		114.3 days
Solids to LA vs. Dewatering & Drying	50%			50%			50%		
Solids to Dewatering & Drying	12,800	lb/d		5,200	lb/d		9,000	lb/d	
Polymer Required for Dewatering	38.0	lb/DT active	44% Active	38 0	lb/DT active	44% Active	38.0	lb/DT active	44% Active
Dewatering Energy Consumption	10.0	kW/DT	Huber Factor	10.0	kW/DT	Huber Factor	10.0	kW/DT	Huber Factor
Dewatered Total Solids	22%	TS		22%	TS		22%	TS	
Dry Total Solids	92%	TS		92%	TS		92%	TS	
Evaporative Load	7,600	ton/yr		3,000	ton/yr		5,300	ton/yr	
Dryer Electrical Energy Efficiency	0.037	kW/lb H2O evap	Est. from Historical Data	0.037	kW/lb H2O evap	Est. from Historical Data	0.037	kW/lb H2O evap	Est. from Historical Data
Class B liquid biosolids to land application	25,000	gpd		10,000	gpd		17,500	gpd	
Class A Biosolids beneficially used	2,412	ton/yr		980	ton/yr		1,696	ton/yr	

Cost Impacts									
	Baseline Alternative			Eliminate HSW Alternative			Refined HSW Receiving Alternative		
	Capital Costs	Annual O&M Expenses		Capital Costs	Annual O&M Expenses		Capital Costs	Annual O&M Expenses	
		hr/wk	$/year		hr/wk	$/year		hr/wk	$/year
Receiving Station	$1,800,000			$0			$1,800,000		
Operating Labor Expenses		7	$15,142		0	$0		7	$15,142
Maintenance Labor Expenses		1	$2,163		0	$0		1	$2,163
Electrical Expenses									
Digester Upgrades	$1,600,000			$430,000			$430,000		
Operating Labor Expenses			$0			$0			$0
Maintenance Labor Expenses			$0			$0			$0
Electrical Expenses			$54,400			$40,800			$40,800
Thickening	$0			$0			$0		
Operating Labor Expenses		7	$15,142		4.1	$8,955		5.6	$12,074
Maintenance Labor Expenses			$0			$0			$0
Electrical Expenses			$549			$325			$438
Polymer			$44,451			$26,287			$35,443
Microturbines	$1,000,000			$0			$200,000		
Total Expenses			$47,748			$47,748			$47,748
Oil & Media - 30kW			$10,092						$2,016
Maintenance Labor Expenses - 30kW		3	$6,573						$1,315
Oil & Media - 200kW			$9,426			$9,426			$9,426
Maintenance Labor Expenses - 200kW		3	$5,450		3	$5,450		3	$5,450
Electrical Production(negative cost)			($507,350)			($131,400)			($350,400)
Natural Gas Requirements			$37,305			$32,400			$40,410
Sludge Dewatering	$0			$0			$0		
Operating Labor Expenses		7	$15,142		2.8	$6,152		4.9	$10,647
Maintenance Labor Expenses			$0			$0			$0
Electrical Expenses			$2,336			$949			$1,643
Polymer			$163,251			$66,821			$114,766
Sludge Drying	$0			$0			$0		
Operating Labor Expenses		10.5	$22,714		4.3	$9,227		7.4	$15,971
Maintenance Labor Expenses			$0			$0			$0
Electrical Expenses			$56,240			$22,200			$39,220
HSW Tipping Fee Revenue (negative cost)			($48,509)			$0			($24,200)
Class B Liquid Land Application Expense			$273,750			$109,500			$191,625
Class A Dried Biosolids Application Revenue			($24,122)			($9,799)			($16,961)
TOTAL	$4,400,000	38	$201,895	$430,000	14	$244,539	$2,430,000	28	$194,757
Net Present Value	$4,400,000		$1,637,547	$430,000		$1,983,430	$2,430,000		$1,579,657
Total Net Present Value (capital & operating)		$6,037,547			$2,413,430			$4,009,657	

Cost Model Common Inputs

Life of projects (years)	10	
Interest Rate (as decimal)	0.04	
Net Present Value Factor for Annual Costs	8.1109	
Electrical cost ($/kw-hr)	$0.10	Based on 2016 plant records
Natural gas cost ($/therm)	$0.45	Based on 2016 plant records
Polymer cost ($/lb)	$0.80	Per Sharon 03-23-17
Labor cost ($/hr)	$42	Per Sharon 02-27-17, raw labor is $26/hr. 60% added in to cover benefits.
HSW tipping fee revenue ($/gal)	$0.0030	
Liquid land application cost ($/gal)	$0.03	per Sharon 02-27-17 email
Dried biosolids application revenue ($/dry ton)	$10	per Sharon 02-27-17 email, revenue starts in 3rd year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