Madison Metropolitan Sewerage District

2020 ENERGY MANAGEMENT MASTER PLAN

FINAL | December 2021

in association with:

Madison Metropolitan Sewerage District

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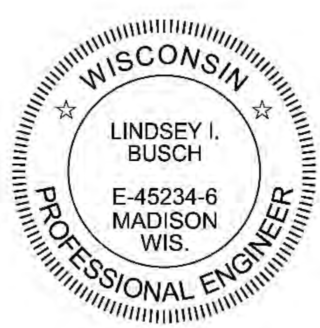

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Abbreviations

AA	annual average
AACE	Association for the Advancement of Cost Engineering
AC	alternating current
AEL	alternative effluent limits
AM	adaptive management
ANR	ANR Pipeline Company
BACT	best available control technology
BCPL	Board of Commissioners of Public Lands
BFC	Badfish Creek
BFP	belt filter press
BG	biogas
bhp	brake horsepower
BMC	Badger Mill Creek
BMP	biosolids management plan
BOD	biochemical oxygen demand
BRIC	Building Resilient Infrastructure and Communities
BS	biosolids
Btu	British thermal unit
Btu/hr	British thermal unit per hour
Carollo	Carollo Engineers
CD	co-digestion
CEC	compounds of emerging concern
CEPT	chemically-enhanced primary treatment
cf	cubic feet
cfd	cubic feet per day
CFU	colony forming units
CHP	combined heat and power
CIP	capital improvements plan
CMOM	compliance, management, operation, and maintenance
CNG	compressed natural gas
CO_2	carbon dioxide
CO	carbon monoxide
CWFP	Clean Water Fund Program
DAF	dissolved air flotation
DC	direct current
deg. F	degrees Fahrenheit
DOE	Department of Energy

EI&C	electrical, instrumentation and controls
EIF	Environmental Improvement Fund
ELA	engineering, legal, and administrative
EP	effluent pumping
EPA	US Environmental Protection Agency
EPC	energy performance contract
ES	energy storage
ESCO	energy service company
ET	emerging technologies
FEMA	Federal Emergency Management Association
FOA	funding opportunity announcement
FOG	fats, oils and grease
ft	feet
gal	gallon
GBT	gravity belt thickener
GC OH&P	general contractor overhead and profit
GHG	greenhouse gas
gpd	gallons per day
gpm	gallons per minute
GPT	green power tomorrow
hp	horsepower
H_2S	hydrogen sulfide
HSW	high-strength waste
HSW-FOG	high-strength waste and fat, oil and grease
HVAC	heating, ventilation, and air conditioning
IC	internal combustion
I/I	infiltration/inflow
ISI	Institute for Sustainable Infrastructure
kBtu/hr	kilo British thermal units per hour
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
kWh/day	kilowatt-hour per day
kWh/MG	kilowatt-hour per million gallons
kWh/yr	kilowatt-hour per year
kWp	kilowatts peak
lb	pounds
LOI	letter of interest
M	million

MDV	multidischarger variance
MG	million gallons
mgd	million gallons per day
MG&E	Madison Gas and Electric
mg/L	milligrams per liter
mL	milliliter
mm	millimeter
MMBtu	million British thermal units
MMBtuh	million British thermal unit per hour
MMBtu/yr	million British thermal units per year
MMSD	Madison Metropolitan Sewerage District
MPN	most probable number
MT CO_2e	metric tons of carbon dioxide equivalent
MW	megawatt
MWh	megawatt hour
No.	number
NOFA	Notification of Funding Announcement
NO_x	nitrogen oxide
NPV	net present value
NSC	Nine Springs Creek
NSPS	new source performance standards
NSWTP	Nine Springs Wastewater Treatment Plant
O&M	operation and maintenance
PFA	Public Finance Authority
PFAS	per- and polyfluoroalkyl substances
PFD	process flow diagram
PI	phosphorous index
Plan	2020 *Energy Management Master Plan*
PLC	programmable logic controller
PPA	power purchase agreement
ppd	pounds per day
Project	2020 Energy Management Master Plan Project
PS	primary sludge or pump station
PSA	pressure swing adsorption
psi	pounds per square inch
PV	photovoltaic
RAS	return activated sludge
RE	renewable energy
RECIP	Renewable Energy Competitive Incentive Program

RER	renewable energy rider
RFP	request for proposal
RFS	Renewable Fuel Standard
RIN	renewable identification number
RNG	renewable natural gas
SCB	sludge control building
SSO	sanitary sewer overflow
SUO	sewer use ordinance
TH	thermal heating
THP	Thermal Hydrolysis Process
TM	technical memorandum
TM 1.1	*Technical Memorandum 1.1: Project Vision and Screening Criteria*
TM 1.2	*Technical Memorandum 1.2: Existing Infrastructure Evaluation Results*
TM 1.3	*Technical Memorandum 1.3: 2020 Energy Baseline*
TM 2.1	*Technical Memorandum 2.1: Summary of Expert Panel Workshop*
TM 2.2	*Technical Memorandum 2.2: Alternatives Evaluation*
TM 3.1	*Technical Memorandum 3.1: Regulatory Drivers*
TM 3.2	*Technical Memorandum 3.2: Funding Opportunities*
TM 4.1	*Technical Memorandum 4.1: Business Case Evaluation*
TM 4.2	*Technical Memorandum 4.2: Capital Improvement Recommendations*
TMDL	total maximum daily load
TN	total nitrogen
TPAD	temperature-phased anaerobic digestion
TS	total solids
TSS	total suspended solids
TWAS	thickened waste activated sludge
US	United States
UV	ultraviolet
UW	University of Wisconsin
VFD	variable frequency drive
VOC	volatile organic compound
VS	volatile solids
VSR	volatile solids reduction
VSS	volatile suspended solids
WAS	waste activated sludge
WDNR	Wisconsin Department of Natural Resources
WEP	water extractable phosphorous
WIFIA	Water Infrastructure Finance and Innovation Act
WPDES	Wisconsin Pollutant Discharge Elimination System

WQT	water quality trading
WS 1.1	Kickoff and Visioning Workshop 1.1
WS 2.1	Expert Panel Workshop 2.1
WSGC	Water Security Grand Challenge
w/w	by weight
WWTP	wastewater treatment plant
Yahara WINs	Yahara Watershed Improvement Network

EXECUTIVE SUMMARY

ES.1 A Plan Centered on Sustainable Infrastructure and Responsible Energy

For over nine decades, the Madison Metropolitan Sewerage District (MMSD) has served the Madison metropolitan area with safe, reliable wastewater collection and treatment. In recent years, MMSD and stakeholder communities have become increasingly dedicated to sustainable practices, including resource recovery, conservation, and energy efficiency, that protect the environment and public health.

In 2020, MMSD set out to understand how to upgrade or replace aging energy-producing and -consuming infrastructure at the Nine Springs Wastewater Treatment Plant (NSWTP). MMSD sees the need to replace aging infrastructure as an opportunity to consider new ways to improve NSWTP operations and its energy use footprint. MMSD currently reclaims approximately 42 million gallons (MG) of wastewater every day at NSWTP at an energy cost of 90,000 kilowatt-hours (kWh) per day (kWh/day), which is enough to power roughly 3,100 homes. This energy demand is predicted to increase 20 percent by 2040 if MMSD does nothing but maintain existing infrastructure. Additionally, NSWTP's aging energy-producing and -consuming infrastructure will struggle to meet facility needs in their current condition.

To systematically upgrade or replace these aging assets while reducing the plant's energy usage, operational costs, and energy-related environmental footprint, MMSD prepared the *2020 Energy Management Master Plan* (Plan), a document that recommends prioritized, targeted improvements to the NSWTP's aging energy infrastructure and energy-management approaches over the next 10 to 20 years.

ES.2 Developing Viable Alternatives

This Plan focuses on plant assets that handle biosolids, use biogas, and produce electrical and thermal energy. This process equipment is essential to meeting MMSD's permitting requirements with the Wisconsin Department of Natural Resources (WDNR) and recovering energy throughout the NSWTP. However, this infrastructure currently faces complex operational challenges and capacity limitations. This is because most of this equipment has been in use for several decades and is in varying stages of deterioration. The 20-year life cycle cost to simply rehabilitate, replace, and modify this infrastructure, without any process or energy optimization, is approximately $88 million to $93 million. These basic improvements are considered the baseline.

The Plan's main objective is to look for alternative approaches to replace existing energy-producing and -consuming infrastructure that allows MMSD to reduce its energy footprint by decreasing overall energy demands and by increasing generation and use of renewable energy. To do this, the Plan uses a comprehensive screening process that considered cost, present and future regulations, technological flexibility, and other key criteria to identify 133 unique energy-management and facility-augmentation strategies, which were then narrowed down and synergistically combined into several potential scenarios.

ES.3 Comparison of Possible Paths Forward

The Plan identifies four potential scenarios that MMSD could pursue to address aging infrastructure concerns and advance energy goals. These include:

- **Enhanced Baseline** scenario is focused on upgrading heat and power systems to improve system reliability and efficiency and partnering with Madison Gas and Electric (MG&E) to procure solar energy through MG&E's Renewable Energy Rider (RER) program.
- **Maximize Renewable Energy Production** scenario contains the same components as the Enhanced Baseline scenario and includes new processes to capture and beneficially use additional waste heat energy.
- **Energy Grid Resilience** scenario is focused on upgrading heat systems and significantly expanding on-site power generation by using both biogas and natural gas in large co-generation systems in order to allow NSWTP to operate "off grid".
- **Reduce Infrastructure Complexity** scenario is focused on simplifying MMSD's infrastructure by upgrading heat systems, partnering with MG&E to procure renewable energy through the RER program, and exporting renewable natural gas (RNG) to the renewable fuels market instead of using this gas for onsite power production. This scenario promotes an overall increase in renewable energy use, but a portion of this energy is not used directly by MMSD.

Additionally, all scenarios include the same provisions to reconfigure biosolids treatment processes to reduce the labor and transportation fuel needed for biosolids distribution.

Overall, as shown in Table ES.1, the Plan finds that both the **Enhanced Baseline** and **Reduce Infrastructure Complexity** scenarios bring improvements over the baseline option of continuing to rehabilitate and maintain MMSD's existing infrastructure. Both scenarios offer increased benefits with little to no drawbacks and have lifecycle costs similar to or less than the baseline cost of $88 to $93 million.

Table ES.1 Comparison Matrix

		Scenario			
		Enhanced Baseline	Maximize Renewable Energy Production	Energy Grid Resilience	Reduce Infrastructure Complexity
Comparison Criteria	Reliability Improved	**Yes**	**Yes**	**Yes**	**Yes**
	Renewable Energy Generation	**More**	**More**	**More**	**More**
	GHG Emissions	**Reduced**	**Reduced**	**Reduced**	**Reduced**
	Infrastructure Impact	Similar	More	Similar	**Less**
	20 Year Life Cycle Cost	$ 83-93 M	$ 119-134 M	$ 90-103 M	**$ 67-87 M**
	Electricity Provider	MMSD & Utility	MMSD & Utility	MMSD	Utility
Recommended for further evaluation		**Yes**	No	No	**Yes**

Notes:
(1) [green] Benefit relative to baseline condition.
(2) [red] Drawback relative to baseline condition.

The Plan shows that both scenarios position MMSD to replace the NSWTP's aging energy infrastructure and beneficially use biogas for either on-site electricity generation or RNG production. The **Enhanced Baseline** scenario successfully meets every one of MMSD's infrastructure and energy goals and allows NSWTP staff to continue practicing familiar, but enhanced, operations. Meanwhile, the **Reduce Infrastructure Complexity** scenario simplifies infrastructure, lowers the plant's operational complexity, and opens doors for new revenue streams through the sale of RNG. The Plan recommends that these two scenarios be investigated further as part of facilities planning efforts in the future.

ES.4 Insights Gained

In developing the Plan, MMSD has gained several insights to improve its energy footprint. With regards to reducing energy demands, the Plan shows that treatment processes evaluated at the NSWTP are already optimized and there are no alternative options that would result in appreciable, cost-effective energy demand reductions in the areas considered. Also, business models such as accepting additional hauled waste to increase biogas production do not appear favorable at this time due to an apparent lack of desired feedstocks in the region. Lastly, the Plan shows that MMSD can advance goals to increase generation and use of renewable energy without having to bear the burden of owning and operating renewable energy infrastructure by establishing partnerships with MG&E or other entities.

ES.5 What's Next?

The *2020 Energy Management Master Plan* is a high-level document intended to help guide MMSD as it considers upcoming aging infrastructure replacement projects. Future facility planning efforts will further evaluate the options recommended in the Plan to determine a path forward. In the process, MMSD will engage stakeholders and community partners to earn their support in developing effective, responsible, and transparent projects that bring value to the community.

Refer to Appendix A for a full Executive Summary on the Project.

Chapter 1

PHASE 1

1.1 Phase 1 Overview

Phase 1 of the project started with project visioning and development of screening criteria for the alternatives to be developed in Phase 2. It also included a condition assessment of the relevant assets, as well as the development of baseline conditions and 2040 status quo projections for electrical and thermal energy, and greenhouse gases.

1.2 Technical Memorandum 1.1: Project Vision and Screening Criteria (TM 1.1)[1]

1.2.1 Introduction

1.2.1.1 Project Background and Scope

In 2020, MMSD set out to understand how to upgrade or replace aging energy-producing and -consuming infrastructure at the NSWTP. MMSD saw the need to replace aging infrastructure as an opportunity to consider new ways to improve NSWTP operations and its energy use footprint. Therefore, this 2020 Energy Management Master Plan Project (Project) set out to identify and evaluate alternatives intended to upgrade or replace energy-producing and -consuming infrastructure at NSWTP, and in doing so, explore ways to improve NSWTP operations and its energy-use footprint. Of specific focus in this Project were alternatives that require action within the next 10 years that could provide long-lasting impacts on MMSD's energy production and use.

This Project included the following major scope items:

- Evaluate the existing baseline energy production and consumption for the liquid and solid process stream, pump stations, biosolids hauling and land application. Document energy consumption by process area by updating the last 2014 energy baseline information for the NSWTP. Benchmark these data by process against data from similar industry peers where available.
- Project the current energy baseline into the future year 2040 for both status quo conditions, and assuming the recommended alternatives are implemented. The status quo baseline will consider how known improvements planned for coming years would change energy projections; for example, upgrades to the ultraviolet (UV) disinfection system.
- Assess the impact of existing and alternative larger equipment and system components on energy production and consumption.
- Outline feasible strategies and their timeline to address aging infrastructure needs through infrastructure rehabilitation, replacement, and/or modifications. The overall objectives of the strategies were to improve energy supply resilience and reliability, reduce MMSD's energy usage, operational costs, and energy related environmental footprint while continuing to provide needed wastewater treatment and resource recovery services. The selected strategies aim to advance

[1] See Appendix B for additional information.

sustainability metrics and increase resource recovery. To this end, the team agreed to the following definitions:
  - Resilience: Ability to adapt to and recover from a significant event or disruption by minimizing level of service failure magnitude and duration.
  - Reliability: The ability for an asset or system to continue to provide its expected level of service under normal/expected operating conditions.
- Develop an infrastructure replacement and upgrade plan. The plan will outline a time and cost schedule for the next 10 years of recommended improvements based on the priority of asset conditions and energy related impact.

1.2.2 Energy Related Initiatives and MMSD Objectives

1.2.2.1 MMSD Priorities

The overall mission of MMSD is to protect public health and the environment. At the heart of MMSD's vision on how to accomplish this mission is enriching life through clean water and resource recovery. Returning clean treated water back to nature, providing farmers with biosolids for soil amendment to grow food, and practicing conservation are steps for MMSD to contribute to a resource-conscious and sustainable community.

MMSD's mission, vision, ideals, and goals make up its strategic plan that are supported by five key result goals, all of which were relevant for this Project:

1. **Environment.** Increase the recovery of resources while meeting permit requirements.
2. **Community.** Improve partnerships to build and increase public support.
3. **Employees.** Achieve a culture of positive engagement.
4. **Effectiveness.** Adopt best business practices to increase MMSD efficiency and effectiveness.
5. **Infrastructure.** Achieve expected community level of services at the lowest total cost of ownership.

MMSD's Commission has issued several policies in past years that are pertinent to this Project and have been referenced for the development of term definitions that were applied in this Project.

1.2.2.2 Envision™

MMSD is one of many agencies in the US in the public sector who uses the Envision™ framework for civil infrastructure planning, design, construction, operation, and decommissioning as well as within their organizational workforce. As a member agency, MMSD tracks and manages staff's involvement and progress in Envision™. Envision™ is a framework for assessing sustainability and resilience in infrastructure that sets standards and defines metrics for what constitutes sustainable infrastructure. The framework provides a flexible system of criteria and performance objectives to aid decision makers and help project teams identify sustainable approaches during planning, design, and construction. These approaches would continue throughout the project's operations and maintenance and end-of-life phases.

The use of Envision™ served as a useful exercise to explore how the chosen alternatives would score, identifying alternatives that could result in additional achievements in the Envision™ framework. It should be noted, though, that Envision™ was not used to guide decision-making and design conclusions.

1.2.2.3 Energy Goals of Other Communities in Service Area

Several stakeholder communities served by MMSD, as well as MG&E, have set various energy goals in recent years related to reducing carbon footprint, increasing renewable energy use, and increasing energy efficiency. These communities include Madison, Fitchburg, Middleton, Monona, Dane County, Verona, Dane, Shorewood Hills, and Waunakee. Among those customer communities, Madison, Middleton, Fitchburg, and Monona alone account for 5 out of every 6 people served by MMSD. This indicates that the owner communities that represent and serve a majority of MMSD's customer base are in support of service beyond simple cost economics. Based on these communities' stated goals and priorities, along with those of Dane County (which encompasses all communities served by MMSD), MMSD considered the regional attitudes to be generally in support of advancing energy, sustainability, and resource recovery. The Project team was also cognizant of potential varying stakeholder priorities.

1.2.2.4 MMSD Project Goals

MMSD initially provided seven goals for this Project that served as general guidelines to improve understanding and a starting point for the evaluation process, summarizing the minimum expectations for energy related improvements. These goals were as follows:

1. **Greenhouse Gas (GHG) Reduction.** Reduce fossil fuel-based GHG emissions by a minimum of 10 percent within 10 years compared to 2020 levels.
2. **Peak Demand Costs.** Implement acceptable cost solutions. Specifically, reduce costs associated with peak electricity demand by a minimum of 5 percent within 10 years compared to 2020 costs.
3. **Energy Efficiency.** Reduce operational energy consumption by a minimum of 10 percent in million British thermal units per million gallons per day (MMBtu/mgd) within 10 years compared to 2020 levels.
4. **Renewable Energy.** Increase renewable energy generation at MMSD facilities for operations or sale. Specifically, use renewable energy sources to meet a minimum of 50 percent of total energy demands within 10 years.
5. **Energy for Biosolids Production.** Identify operational strategies and/or process changes to the existing liquid Class B biosolids processing and reuse program that reduces energy demands or produces a higher value biosolids product without significantly increasing energy demands.
6. **Energy Sources.** Improve reliability and resiliency of energy sources.
7. **Infrastructure.** Improve reliability of energy using and consuming infrastructure.

With this Project, MMSD set minimum expectations instead of hard targets in order to understand and compare the costs and benefits of alternatives at different levels of achievement. Throughout this process, the approach and perspective on the Project goals evolved according to new information and discoveries as the evaluation process progressed and priorities subsequently changed.

1.3 Technical Memorandum 1.2: Existing Infrastructure Evaluation Results (TM 1.2)[2]

1.3.1 Background and Scope of Existing Infrastructure Evaluation

Phase 1 of the Project included an existing infrastructure evaluation. During this evaluation phase, the aging infrastructure and operational challenges were assessed by reviewing existing information, interviewing key staff and conducting a site visit. The objective of Phase 1 was to develop a replacement prioritization ranking of existing energy related infrastructure that served as a supplement to MMSD's existing asset registry.

The scope of the infrastructure evaluation included the review of the biosolids handling, biogas-driven, and thermal energy producing equipment along with their respective automation and controls. Each system was evaluated based on criteria that were prioritized at the Kickoff and Visioning Workshop 1.1 (WS 1.1) during the Phase 1 and Basis of Planning discussion. The liquids process (with the exception of effluent pumping) and buildings systems (heating ventilation, and air conditioning [HVAC], etc.) were evaluated in separate studies and therefore excluded from this Project's evaluation.

[2] See Appendix C for additional information.

MMSD's current asset registry contains over 5,700 assets. The team narrowed the list for evaluation to approximately 300 assets that provide a central role in the energy-producing and -consuming process and were important in achieving MMSD's Project goals.

1.3.2 Development of Evaluation Factors and Ranking Strategy

Seven factors were selected to evaluate and rank the existing infrastructure, which were further grouped into two categories: 1) Process and Operations, and 2) Replacement Prioritization.

1.3.2.1 Process and Operations

Five of the seven infrastructure evaluation factors were grouped into the "Process and Operations" category:

1. Condition and Performance.
2. Capacity.
3. Level of Efficiency.
4. Operational Ease.
5. Flexibility for Strategic Value.

The assets evaluated were ranked from 1 to 5 for each evaluation factor, and then all five evaluation factors were added to produce an overall evaluation score ranging from 5 (best asset condition) to 25 (worst asset condition). Based on these overall scores, the asset received a green (less than or equal to 13; good condition), yellow (between 14 and 16; fair condition), or red rating (above 17; poor condition).

The overall score for the Process and Operations Category provided a single ranking that represented the condition, operations, and performance of an existing asset.

1.3.2.2 Replacement Prioritization

The two remaining evaluation factors were grouped into the category "Replacement Prioritization".

- Remaining Useful Life.
- Process/System Impact.

This category utilized a -1, 0 and +1 ranking system, which in the context of remaining useful life corresponded to equipment life that was longer, similar, or shorter than indicated, respectively. In the context of process/system impact, those same scores were representative of the criticality of the asset to operation, corresponding to no interruption, short downtime, and major, critical downtime, respectively.

This category identified the age and condition of infrastructure that was critical to the system's operations and replacement priority, emphasizing the two highest priority criteria selected by MMSD: Improve Reliability / Resiliency and Address Aging Infrastructure.

1.3.3 Asset Evaluation Results

1.3.3.1 Biosolids Assets

The evaluation of biosolids assets included the main equipment playing a fundamental role in the biosolids digestion, biogas production, and energy usage.

The schematic in Figure 1.1 presents a summary of the solids handling system at MMSD´s NSWTP with a color-coded representation of the asset scoring.

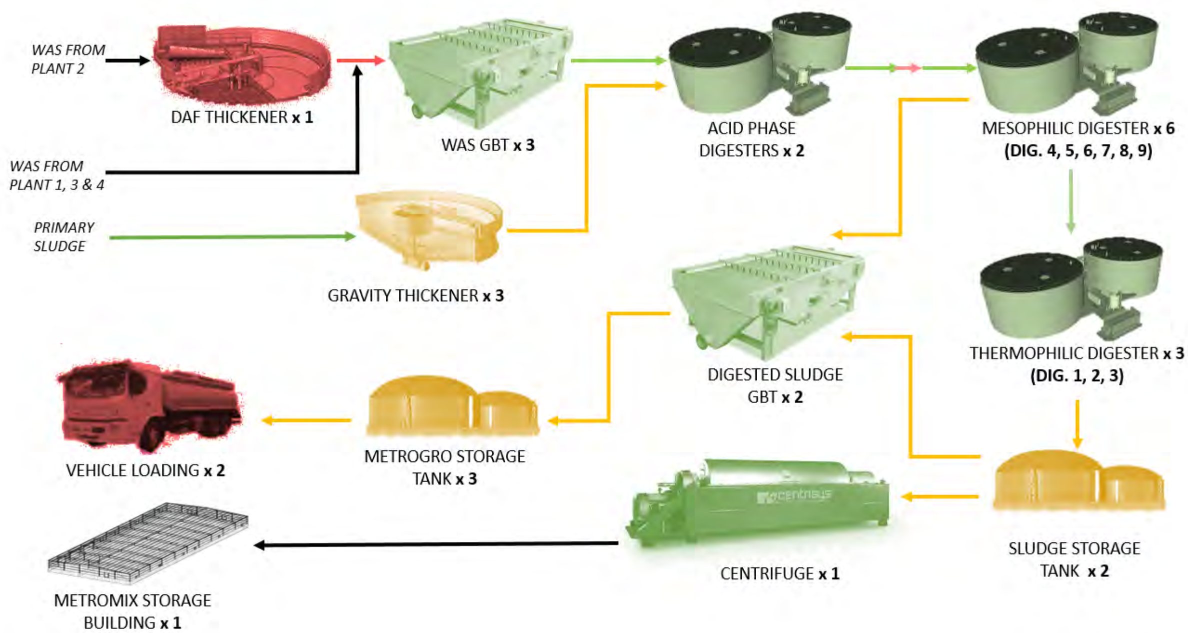


Figure 1.1 NSWTP Solids Handling Schematic and Asset Scoring Results

General Asset Background

The biosolids assets evaluated covered the solids handling processes including thickening, digestion, and dewatering.

The waste activated sludge (WAS) from plant 2 and scum from plants 1 through 4 is thickened in a dissolved air flotation (DAF) thickener before it is combined in the two WAS treatment tanks with the WAS from plants 1, 3, and 4 for phosphorus release. All WAS is then thickened with three gravity belt thickeners (GBT) before being pumped to the two acid phase digesters.

The primary sludge (PS) is thickened in three gravity thickeners. MMSD´s NSWTP utilizes anaerobic digestion for primary and waste activated sludge stabilization. MMSD's current anaerobic digestion process includes acid phase, mesophilic and thermophilic digesters.

Current volatile solids (VS) loading rates restrict operation to only one acid phase digester at a time. Two steam injectors heat thickened waste activated sludge (TWAS) and recirculated acid sludge in the acid phase digesters. The sludge is then transferred to six mesophilic digesters. Once digested, a portion (approximately 15 percent) of the mesophilic sludge is pumped to three thermophilic digesters and the rest is thickened using two digested sludge gravity belt thickeners.

The thermophilic digesters' solids retention time and elevated temperature allow MMSD to produce a Class A sludge. After batching in the thermophilic digesters, the thermophilic sludge is then pumped to two sludge storage tanks where it is cooled to then either be thickened via the two digested sludge gravity belt thickeners or dewatered using a centrifuge. The dewatered sludge is conveyed to the end use building until it is hauled away for land application.

The remaining 85 percent of the digested sludge (mesophilically digested) is considered Class B and is thickened by the digested sludge gravity belt thickeners before being pumped to the three Metrogro storage tanks. The sludge is stored here until it is pumped to the vehicle loading station or the vehicle loading building to fill tankers for land application.

Biosolids Equipment Scoring

Overall, the biosolids system assets received a score of 12.9, which is shown visually in Figure 1.1. The items in black were not evaluated.

System Evaluation Results

The biosolids process stabilizes the biosolids to allow MMSD to meet their WDNR permit requirements and allow land application. The anaerobic digestion of biosolids creates biogas for utilization and requires thermal energy to maintain efficient operation. Having a resilient and robust biosolids process is necessary when looking at improving energy efficiency and production. This section reviews the biosolids process as a whole and identifies system challenges that may impede progress in achieving MMSD's goals.

Loading

The loading of the biosolids process and each individual process unit has an impact on digestion efficiency, biogas production, and thermal use. The current loading is approximately 1,500 pounds of volatile suspended solids per day per 1,000 cubic feet (lb VSS/day/1,000 cf) using one of the two acid digesters at a time. Aside from that, the mesophilic digesters are loaded at approximately 100 lb VSS/day/1,000 cf. Both of these process loadings are within the typical operating range and accordingly are performing as expected.

Flow Split

MMSD's biosolids process is complex due to design decisions surrounding the operational strategy and process configuration of the existing infrastructure that have resulted in some unique flow splits that underutilize certain solids handling unit operations. For example, the digested sludge GBTs receive around 85 percent of biosolids flow, while having the capacity for 100 percent. Similarly, the centrifuge is also underutilized, handling less than 15 percent of the biosolids flow but with the capacity to handle more. However, even though some solids handling infrastructure is currently underutilized, this is by design and therefore is not a cause for further upgrades.

Process Instrumentation

The operational staff's responsibilities are complex and are made more difficult by a number of critical processes that require manual operation such as the digester level control. To better assist operational staff, critical processes should include improved instrumentation and automation to further efforts to streamline operation. Operations staff identified the following limitations in current instrumentation and automation related to the biosolids system:

- Digester Level Control Monitoring and Automation – Digester levels are currently controlled manually, which can impact the desired responsiveness to maintain proper mixing effectiveness and reduce temperature variations. It is recommended to add instrumentation to monitor and automate the digester level to help with future operations.
- Digester Influent Loading Monitoring – Online monitoring of digester loading can help predict and avoid operational problems.

- Foam Detection and Control – Foaming is the largest operational challenge faced by MMSD and MMSD has had poor results with foam detection in the past. Alternative technologies should be considered to better allow MMSD to monitor existing conditions and develop a historical record of when issues occurred.

1.3.3.2 Biogas Assets

The evaluation of biogas assets included the main equipment playing a fundamental role in the biogas production, cleaning, transfer and usage.

Figure 1.2 presents a summary of the biogas production, transferring and usage at NSWTP, as well as a color-coded representation of the biogas assets scoring:

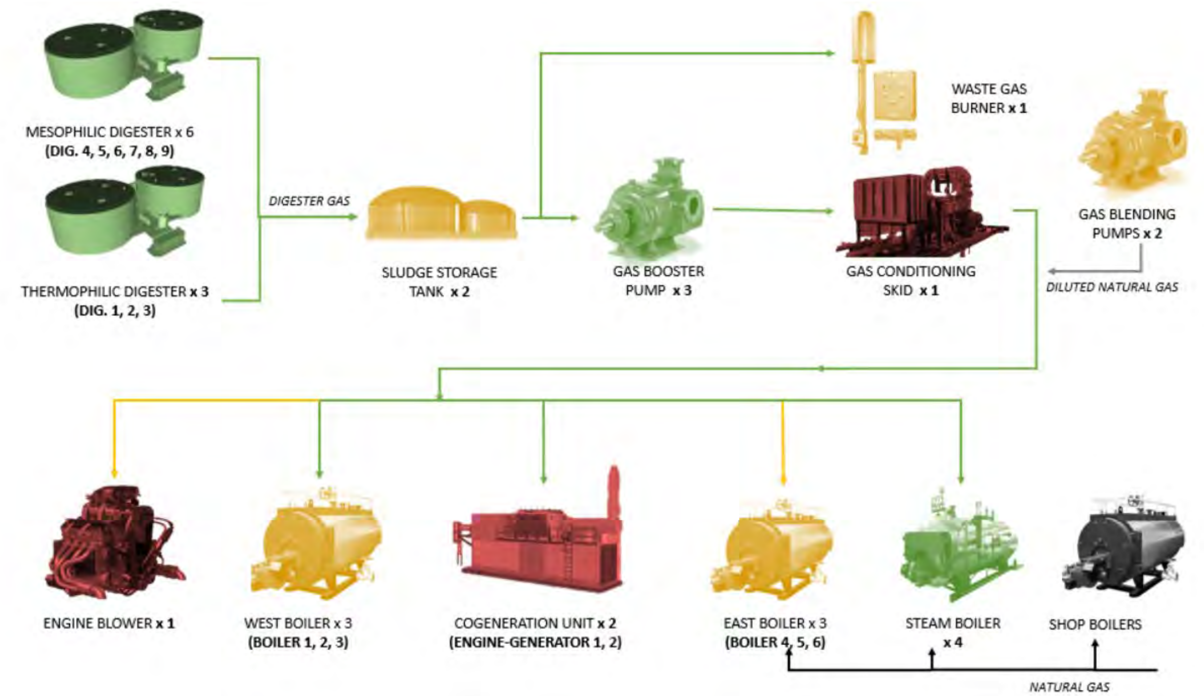


Figure 1.2 NSWTP Biogas Schematic and Asset Scoring

General Asset Background

NSWTP produces digester gas during the anaerobic digestion of their combined primary and waste activated sludge. The combined thickened sludge is fed continuously to two acid phase digesters and then transferred to six mesophilic digesters (Digester No. 4, No. 5, No. 6, No. 7, No. 8 and No. 9). In addition to thickened combined sludge, NSWTP has the ability to feed high-strength waste and fat, oil and grease (HSW-FOG) to their anaerobic digesters using their two whey pumps. It should be noted, though, that the whey wells are not heated nor are they mixed, therefore, this is not regularly done.

The plant generates digester gas from all nine anaerobic digesters (approximately 800,000 cubic feet per day [cfd]) at an average of 60 percent methane. All digester gas is treated in a gas conditioning skid located outdoors before it is used as fuel. Once the gas is pressurized and conditioned, it travels through the pressurized biogas piping to the various end-use equipment. To increase the amount of fuel available when equipment is using biogas and storage levels are dropping, the biogas is amended natural gas to produce blended gas (a combination of natural gas and air). A waste gas burner is used to combust excess biogas as needed.

Biogas Equipment Asset Scoring

The biogas infrastructure evaluation assessed the condition of the following equipment:

- Digester gas collection equipment, such as digester cover gas safety equipment and sludge storage tank covers.
- Gas cleaning and pressurizing equipment, such as gas booster pumps, blended gas booster pumps, and gas conditioning skid.
- Gas using equipment, such as engine-generators, boilers, and waste gas burner.

Overall, the biogas equipment system assets received a score of 14, which is shown visually in Figure 1.2. The Shop Boilers (shown in black) were not evaluated as part of this study since they do not run on biogas, but plant staff have indicated that the boilers are nearing the end of their useful life, are showing signs of deterioration, and will require replacement in the next several years.

System Evaluation Results

Having a resilient and streamlined biogas producing, conditioning and distribution process is necessary when looking at improving energy efficiency at the NSWTP. The main limitations found for the biogas production, conditioning and distribution that could be an obstacle to progress in achieving MMSD's goals are:

- Digester Gas Storage:
  - Storage capacity is limited, and the fixed digester covers do not offer any additional capacity.
- Digester Gas Conditioning System:
  - Serves as a bottleneck in the biogas utilization system. Its occasional seasonal throughput issues make reliability a concern.
  - The asset should be rehabilitated to improve biogas usage.
- Biogas Pressure Control and Distribution:
  - Gas distribution and transfer from the storage tanks to the end-using equipment is poor due to inadequate pressure control.
  - The system is imbalanced and adjusting biogas pressure set points, improving controls, and/or consolidating biogas-using equipment to a centralized location may improve the biogas storage and distribution to the end-uses.

1.3.3.3 Thermal Assets

The evaluation of thermal assets included the main equipment playing a fundamental role in the production of thermal energy, thermal transfer, and thermal usage.

Figure 1.3 presents a summary of the thermal production, transferring and usage at MMSD´s NSWTP, as well as a color-coded representation of the asset scoring:

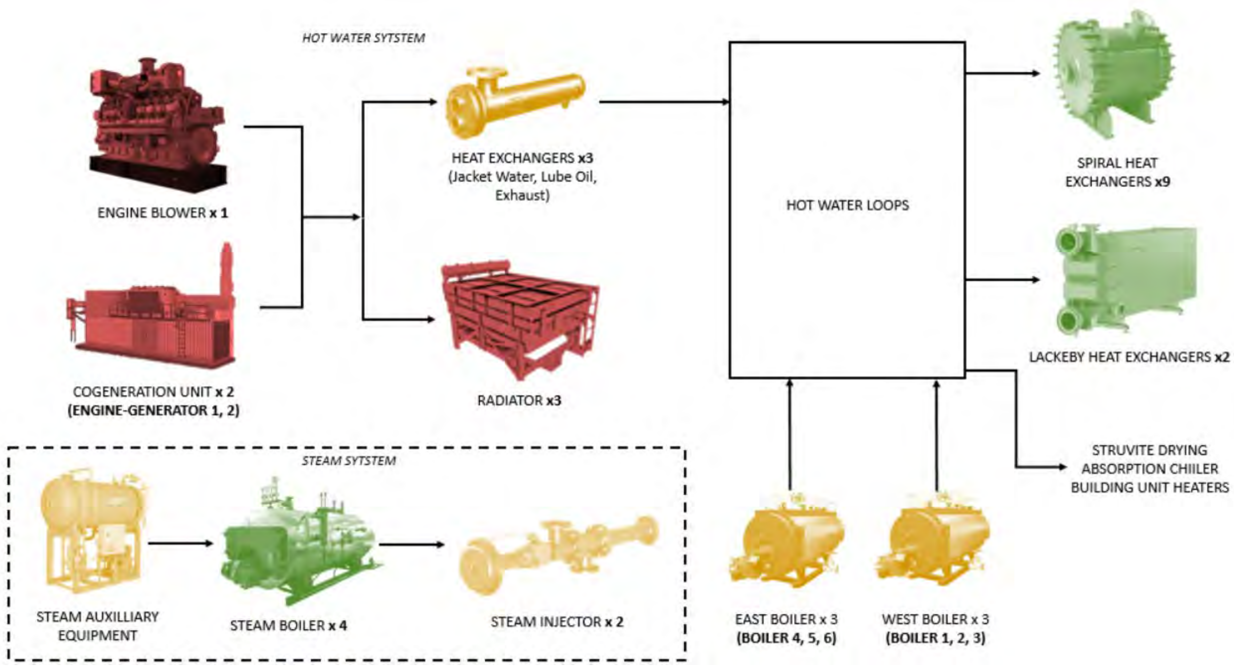


Figure 1.3 NSWTP Thermal System Schematic and Asset Scoring

General Asset Background

NSWTP has four hot water loops: North, Central, East, and West. The North loop, or Shop loop, is separated from the others at the North end of the facility and supplies hot water to Shop Buildings 1 and 2, Storage 1 and 2, and the Effluent Building. The East, West, and Central loops are interconnected and supply hot water to the heating units and process equipment throughout the plant, excluding the buildings serviced by the North loop.

Waste heat from the engines is the primary source of heat entering into the system. NSWTP captures heat mainly from the lube oil and jacket water with the option to extract from the exhaust, if needed. Supplemental heat is provided by the West and East boilers. The primary uses of heat from the hot water system are digester heating, HVAC system use, and the struvite dryers.

There are nine spiral heat exchangers for digester heating: six are used to maintain mesophilic digester temperature and three maintain thermophilic digester temperature. MMSD also has two operational Lackeby heat exchangers to bring temperatures up to thermophilic conditions. NSWTP also operates four steam boilers to supply steam solely for the acid phase digesters. The boilers' firing is based on steam demand for the digester heating. Due to inconsistent loading, the boilers may fire several times in an hour.

Thermal Equipment Asset Scoring

Overall, the thermal system assets received a score of 15.1. This was primarily due to the poor condition of the thermal generation equipment, particularly the engine blower and engine generators. The schematic in Figure 1.3 presents the scoring summary for the main thermal system assets at NSWTP.

System Evaluation Results

The thermal system is comprised of several critical subsystems located across the facility. The system as a whole is difficult to balance and operate mainly due to the following limitations:

- Geographical Location of Heat Sources and Sinks:
  - The system layout makes it difficult to effectively transfer heat from one loop to another.
- Variable Demand Caused by Operational Equipment:
  - The variety of relatively stable thermal demands (i.e. digesters) versus the instantaneous and variable thermal demands (absorption chiller and struvite dryers) creates a system bottleneck.
- Lack of Automation and Set Operating Procedures:
  - System operation is dependent on a combination automated and manual control, which along with the shifting thermal demands of the system requires extensive inherent operator knowledge for efficient operation.
  - Operating knowledge required includes knowing when to shift flow, manually start/stop boilers and heat exchangers, and projecting seasonal demands. This increases system complexity that produces another major bottleneck.
- Capacities and Inefficiencies of Thermal Equipment:
  - Many of the critical assets in the thermal system are inappropriately sized for their current application.

1.3.3.4 Controls Assets

General Asset Background

The control assets associated with the biosolids, biogas and thermal systems were reviewed as part of the overall system operability. The systems were evaluated for the existing conditions and the availability to accept controls/instrument changes that may be recommended to improve efficiency.

Control Equipment Asset Scoring

The control assets evaluation assessed the condition of the instrumentation, programmable logic controller (PLC) and control infrastructure. Overall, the control assets received a score of 10.8. Out of the control assets evaluated, the control infrastructure for the generator at the Sludge Control Building No. 2 received the worst score (19), due to the control panel not having room for expansion and the PLC reaching its life expectancy. It should be noted that this issue is currently being addressed and that engine generator panels are in the process of being replaced.

System Evaluation Results

Overall, the instruments are relatively new and appear to be maintained. Control panels are installed in acceptable environments. There are four locations with PLCs that should be upgraded as part of process improvements. The process equipment allows for manual operation, which reduced the criticality of a control asset failure.

1.3.3.5 Summary of Overall Results

A visual depiction of the Consolidated Total Score distribution for the evaluated assets is depicted in Figure 1.4 below. The Consolidated Total Score combines the Process and Operations category score with the Replacement Prioritization Category score that results in a possible scoring range from 3 (best asset condition) to 27 (worst asset condition). The number at the top of each column presents the number of assets that received a Consolidated Total Score within a particular score range (z-axis) for each treatment process (x-axis).

According to the results of this visual depiction of the asset scoring by treatment process area, the engine blowers and engine generators are the greatest area of concern and in greatest need of addressing, with all assets scoring in the poor condition range. The WAS thickening process area should be considered the second greatest area of concern with the second highest proportion of assets scoring in the poor condition range (43 percent).

On the flip side, a number of treatment process areas had all assets with condition scores of fair or better including primary sludge thickening, digester mixing and recirculation, sludge storage/cooling tanks, biogas safety equipment, biogas boosting and treatment, and digester heat exchangers. Among these treatment process areas, biogas safety equipment (92 percent), biogas boosting and treatment (92 percent), and digester heat exchangers (100 percent) had the highest proportion of assets that received a good condition score.

This figure can be utilized to help inform and guide decision making regarding the proper allocation of resources. Resources need to be invested in the most cost-effective way possible, prioritizing the assets in need of rehabilitation or replacement over those still in good and operable condition.

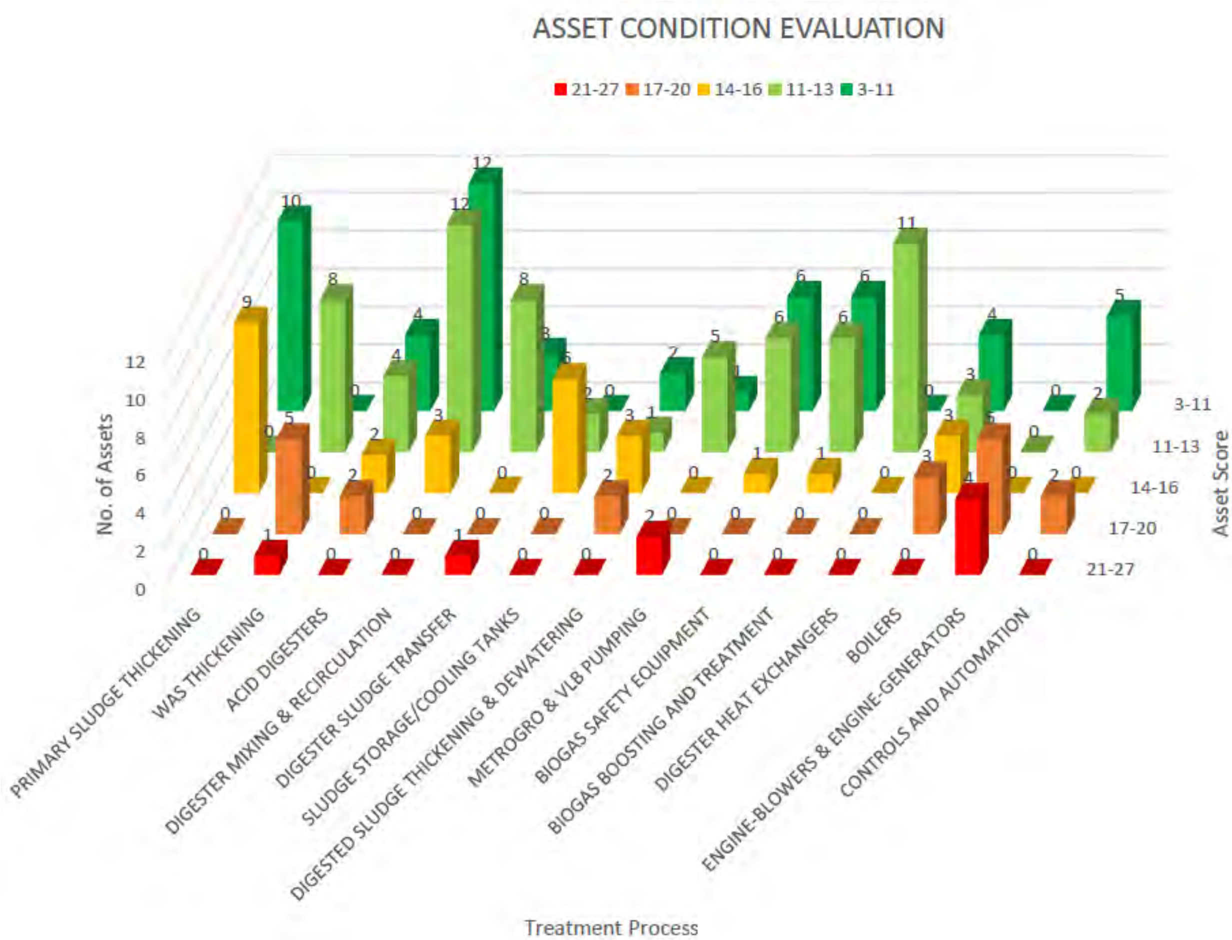


Figure 1.4 Consolidated Total Score for Evaluated Assets - Organized by Process

Common themes and challenges across the three systems (biosolids, biogas, and thermal) were observed during the asset evaluation:

- Individual Asset and System Capacities:
  - Imbalance in the capacities of individual assets compared to the systems as a whole creates a challenge, with some processes underloaded, while others are highly loaded.
- Physical Location Challenges:
  - The systems are physically distant, which presents challenges with the biogas and thermal energy distribution.
- Rely on Manual Operation:
  - Equipment that is central to system operation relies on manual operation with little process monitoring and/or automation.
- Complexity and Interdependency:
  - Each of the systems is complex and highly interconnected; therefore, the efficiency of one system is dependent on the operation of other assets and process systems, with issues in one system propagating to other systems.

1.4 Technical Memorandum 1.3: 2020 Energy Baseline (TM 1.3)[3]

1.4.1 Introduction

Energy baselining was an important step in the energy master planning process. Understanding the current breakdown of energy consumption was used to help target potential savings opportunities and establish the current energy consumption for use in evaluating potential energy optimization alternatives.

Current estimates of energy use for the major equipment groups of MMSD's NSWTP and collection system pump stations are summarized herein. Energy projections were also made for year 2040 conditions (the projected baseline) assuming similar infrastructure at NSWTP is maintained to understand expected future energy outcomes for a status quo operation scenario. The current baseline included the energy use from the previous UV disinfection system that was replaced in 2021. Future energy use projections accounted for energy use changes from the new UV system, but do not consider any energy reductions or increases that would result from upcoming liquids facility upgrades or possible Badger Mill Creek (BMC) phosphorus compliance solutions. The projected baseline accounted only for changes in flows and loadings.

1.4.2 Energy Baseline Summary

1.4.2.1 Annual Energy Use Summaries

Figure 1.5 summarizes the electrical energy use profile for NSWTP from 2007 through 2019. Figure 1.6 shows similar information for MMSD's pump stations, including Pump Stations 9 and 17 which are serviced by Alliant Energy rather than MG&E. Figure 1.7 shows the thermal energy use including the recently installed steam boilers.

[3] See Appendix D for additional information.

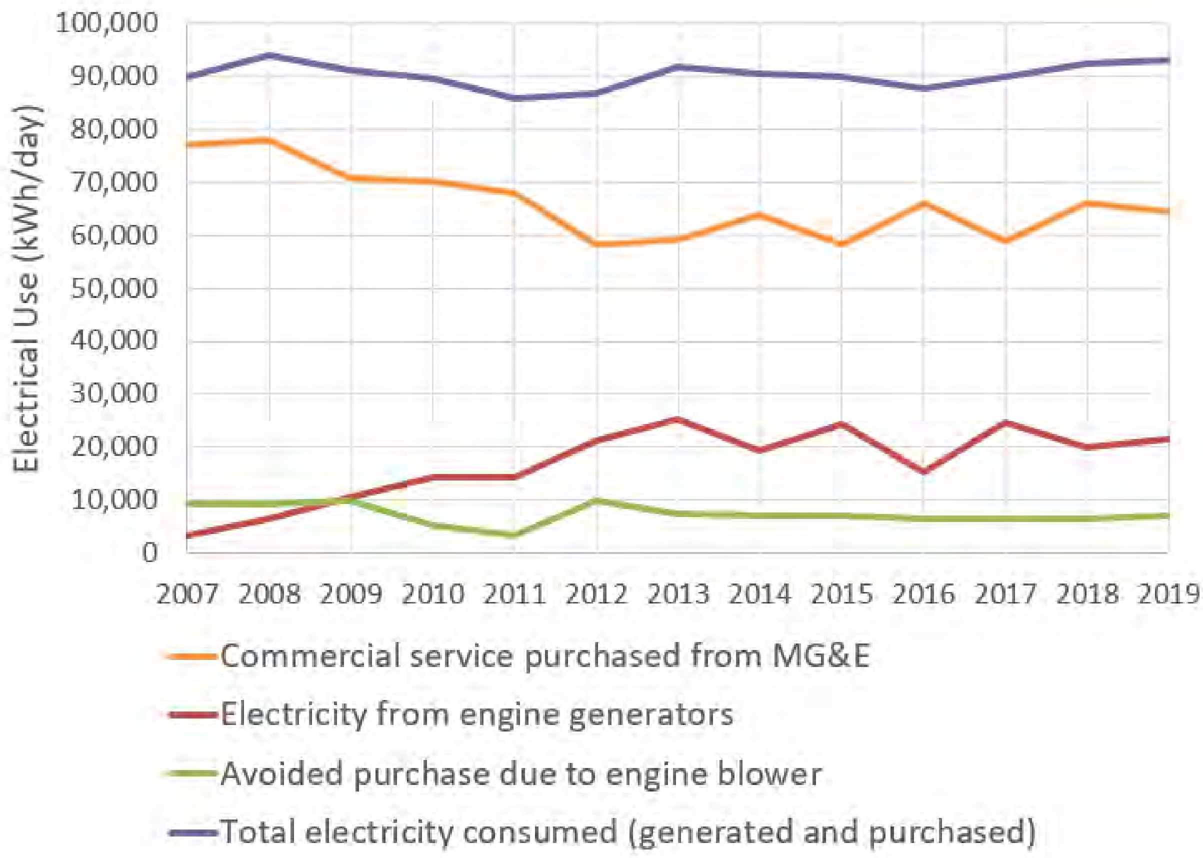


Figure 1.5 NSWTP Annual Electrical Energy Use

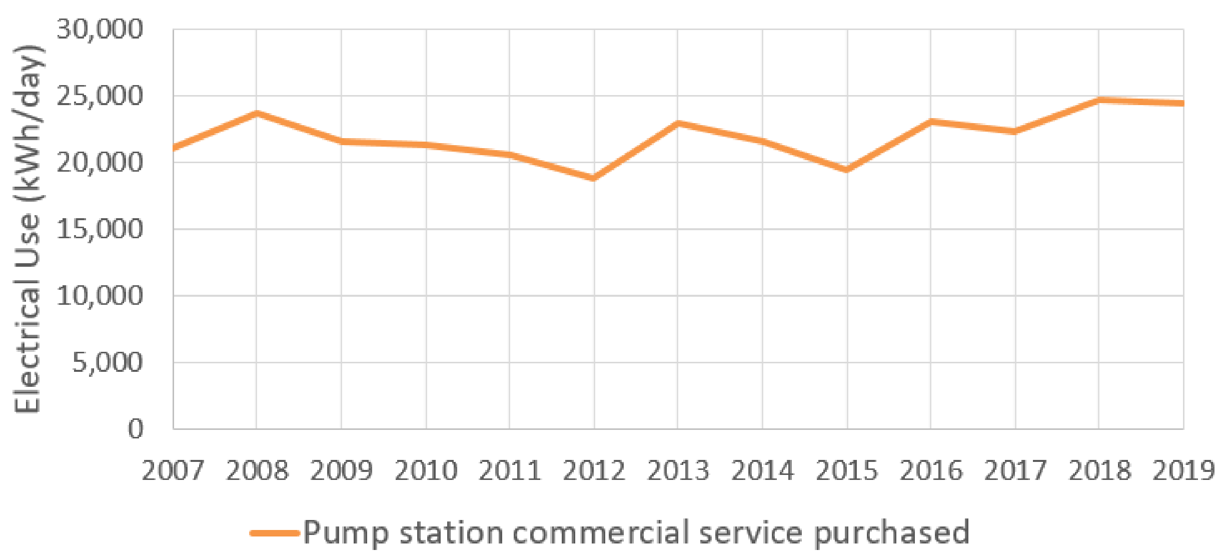


Figure 1.6 Pump Station Annual Electrical Energy Use Summary

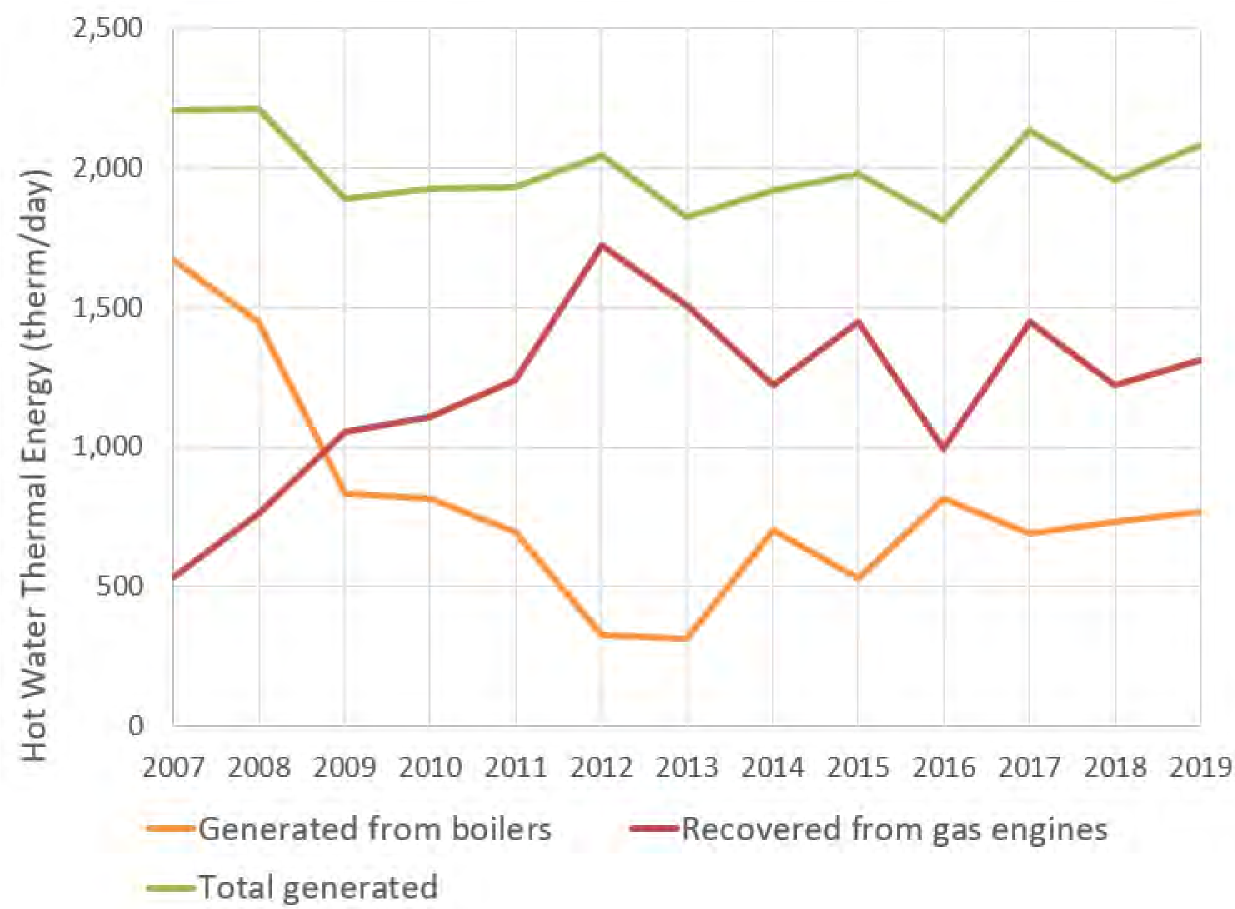


Figure 1.7 NSWTP Annual Thermal Energy Use Summary

Electrical energy use is shown to hold relatively steady across the given time period with on-site electrical generation gradually increasing, while in an inverse fashion, purchased electricity gradually decreases. This suggests that MMSD has already begun trending towards greater energy independence, but as initial gains have become stagnant, there exists room for expansion and an opportunity to extend these efforts even further. In terms of thermal energy use, a shift is observed whereby thermal energy generated from the boilers goes from the greatest contributor to total thermal energy generated to thermal energy recovered from gas engines accounting for a greater portion.

The NSWTP treated a flow of 44.3 mgd on average from 2015 through 2019. On a normalized basis, the NSWTP used 2,150 kWh/MG (purchased and generated power) to pump and treat this flow, not including energy used in the collection system. This average energy intensity is in line with other wastewater treatment plants per reviewed surveys and studies. It should be noted that this energy intensity metric is a very basic first-order method of benchmarking energy performance and does not account for variations in plant sizes, organic loading, or treatment levels.

1.4.2.2 Energy Consumption Types: Electrical, Natural Gas, and Transportation Fuels

Table 1.1 summarizes the various energy inputs to the NSWTP (not including collection system) on a cost, British thermal unit (Btu), and carbon footprint basis.

Table 1.1 Comparison of Purchased Energy Types at NSWTP

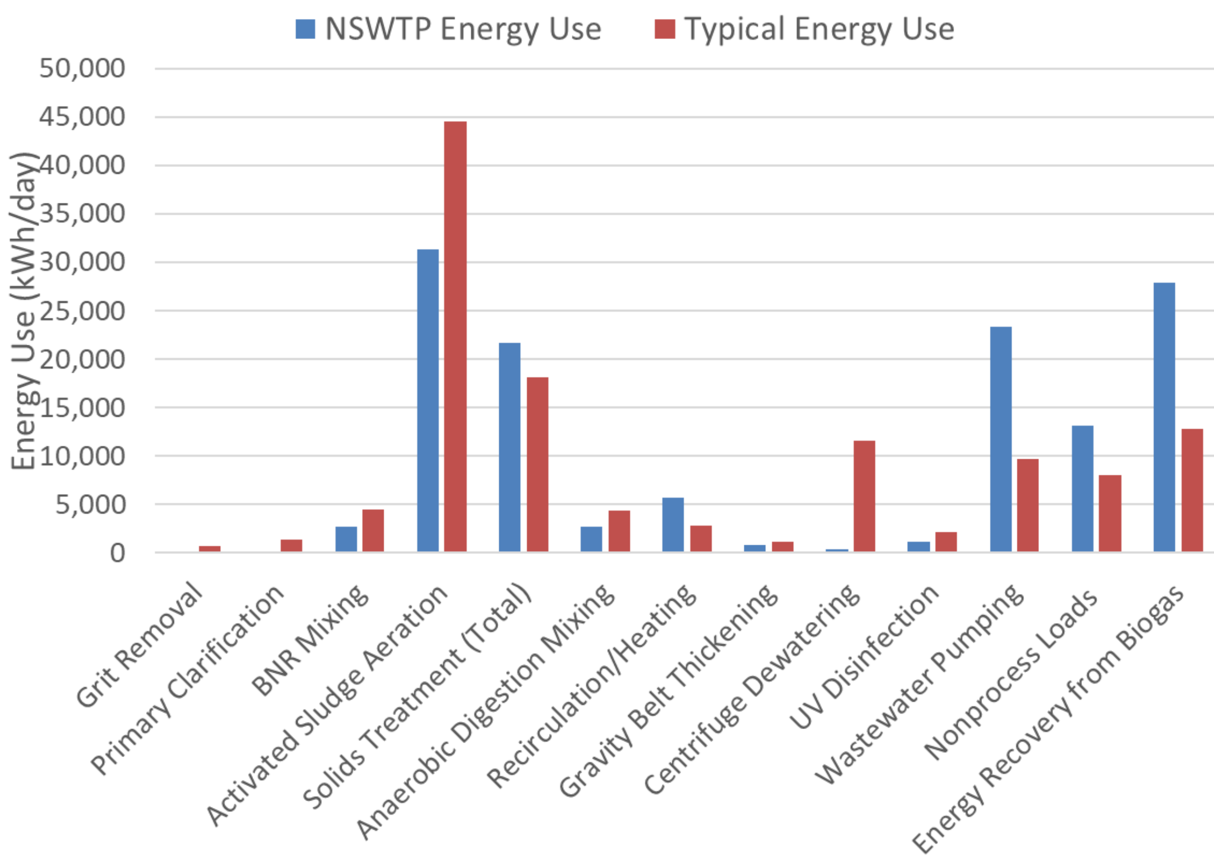
	Purchased Electrical Energy	Natural Gas	Diesel Fuel (2)	Unleaded Gasoline
2015-2019 annual cost	$1,970,000	$53,000	$62,000	$32,000
2015-2019 annual units	22,871,000 kWh	28,100 MMBtu	50,400 gallons	13,100 gallons
Energy conversion	0.003412 MMBtu/kWh	0.100 MMBtu/therm	0.137 MMBtu/gal	0.120 MMBtu/gal
Carbon intensity	1,678 lb CO_2/MWh(1)	117 lb CO_2/MMBtu	22.4 lb CO_2/gal	19.6 lb CO_2/gal
2015-2019 annual energy flow	78,000 MMBtu	28,100 MMBtu	6,900 MMBtu	1,600 MMBtu
2015-2019 carbon footprint from purchased energy	19,200 tons	1,700 tons	560 tons	130 tons

Notes:
(1) Carbon equivalents, EPA eGRID 2018, based on data for the MRO East electrical subregion which serves the majority of central Wisconsin.
(2) Cost does not include the cost of fuel paid by contract haulers.
(3) Abbreviations: CO_2 = carbon dioxide, gal = gallons, MMBtu = million Btu, MWh = megawatt hour.

A notable takeaway is the significant annual cost and carbon footprint contribution for which purchased electrical energy is responsible versus other purchased energy types. Accounting for an overwhelming majority in both categories is justification enough to encourage exploration of electricity demand reductions and/or renewable electricity alternatives to reduce annual costs and have a substantial impact on the carbon footprint of NSWTP.

Figure 1.8 provides a comparison of the electrical use in the unit process areas of NSWTP (collection system not included) compared to a breakdown of comparable wastewater facilities.

Based on the available data, it appears that NSWTP uses less electrical energy than typical for secondary treatment and thickening/dewatering, but more energy than typical for solids treatment/handling and wastewater pumping. NSWTP also appears to recover significantly more electrical energy from biogas compared to typical facilities. Non-process electrical compares well with similar size facilities.



Notes: Typical Energy Use Sources include: WEF "The Energy Roadmap: A Water and Wastewater Utility Guide" 2013, WEF/EPRI "Electricity Use and Management in Municipal Water Supply and Wastewater Industries" 2013, Applied Energy "Monitoring and Diagnosis of Energy Consumption in Wastewater Treatment Plants" 2016.

Figure 1.8 Typical Wastewater Treatment Plant Energy Use and Energy Use at NSWTP

1.4.3 Electric Power Use

This section describes the use of electrical power at the NSWTP, including rates and major electrical consuming equipment.

1.4.3.1 Electric Rates

The NSWTP is billed by MG&E at a CG-6 rate schedule. The NSWTP electrical bills are dominated by consumption (kWh) charges, which account for approximately 74 percent of monthly NSWTP electrical billings. The average cost of power from 2015 through 2019 was $0.086 per kWh and has remained relatively constant during this time frame.

Utilization of renewable or green energy was included in MMSD's goals related to energy management. MG&E offers several programs related to renewable energy that could be utilized by MMSD to fulfill their green energy needs, including Green Power Tomorrow (GPT) and RER.

MG&E has indicated that there is adequate green energy available through the GPT program to satisfy 100 percent of MMSD's energy needs right now. This approach would result in purchasing energy from existing renewable sources at an additional cost of $0.01/kWh for the percentage of green energy selected. While offering the advantage of procuring energy from 100 percent renewable sources immediately, it does not encourage the development of new sources of renewable energy.

1.4.3.2 Existing Equipment: Baseline Studies

The NSWTP has numerous power meters serving each process area. Each process area meter reads the aggregate power draw of the individual equipment groups within the area. The equipment electrical loads within each process area are broken down as follows:

- Liquid Stream Treatment:
  - Largest energy load = 33,400 kWh/day.
- Effluent Pumping:
  - Second largest load = 23,300 kWh/day.
- Other Major Liquid Stream Loads:
  - 4,400 kWh/day.
- Solids Treatment, Handling, and Beneficial Reuse:
  - 18,900 kWh/day.
  - Digesters produce a large portion of the plant's energy, but also contains energy-intensive equipment.
- Building, Lighting, and HVAC:
  - 13,100 kWh/day (with unaccounted for loads).
- Collection System Pump Stations:
  - 23,200 kWh/day.
  - MMSD serves a large geographic with variable terrain, drawing a significant amount of energy to collection pump stations.

1.4.4 Current (Year 2020) and Projected (Year 2040) Baseline Electrical Use

This section provides an overview of annual energy use, summarizes energy consumption types in use at the plant, and includes annual energy use for the projected baseline conditions. The electrical consumption within MMSD's facilities is summarized in Table 1.2 and serves to provide insight into historical annual energy use trends and expectations for the future based on these trends if status quo operation is maintained.

Table 1.2 Current and Projected Electrical Use Summary by Treatment Area

	2014 Energy Baseline (kWh/day)	Current (Year 2020) (kWh/day)	Projected (Year 2040) (kWh/day)
Collections System	19,800	22,800	28,800
Headworks	1,900	2,200	2,300
Primary Treatment	400	400	400
Secondary Treatment	35,900	33,400	39,800
Effluent Pumping and Disinfection	21,700	25,200	31,300
Thickening, Digestion and Post-Thickening	16,600	16,200	18,200
Metrogro Storage, Pumping and Dewatering	3,400	2,700	3,200
Operations Building	4,800	3,400	3,400
Unaccounted for Electrical Use	2,700	7,100	7,100
Total	**107,200**	**113,400**	**134,500**

1.4.5 System-Wide Summary of Major Equipment Electrical Use

Figure 1.9 breaks down the top eight energy use asset categories at NSWTP comparing the 2014 Energy Baseline with the current estimated electrical use and the future projected energy use in 2040. This figure serves to illustrate how energy use has changed over time and based on those trends, forecasts future energy use and distribution across equipment groups, assuming existing operation and systems are maintained. Notable observed trends include the steady increase in the energy use for the Badfish Creek (BFC) pumps and the change in energy demand for the east aeration blowers which decreased from 2014 to 2020 but is expected to rebound according to projections for 2040. In both cases, this can likely be attributed to increases in both flows and loadings.

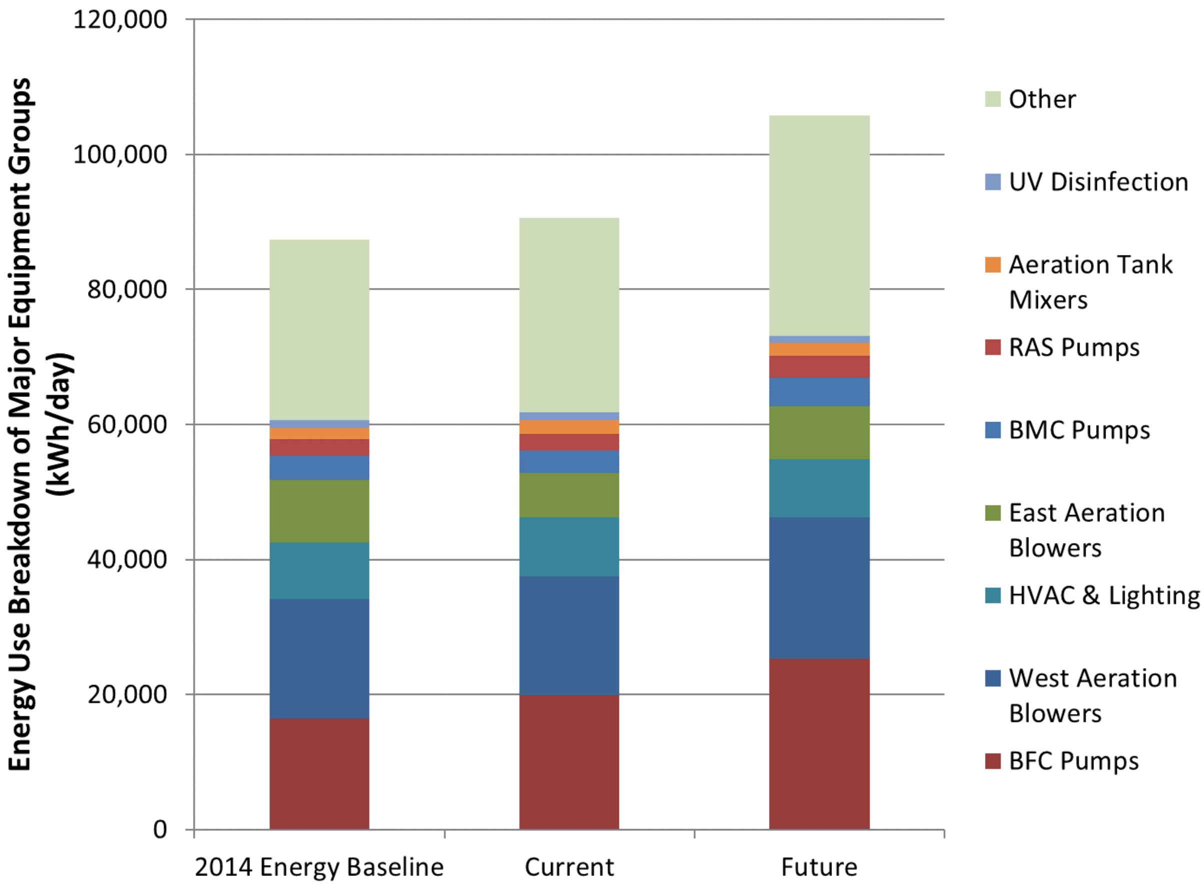


Figure 1.9 Breakdown of Major Equipment Group Electrical Energy Use

1.4.6 Digester Gas and Natural Gas Use

Essentially all digester gas is utilized in engines or boilers at the plant with less than 4 percent of the digester gas being flared on average (mainly in summer months). The plant produces approximately 800,000 cfd of digester gas (18 million British thermal units per hour [MMBtuh]). In addition to digester gas, the NSWTP has four metered natural gas services for the following purposes/locations: blended natural gas, Vehicle Loadout Building heating, Shop 1 Boilers, and East Boiler.

1.4.6.1 Projected Digester Gas and Natural Gas Baseline

Additional influent loadings to NSWTP will increase both digester gas production and the energy required to heat the raw sludge during the digestion process. Table 1.3 summarizes the current (year 2020) and projected (year 2040) values for natural gas and digester gas. Thermal energy captured represents the energy content of all digester gas and natural gas that is beneficially used (i.e. not flared). The thermal energy required represents the total heating demands at NSWTP, not including efficiency losses. Despite thermal energy captured being far greater than thermal energy required for all baselines, additional natural gas is still purchased due to seasonal variations in thermal energy production and requirements. During warmer times of the year, more thermal energy is produced than needed, while during colder times of the year more thermal energy is required than can be produced, requiring natural gas to be purchased to supplement.

Table 1.3 Current and Future Digester Gas and Natural Gas Baseline - NSWTP

	2014 Energy Baseline	Current (Year 2020) Baseline	Projected (Year 2040) Baseline
Digester Gas Production (MMBtu/yr)	150,600	160,300	190,300
Natural Gas Purchased (MMBtu/yr)	32,200	28,100	28,100
Total Thermal Energy Produced/Purchased (MMBtu/yr)	182,800	188,400	218,400
Thermal Energy Captured(1) (MMBtu/yr)	178,900	182,500	194,200
Thermal Energy Required(2), (3) (MMBtu/yr)	83,200	86,100	92,400

Notes:
(1) Future estimate is based on current overall thermal efficiency and current level of use in engine generators and blower engine.
(2) Assumes 15 percent of biosolids are digested at thermophilic temperatures. Does not include efficiency losses.
(3) Thermal energy required includes all thermal demands at NSWTP.
(4) Abbreviations: MMBtu/yr = million British thermal units per year.

1.4.7 Transportation Fuel Use

Fuel represents a relatively small part of MMSD's energy consumption (approximately 3 percent) and includes diesel fuel used by Metrogro hauling contractors.

1.4.8 Greenhouse Gas Emissions Baseline

The GHG emissions (and offsets) baseline is provided in Table 1.4 and summarizes emissions associated with electricity, natural gas, diesel fuel, unleaded gasoline, and biogas combustion and disposal in aeration basins (acid digester gas treatment), as well as those avoided through the generation of electricity and heat onsite from the use of biogas and natural gas.

Table 1.4 Summary of the Current and Projected Greenhouse Gas Emissions in Metric Tons of Carbon Dioxide Equivalents per Year

Source	Current (Year 2020) MT CO_2e/Year	Projected (Year 2040) MT CO_2e/Year
Purchased Electricity	23,750	29,690
Natural Gas	1,490	1,490
Diesel Fuel	270	320
Unleaded Gasoline	120	140
Digester Gas (Combustion)	40	50
Acid Digester Gas Treatment (Aeration Basins)	120	140
Total Greenhouse Gas Emissions	**25,790**	**31,830**
Offset Electrical & Thermal Energy	(23,980)	(25,270)
Total Offset Greenhouse Gas Emission	**(23,980)**	**(25,270)**

Notes:
(1) Abbreviations: MT CO_2e = metric tons of carbon dioxide equivalent.

1.4.9 Conclusion

Energy use at NSWTP and the collection system has increased in recent years due to increases in loadings and flows from the previous energy baseline and is expected to continue to increase if the existing process systems and operational strategy are maintained. An increase in electrical energy use of 20 percent at NSWTP is projected by year 2040 under the status quo conditions. The updated baseline and breakdown of energy consumption helped target potential savings opportunities and assist in evaluating potential energy optimization alternatives.

According to numerous surveys and studies, the average energy intensity at NSWTP is in line with other wastewater treatment plants and when it comes to energy recovery, NSWTP is above average. With NSWTP in line with or better than other wastewater treatment plants in most energy use categories, there is not a clear and obvious initial step to take or assets to replace that would offer a short payback and immediate improvement. The process areas demanding of the greatest attention, though, are the effluent pumping and the solids handling processes given the significant energy demand of each area, and these are the areas where NSWTP underperforms most relative to other plants.

Chapter 2

PHASE 2

2.1 Phase 2 Overview

In Phase 2 of the project, alternatives were developed using an Expert Panel Workshop approach. They were then screened and sorted, followed by a high-level analysis of the alternatives identified as feasible or strategic, to determine which alternatives would be carried forward for recommendation and inclusion in the business case evaluation as part of Phase 4.

2.1.1 Criteria Selection and Prioritization

The Expert Panel Workshop 2.1 (WS 2.1) kicked off Phase 2, where the team identified options that could optimize existing facilities, reduce energy demands, or increase energy production for the biosolids/biogas/thermal/pumping areas. The subsequent alternatives evaluation was completed in a manner that allowed a multitude of options to be systematically winnowed down to those that were feasible and/or strategic, as shown in Figure 2.1. The first step of this process included an initial "binary" screening of each identified option that resulted in "yes" or "no" answers for specific screening. These criteria were weighted relative to their priorities and results of the overall screening step determined those options that were screened out. The team then sorted the alternatives remaining after screening into one of four categories: Simple, Feasible, Difficult, and Strategic.

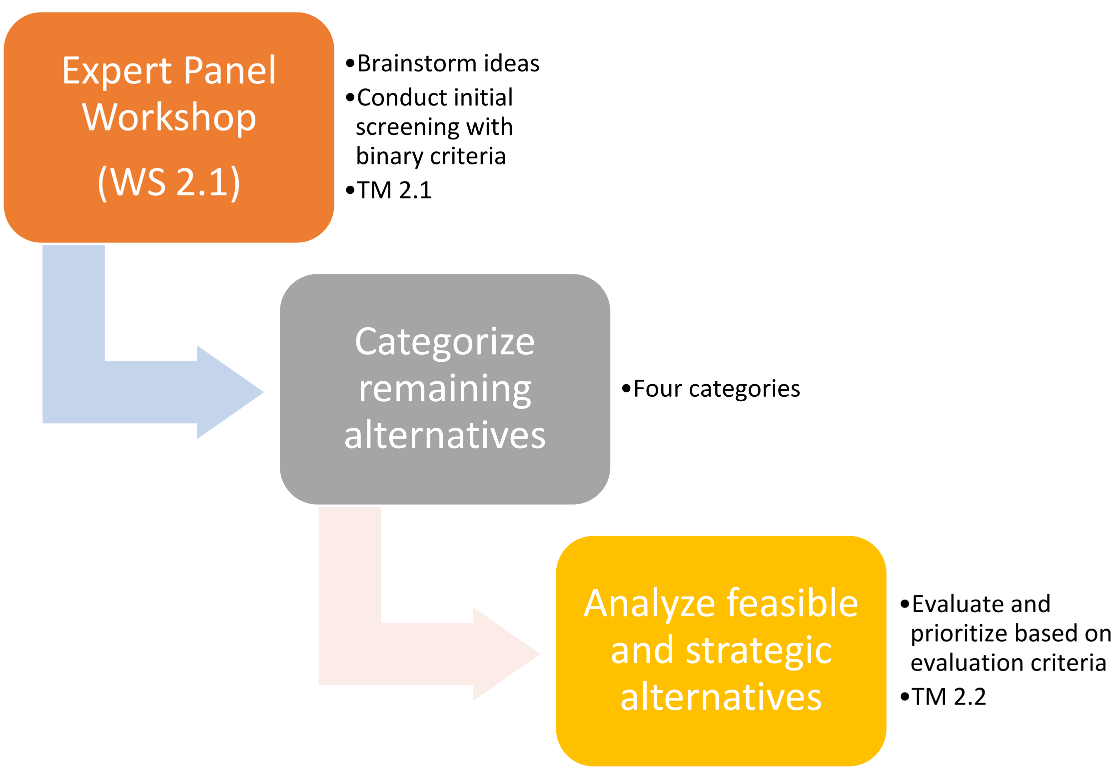


Figure 2.1 Alternatives Developed in Phase 2 were Screened and then Categorized for Further Analysis

2.1.1.1 Selected Priority Criteria for Initial Alternative Screening

The team discussed many potential criteria, which were then voted on by MMSD personnel to determine seven to use for the binary screening. Final questions for the initial, binary screening were developed based on these seven general criteria selected by MMSD.

1. **Improve Reliability/Resiliency (higher priority):** Does this alternative improve reliability or resiliency?
2. **Address Aging Infrastructure:** Does this alternative replace aging infrastructure and/or extend the life of existing systems?
3. **Costs:** Will the alternative cost be low, medium or high? (Low: <$1 M, Medium $1-10 M, High>$10 M)?
4. **Regulatory/Legal Flexibility:** Does this alternative create or maintain flexible platforms to accommodate future regulatory or legal actions?
5. **Technological Flexibility:** Does this alternative create or maintain flexible platforms to accommodate future improvements in technology?
6. **Strategic Value:** Does this alternative offer strategic value?
7. **Increase Use of Renewable Energy (lower priority):** Does this alternative increase MMSD's use of renewable energy within its overall energy portfolio?

These screening questions were used to simply narrow down the identified options to those that meet these absolute minimum criteria.

2.2 Technical Memorandum 2.1: Summary of Expert Panel Workshop (TM 2.1)[1]

2.2.1 Alternative Development and Screening

The Expert Panel Workshop yielded 133 unique alternatives in the following topic areas:

- Emerging technologies.
- Solids processing and management.
- Co-Digestion.
- Biogas.
- Thermal energy.
- Effluent pumping.
- Renewable energy sources.
- Energy storage.
- HVAC/Lighting.
- Automation/control/operating procedures.

The alternatives then received a "binary" screening that resulted in "yes" or "no" answers to the seven screening criteria identified in WS 1.1 and listed in Section 1.1.3.1. "Yes" answers received a score of 1, while "No" answers received a score of 0, with the exception of cost.

These criteria were also weighted relative to their priorities using a pairwise comparison analysis. The matrix generated based on the qualitative rankings and discussions from WS 1.1 and 2.1 that was used to develop the relative weights for the screening criteria is shown in Figure 2.2.

[1] See Appendix E for additional information.

	FINAL								
Criteria	**Improve Reliability/Resiliency**	**Address Aging Infrastructure**	**Costs**	**Regulatory/Legal Flexibility**	**Technological Flexibility**	**Strategic Value**	**Increase Use of Renewable Energy**	**Score**	**Relative Weights**
Improve Reliability/Resiliency	1	1.00	3.00	3.00	4.00	3.00	2.00	17.0	24.2%
Address Aging Infrastructure	1.00	1	3.00	3.00	4.00	3.00	2.00	17.0	24.2%
Costs	0.33	0.33	1	2.00	3.00	3.00	2.00	11.7	16.6%
Regulatory/Legal Flexibility	0.33	0.33	0.50	1	3.00	3.00	2.00	10.2	14.5%
Technological Flexibility	0.25	0.25	0.33	0.33	1	2.00	1.50	5.7	8.1%
Strategic Value	0.33	0.33	0.33	0.33	0.50	1	1.50	4.3	6.2%
Increase Use of Renewable Energy	0.50	0.50	0.50	0.50	0.67	0.67	1	4.3	6.2%
Total								**70**	**100%**

Figure 2.2 Pairwise Matrix for Screening Criteria Weighting

In addition to the weighted score, the team also discussed and answered questions for each topic area to determine which alternatives to carry forward to further sorting. Two of the questions asked for each topic area included:

- What are the top 3 alternatives that you think would have the greatest positive impact on Reliability or Resiliency?
- What are the top 3 alternatives that you think would be most Strategic?

Based on the process of screening, scoring, and identification of alternatives that were consistent with MMSD's goals, objectives, processes, and interests, of the 133 alternatives developed, a total of 61 were recommended to be carried forward to the sorting phase. Figure 2.2 depicts a summary of the screening results per category.

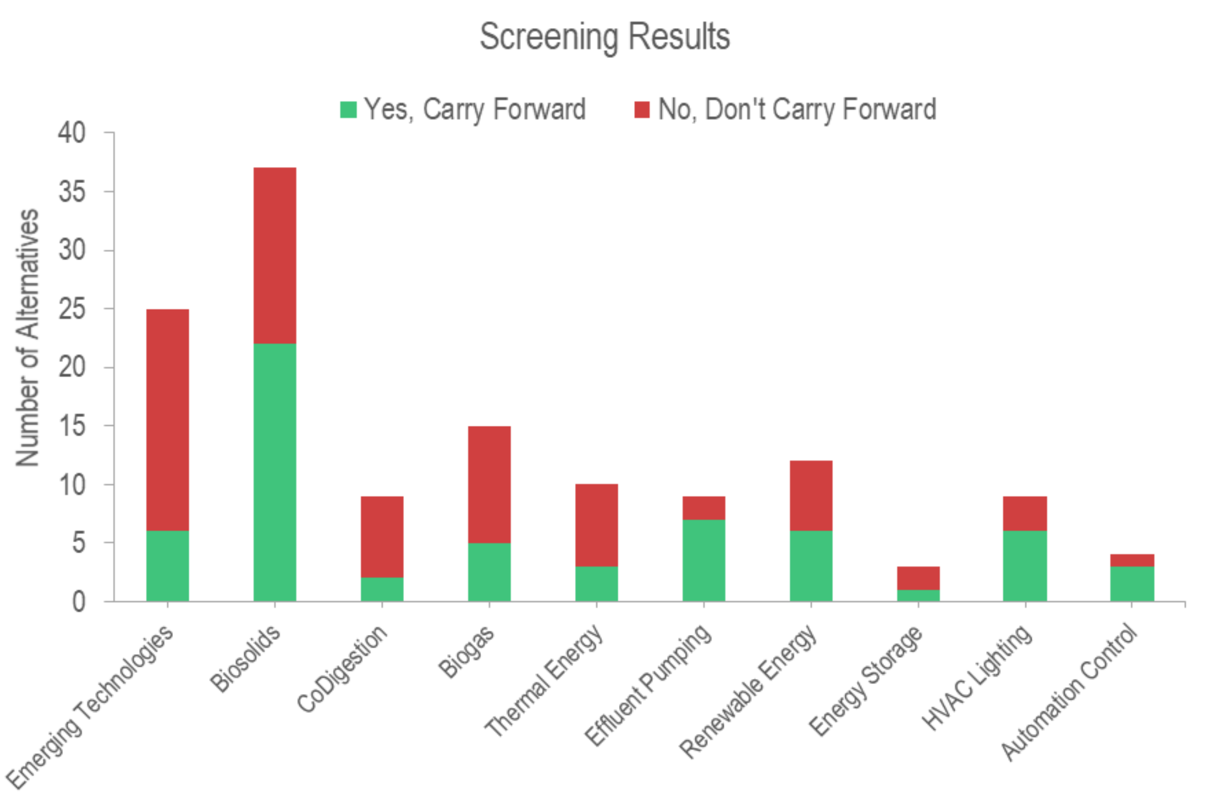


Figure 2.3 Summary of Screening Results by Category

2.3 Technical Memorandum 2.2: Alternatives Evaluation (TM 2.2)[2]

2.3.1 Background

2.3.1.1 Alternatives

The 61 alternatives recommended to be carried forward after screening were sorted into one of four categories: Simple, Feasible, Difficult, and Strategic which are defined as follows:

- **Simple alternatives** are those that are easy to implement and are recommended to be implemented by MMSD. Because these alternatives are relatively straightforward to implement, they were not evaluated further as part of this Project.
- **Difficult alternatives** are those that are hard to implement (e.g. large time and financial investment, highly complex technology, complex operationally, etc.). As such, these alternatives were recommended to be tabled and revisited at a future date.
- **Strategic alternatives** are those that are hard to implement today but are anticipated to have a high impact. Alternatives in this category were evaluated further during Phase 2.
- **Feasible alternatives** are those that are easy to implement, but that are anticipated to have a low impact. Alternatives in this category were evaluated further during Phase 2.

This categorization of alternatives was intended to identify alternatives, those considered Feasible or Strategic, that could most likely be incorporated into this work with a measurable impact and therefore, warranted the most attention and exploration into their individual merits and features. This approach was considered the most effective means of allocating time and resources by avoiding devoting said time and resources on alternatives that could either be easily added on or alternatives that would be too difficult implement at this time.

The categorization results after discussion and sorting are summarized in Figure 2.3. A total of 26 alternatives were determined to be either strategic or feasible. These alternatives are summarized in Table 2.1 with a high-level analysis of each included in the following sections.

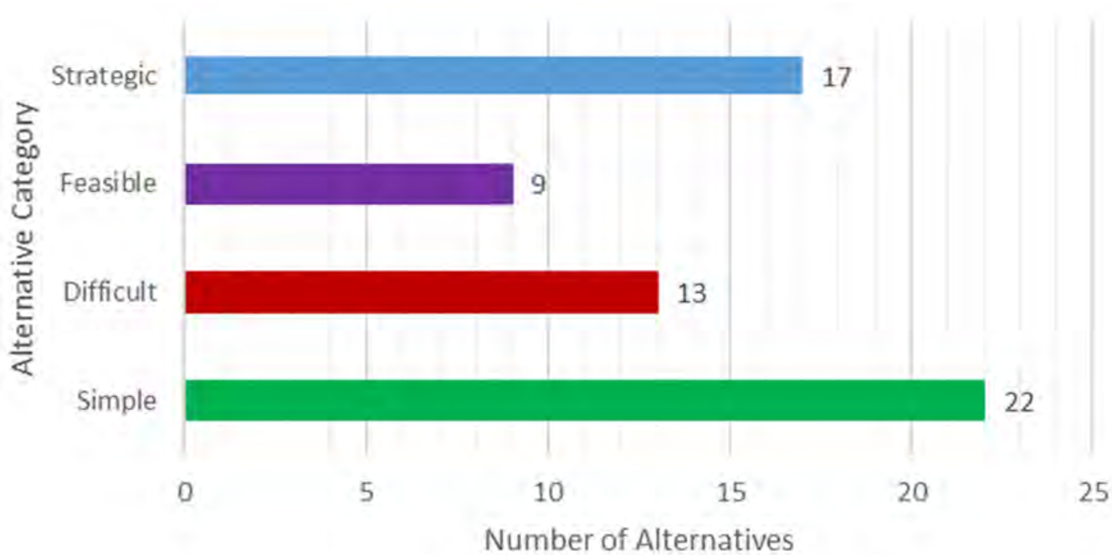


Figure 2.4 Summary of Categorization of Alternatives

[2] See Appendix F for additional information.

Table 2.1 Summary of Strategic and Feasible Alternatives

Option ID(1)	Option Name	Description	Category
BG6	Status Quo Operation (Engine-Driven Blowers; Boilers; Cogen Engines) with Replacement of Aging Equipment	Continue use of biogas for engine-driven blowers, existing boilers and cogen; replace aging equipment as needed.	Feasible
BG7	Replace Cogeneration with Microturbines	Replace existing cogeneration engines with new microturbines.	Feasible
BG9	Upgrade Cogeneration to Handle all NSWTP Electricity Needs	Install centralized cogeneration facility to produce all needed electricity on site using combination of biogas and/or natural gas. Eliminates risks associated with connection to electricity grid. Can recover excess waste heat.	Strategic
BG14	Condition Biogas for Pipeline Injection	Condition biogas to natural gas standards and inject into pipeline. Capture RIN credits.	Strategic
CD1	Co-Digest Food Waste Slurry from Solid Waste and Food/Beverage Processing Waste (All Digesters)	Receive food waste slurry (from a solid waste base source; pre-processed offsite by waste management firm) for co-digestion in all digesters to increase biogas production. Includes new waste receiving station and needed appurtenances.	Strategic
CD2	Co-Digest FOG (All Digesters)	Receive FOG for co-digestion in all digesters to increase biogas production. Includes new FOG receiving station and needed appurtenances. Gas collection, metering, and utilization systems remain common for all digesters.	Strategic
EP1	Install VFDs and Optimize Pump Operations	Install VFDs on the five (5) effluent pumps and optimize pump operations including automation/controls.	Feasible
EP4	Gravity Discharge to NSC	Eliminate pumped discharge and add gravity discharge to NSC (need to understand regulatory and treatment needs).	Strategic
EP7	Eliminate BMC Discharge	Eliminate BMC discharge and use of associated pumps/piping. Pump all flow to BFC.	Strategic
EP8	Hydroelectric Generation	Install kinetic energy recovery devices on gravity liquid streams, such as gravity pipes, UV channel outfall, west plant aeration tank outfall to mixed liquor channel, etc.	Feasible
EP9	Partnership or Incorporation with Sun Prairie WWTP	Send flow from east side pump stations to Sun Prairie WWTP. Reduce re-pumping pump station flow several times and effluent pumping. Possibly process Sun Prairie biosolids at NSWTP.	Strategic
ES1	Battery Storage and Microgrid	Energy storage for peak shaving or short backup and utilization in overall microgrid setup; reduce demand and/or peak; incorporate solar.	Strategic
RE1	Rooftop Solar	Install solar on various NSWTP building roofs.	Strategic
RE3	Large Scale Solar Array (>1 MW)	Build large scale (>1 MW) solar array on MMSD property. Perhaps in field between NSWTP and PS 11 (could service both facilities).	Strategic
TH3	Simplify Heat Loop	Simplify system and increase thermal energy conveyance ability across plant. Reduce bottleneck and process "traps".	Feasible

Option ID[1]	Option Name	Description	Category
ET6	Biosolids Pyrolysis	Implement pyrolysis for digested biosolids, Syngas and biocarbon, or heat, power, CNG, liquid fuels, hydrogen.	Strategic
ET15	Biosolids Gasification	Gasification of biosolids in a gasifier with limited oxygen to convert biomass into a combustible syngas primarily composed of carbon monoxide, hydrogen and methane and biochar.	Strategic
BS2	Class B Non-Steam Based Thermal Hydrolysis	Implement non-steam based thermal hydrolysis (e.g. LysoTherm) to produce Class B product with better digestibility and dewaterability.	Strategic
BS9	Enhanced Primary Treatment	Divert more organic material to digesters via chemical coagulation/flocculation or filtration. Example CEPT with ferric chloride and polymer in primary treatment.	Feasible
BS14	Meso Acid/Thermo Methane Batch/Meso Methane, Class A Biosolids	TPAD, with mesophilic acid phase before thermophilic batch methane phase tanks followed by mesophilic methane phase tank, to produce Class A biosolids (liquid or cake).	Strategic
BS15	Meso Acid/Meso Methane, Class B Biosolids	Operate only mesophilic digestion and produce Class B biosolids (liquid or cake). Stop thermophilic operations completely.	Feasible
BS22	Biosolids Dewatering	Produce Class A or Class B dewatered cake, as dry as possible with conventional technologies.	Feasible
BS25	Class A Biosolids Through High-Temperature Mechanical Drying	Originally this alternative looked at low-temperature (190 - 300 deg. F) drying to reduce solids volumes and achieve Class A biosolids, as it can utilize waste heat from typical waste heat recovery processes and digestion hot water systems. This was later changed to high-temperature mechanical drying for consistency with the BMP, which is being conducted separately at the same time.	Strategic
BS27	Class A Liquid Fertilizer through Thermo-Chemical Hydrolysis	Implement thermo-chemical hydrolysis to produce Class A liquid fertilizer (e.g. Lystek). Uses low-grade heat and caustic to increase heat and pH for hydrolysis. Requires dewatered cake input and produces liquid, pumpable Class A product (fertilizer).	Feasible
BS29	Incineration with Energy Recovery	Uses incineration to combust biosolids and recovers heat to dry/combust the incoming sludge. Requires dewatered cake to allow for autogenous operation.	Strategic
BS36	Class A with Composting on MMSD Property	Implement composting to produce a Class A biosolids product. Would require bulking material (sawdust, wood chips, etc.), size reduction, and large area for material delivery, compost rows, material turnover, etc. Would also require machinery for bulk material movement/transport and row turnover. May need to be covered to reduce odors.	Strategic

Notes:
(1) Option ID Abbreviations: BG = Biogas; BS = Biosolids; CD = Co-digestion; EP = Effluent Pumping; ES = Energy Storage; ET = Emerging Technologies; RE = Renewable Energy; TH = Thermal Heating.
(2) Abbreviations: BMP = biosolids management plan; CEPT = Chemically-Enhanced Primary Treatment; CNG = compressed natural gas; deg. F = degrees Fahrenheit; FOG = fats, oils, and grease; MW = megawatt; NSC = Nine Springs Creek; PS = Pump Station; RIN = renewable identification number; TPAD = temperature-phased anaerobic digestion; VFD = variable frequency drives; WWTP = Wastewater Treatment Plant.

2.3.1.2 Evaluation Criteria

Each alternative that was sorted as strategic or feasible was assessed relative to the current baseline (i.e. status quo operation) and evaluated based on the criteria defined in Table 2.2.

Table 2.2 Evaluation Criteria with Definitions/Descriptions

	Criteria	Definition/Description
1.	Energy Impact	The overall impact of the alternative on MMSD's 2040 baseline energy usage. This criterion also considered how the alternative impacts MMSD's renewable energy portfolio.
2.	Capital Cost	Conceptual level project cost estimate for implementing the alternative at MMSD's NSWTP.
3.	O&M Cost	Conceptual level annual O&M cost estimates for implementing the alternative at MMSD's NSWTP.
4.	Operational Impacts/ Flexibility	This criterion took into account impacts on current operations, operational complexity of the alternative, and the ability of the alternative to create or maintain flexible platforms to accommodate future improvements. The relative impacts to workforce staffing and required operator knowledge were included in the assessment relative to this criterion.
5.	Aging Infrastructure	The extent to which the alternative addressed aging infrastructure (i.e. in poor condition and/or prohibitively expensive to maintain) by either replacement or ability to discontinue use of existing aging infrastructure. The scores assigned to each of the alternatives evaluated herein correlated to the colored consolidated total score assigned to the existing equipment in TM 1.2. If the alternative included new equipment that would replace a high percentage of existing equipment with a "red" condition score, that alternative would receive an aging infrastructure score of 5. If it replaced existing equipment more in the "green" and "yellow" range, it would receive a score closer to 3. If it did not replace any existing equipment, it would receive a score of 1.
6.	Synergistic Benefit	Whether an alternative offers benefits in more than one process area at the plant, such that overall benefits to the plant are strategic or result in compounding benefits. Those processes that may benefit or be hindered were listed as part of the assessment relative to this criterion. If a specific alternative, when combined with another, potentially offers synergistic benefits that was also noted.
7.	Maturity of Technology	The number and type of installations at wastewater treatment plants (in US, world, pilot-scale, full-scale). Where appropriate and relevant, assessment relative to this criterion included indication of whether the alternative had been implemented in areas similar to MMSD's.
8.	Greenhouse Gas Footprint	Relative impact of alternative on MMSD's overall GHG emissions as compared to baseline operation.

Notes:
(1) Abbreviations: O&M = operation and maintenance.

Pairwise Comparison for Evaluation Criteria Weighting

These criteria were also weighted relative to their priorities using a pairwise comparison analysis similar the screening criteria weighting. Each of the alternatives were assigned a score of 1 through 5 (where 5 is more in alignment with MMSD goals) for each of the non-economic criteria. The weights from the pairwise comparison were applied to each of the scores to obtain a total weighted non-economic score for each alternative.

	FINAL							
Criteria	Energy Impact	Operational Impacts/Flexibility	Aging Infrastructure	Synergistic Benefit	Maturity of Technology	Greenhouse Gas Footprint	Score	Relative Weights
Energy Impact	1	2.00	1.00	1.00	2.00	2.00	9.0	20.6%
Operational Impacts/Flexibility	0.50	1	0.50	0.50	2.00	2.00	6.5	14.9%
Aging Infrastructure	1.00	2.00	1	1.00	3.00	2.00	10.0	22.9%
Synergistic Benefit	1.00	2.00	1.00	1	3.00	2.00	10.0	22.9%
Maturity of Technology	0.50	0.50	0.33	0.33	1	0.50	3.2	7.3%
Greenhouse Gas Footprint	0.50	0.50	0.50	0.50	2.00	1	5.0	11.5%
Total							**44**	**100%**

Figure 2.5 Pairwise Matrix for Evaluation Criteria Weighting

2.3.1.3 Cost Estimating Factors

Conceptual level capital and annual operations and maintenance cost estimates were developed for each alternative. Cost estimates developed represent the Association for the Advancement of Cost Engineering (AACE) International criteria for a Class 5 Planning Level or Design Technical Feasibility Estimate with a typical accuracy of -30 to + 50 percent. Class 5 estimates are used to determine a project's feasibility and to compare and select alternatives.

Capital Cost Estimates

For capital cost estimates, total direct costs were developed using either recently completed project costs or manufacturer budgetary proposals based on the complexity of the alternative.

The total estimated construction cost was developed by adding percentages for estimating contingency, general conditions, and general contractor overhead/profit and then multiplying the percentages by the total direct cost. The total project cost was developed by adding a percentage for engineering, legal, and administrative fees to the total estimated construction cost. Percentages were fixed across all the alternatives and are summarized in Table 2.3.

Table 2.3 Cost Estimating Factors

Cost Factor	Basis
Estimating Contingency	50% of total direct cost
General Conditions	12% of total direct cost
General Contractor Overhead and Profit (GC OH&P)	15% of total direct cost
Engineering, Legal, and Administrative Cost (ELA)	25% of construction cost

Baseline Capital Costs

Baseline capital costs were calculated to account for the costs that would be realized to replace existing infrastructure should the proposed alternatives not be pursued. With this a capital cost differential for each alternative was determined. These baseline capital costs were pulled from the list of planned future asset replacement costs provided by MMSD's asset management program. All costs were based on and reported in 2020 dollars.

Operations and Maintenance Cost Estimates

O&M cost estimates were developed using a combination of process calculations and manufacturer proposals where applicable. Processes were sized based on a 20-year life of assets for all the alternatives, using the 2040 maximum month quantities, and O&M costs were estimated based on the 2040 annual average (AA) quantities. All project and O&M costs are reported in 2020 dollars.

Baseline O&M Costs

Baseline O&M costs were established for the biogas, thermal heating, biosolids, and some effluent pumping alternatives and from which the differential O&M costs could be calculated for each relevant alternative.

2.3.2 Alternative Analysis

The following discussion summarizes the high-level analysis performed on each of the strategic and feasible alternatives. These alternatives present opportunities to amend and improve current plant operations and energy management outcomes while upgrading or replacing aging energy-producing and -consuming infrastructure.

2.3.2.1 Biogas BG6 – Status Quo operation – Replace Existing Aging Biogas Equipment with New Equipment

Alternative Description

This alternative would continue to use the same biogas priority the current system employs, except that two new engine-generators would replace the existing three engines that use biogas (one engine-driven blower and two engine-generators for cogeneration). The new engines would be the lean-burn type, in contrast to the existing rich-burning engines. These new engines have increased electrical efficiency and would generate significantly higher electrical output with significantly lower air emissions.

Description of Modifications Required

The overall biogas system configuration would be similar to the existing condition for this alternative as it includes replacement of existing aging equipment. Operations would remain very similar to current conditions. The following project elements would be included:

- Two new internal combustion (IC) engines located in Sludge Control Building 2 (SCB2) using approximately 22 MMBtuh of biogas.
- New gas conditioning equipment, waste gas burner, and biogas blending system. The existing waste gas burner does not have the capacity recommended for future conditions.
- Removal of the existing three engines that use biogas.
- Replacement of the east and west boilers, including primary hot water loop pumps.
- An additional third engine could be added in the future if MMSD begins implementing co-digestion. A third future engine would need to be located in a different building such as an expansion to SCB3.

This alternative is shown schematically in Figure 2.5.

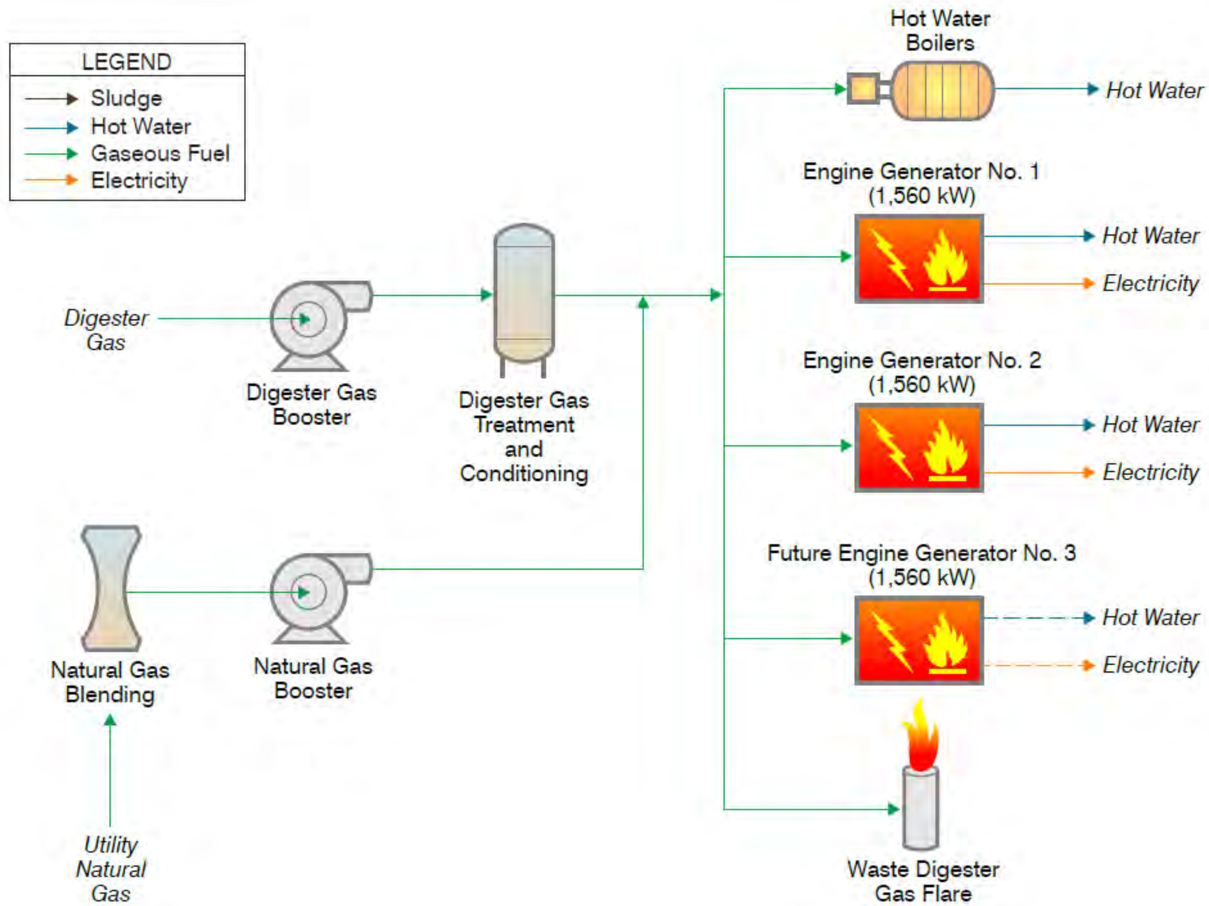


Figure 2.6 BG6 Schematic

Discussion and Considerations

The overall weighted non-economic score for this alternative is 4.15 out of 5, with higher scores being in more alignment with MMSD goals, this is true for all subsequent scores.

This alternative is most similar to current operations compared with all other biogas alternatives. The main benefits of this alternative are familiarity, improved electrical efficiency of the cogeneration system, and replacement of aging infrastructure. However, without co-digestion, NSWTP will still rely on the utility for much of the electrical demand.

The new engines have lower air emissions compared with the existing biogas engines due to more stringent federal regulatory requirements for new equipment. Carbon monoxide will become the hazardous air pollutant with the highest emissions and the limiting factor with respect to the need for a major source air permit. Carbon monoxide emissions could increase from 58,000 lb/year to 185,000 lb/year at 2040 design conditions, without co-digestion, which would approach the current air permit limit of 198,000 lb/year.

2.3.2.2 Biogas BG7 – Replace Existing Cogen with Microturbines (Feasible)

Alternative Description

This option is identical to Alternative BG6 except that microturbines would be used in lieu of engines. Microturbines are gas turbines that burn fuel mixed with compressed air. Microturbines provide relatively clean combustion and low exhaust emissions, particularly with respect to nitrogen oxide (NO_X) components. Heat is recovered off the microturbine exhaust in the form of hot water, which is then used for process heat.

Description of Modifications Required

Like BG6, this alternative would result in minimal modifications to the overall biogas system configuration as it includes replacement of existing equipment. The following project elements would be included:

- New microturbines using approximately 22 MMBtuh of biogas.
- Roof structure placed over microturbines located either south of the existing Boiler Building or exterior to SCB3.
- New gas conditioning equipment, including significant additional compression equipment to deliver the gas to the microturbines at 100 pounds per square inch (psi).
- Replacement of the waste gas burner and biogas blending system.
- Removal of the existing three engines that use biogas.
- Replacement of the East and West boilers, including primary hot water loop pumps.

This alternative is shown schematically in Figure 2.6.

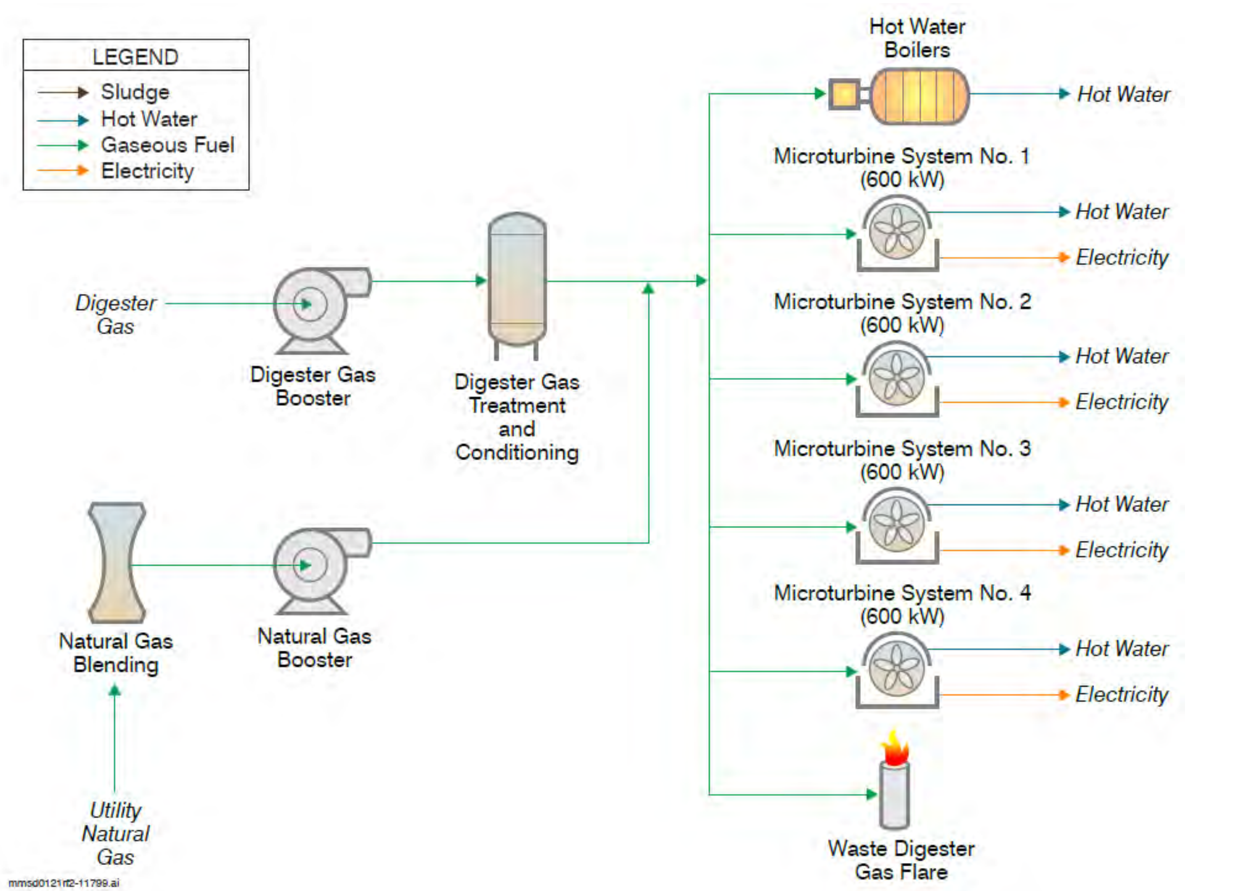


Figure 2.7 BG7 Schematic

Discussion and Considerations

The overall weighted non-economic score for this alternative is 4.15 out of 5.

Microturbines have much lower electrical efficiency compared to new IC engines and require additional gas conditioning. The units should be installed outdoors to provide the greatest efficiency, which requires a roof structure for weather protection. Microturbines would also be an unfamiliar technology for MMSD staff compared with IC engines. This alternative did not appear to have sufficient advantages to warrant further consideration.

2.3.2.3 Biogas BG9 – Upgrade Cogeneration to handle All NSWTP Electricity Needs (Strategic)

Alternative Description

This alternative would change the biogas priority by using all the biogas plus supplemental natural gas in a central IC engine-based cogeneration system to meet nearly all the NSWTP electricity needs. This alternative was considered the most practical means of achieving an energy independence-type operational strategy given the constraints and limitations at NSWTP of other energy independence strategies such as codigestion and battery storage, for example.

Description of Modifications Required

A centralized cogeneration facility would result in modifications to the biogas utilization priority, with all biogas being used in the IC engines. The following project elements would be included:

- Three new IC engines with a total electrical output of approximately 6.0 MW (electrical efficiency ~ 41 to 42 percent). It is not the intent for the engines to supply all power to NSWTP under all conditions; there will still be a connection to utility power.
- New gas conditioning equipment, waste gas burner, and biogas blending system.
- New electrical switchgear and modifications for connection to the heat loop system.
- Significantly more natural gas would be used to supplement biogas if co-digestion is not implemented. Costs are presented for operation with and without co-digestion.
- Removal of the existing three engines that use biogas.
- Replacement of the East and West boilers with natural gas boiler systems, including primary hot water loop pumps. Dual fuel boilers in lieu of natural gas boilers could be installed at a higher capital cost although the annual savings from using digester gas in boilers would be minimal in this alternative. An evaluation of dual fuel boilers for this alternative can be evaluated as a part of future preliminary design efforts.
- Improvements associated with alternative CD1 for the scenario with co-digestion of high-strength waste (HSW).

This alternative is shown schematically in Figure 2.7. The actual engine sizes will vary by manufacturer.

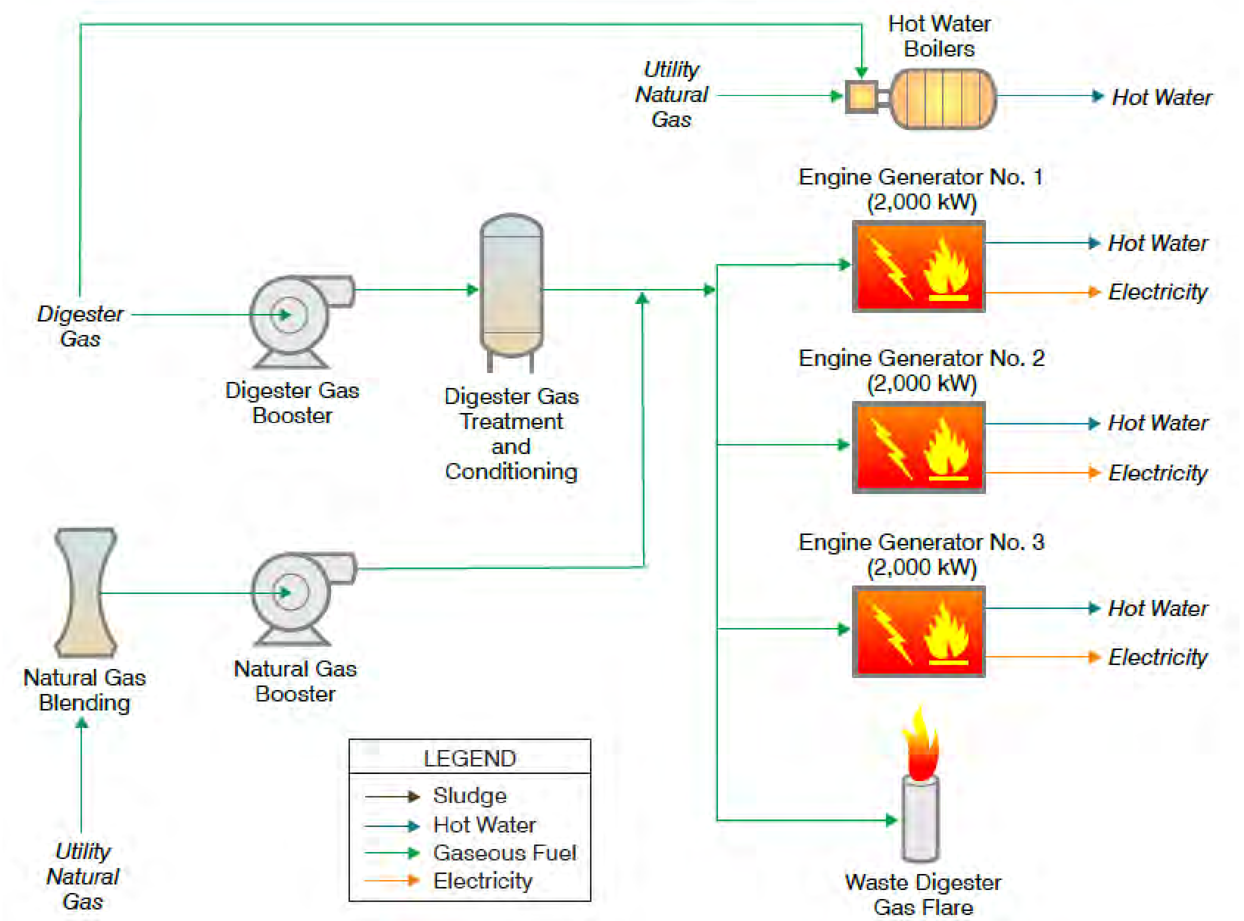


Figure 2.8 BG9 Schematic

Discussion and Considerations

The overall weighted non-economic score for this alternative is 4.89 out of 5. The overall score is the same whether natural gas or co-digestion of HSW is used. Natural gas has the benefit of providing greater operational flexibility. Co-digestion has the benefit of less dependence on the utility for natural gas.

Advantages include MMSD familiarity with equipment, replacement of aging infrastructure, simplification of the overall biogas system, and great reliability and resiliency at NSWTP. Air permitting modifications must be considered as it appears likely this alternative would result in the requirement for air pollution control equipment and/or a major source air permit because uncontrolled emissions of carbon monoxide will be near 100 ton/year.

2.3.2.4 Biogas BG14 – Condition Biogas for Pipeline Quality (Strategic)

Alternative Description

This system removes hydrogen sulfide (H_2S), siloxanes, volatile organic compounds (VOCs), and moisture from the biogas so that it is conditioned to pipeline quality. Carbon dioxide is removed using pressure swing adsorption (PSA) or membranes to produce RNG that can be supplied to a local pipeline. MMSD may install a new connection to a natural gas pipeline or truck RNG to a third-party facility with an existing pipeline connection.

Description of Modifications Required

Conditioning to pipeline quality gas will substantially change the overall operation of the biogas system. All biogas will be routed to the gas conditioning equipment to maximize the revenue from RINs or other RNG markets. Boilers using natural gas will provide all the process heating demand. The associated primary loop upgrades will be refined in a more focused future study depending on the selected biogas alternative. The following project elements would be included:

- New pipeline quality gas conditioning equipment producing up to 21 MMBtuh of biogas without co-digestion of HSW and up to 42 MMBtuh of biogas with co-digestion.
- Removal of the existing three engines that use biogas.
- Replacement of the waste gas burner.
- Replacement of the east and west boilers, including primary hot water loop pumps.
- Either injection of RNG into the ANR Pipeline Company (ANR) natural gas pipeline near the NSWTP or trucking RNG to the Dane County Landfill.
- Injection of RNG into the ANR system requires approximately 3 miles of 4-inch natural gas piping compressed to approximately 975 psi.
- Trucking to Dane County Landfill requires facilities at NSWTP for compressing RNG into tanker trucks at about 3,200-3,800 psi for delivery to the pipeline injection system at the landfill.
- Improvements associated with alternative CD1 for the scenario with co-digestion of HSW.

This alternative is shown schematically in Figure 2.8 below.

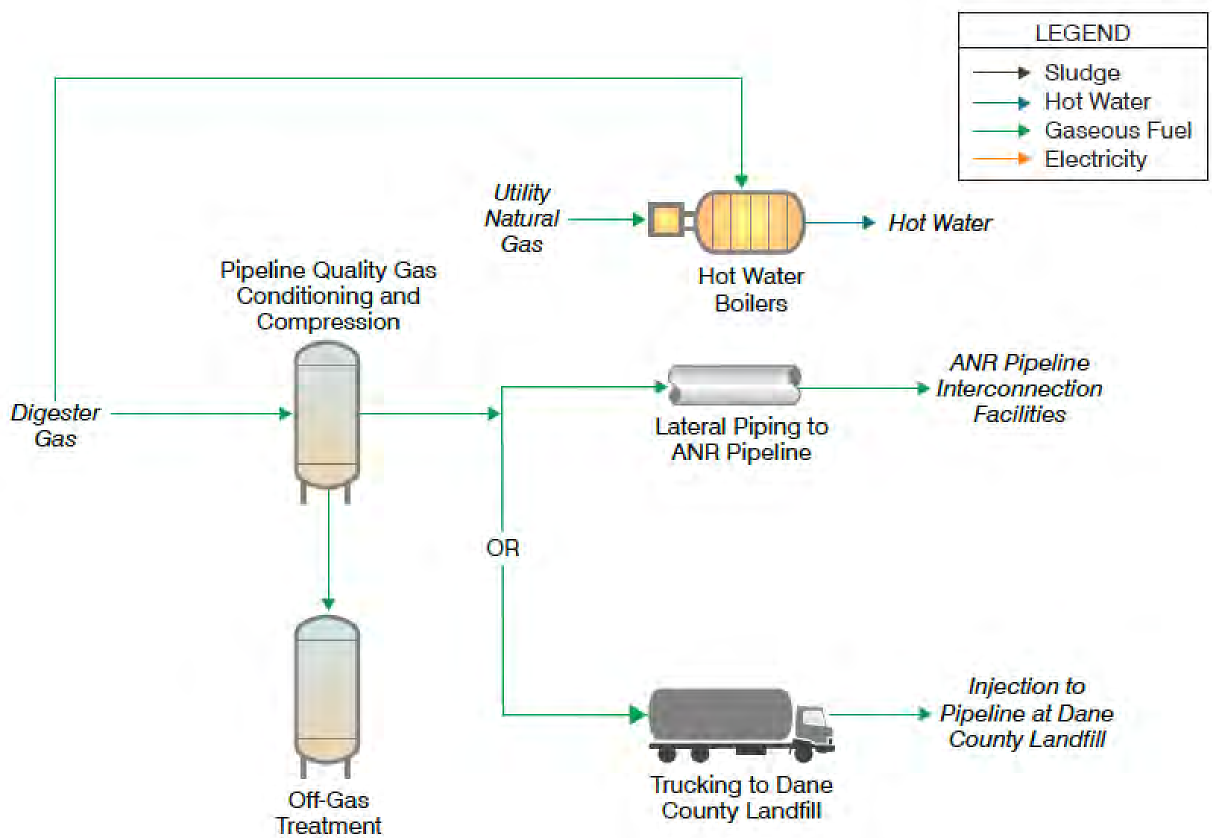


Figure 2.9 BG14 Schematic

Discussion and Considerations

The overall weighted non-economic score for this alternative is 4.23 out of 5.

This alternative offers the advantage of simplifying the infrastructure and lowering the operational complexity by eliminating the cogeneration engines and conditioning all biogas to pipeline quality. By doing so this alternative has the potential for providing a faster payback compared with cogeneration alternatives, but it has a high level of uncertainty because of the fluctuating value of RINs.

2.3.2.5 Co-Digestion CD1 – Co-Digestion of Food Waste Slurry and Food/Beverage Processing Waste in All Digesters (Strategic)

Alternative Description

Food waste slurry and food/beverage processing waste both fall under the larger category of HSW. HSW generally refers to wastes with greater volatile solids concentrations than the PS and WAS currently sent to the anaerobic digesters. HSWs are highly biodegradable and co-digestion with PS and WAS increases the biogas production of the digesters.

Food waste slurry is not currently a readily-available feedstock for co-digestion for MMSD, but opportunities may become available for collaboration with Dane County Landfill on such a project in the future. Food/beverage processing waste is also an excellent feedstock for co-digestion but information regarding HSW feedstocks is lacking and a formal study should be pursued.

For the purpose of analyzing this alternative, it was assumed that food slurry/HSW would be blended with municipal sludge and that the resultant biogas would be utilized for cogeneration.

Description of Modifications Required

Although it appears feedstocks are not readily available for co-digestion of HSW, a hypothetical analysis of the modifications required at NSWTP to accommodate future co-digestion of food slurry/HSW was performed. A preliminary process flow diagram (PFD) for the system is shown as Figure 2.9. The modifications required assume that the food slurry/HSW is processed by a third party offsite.

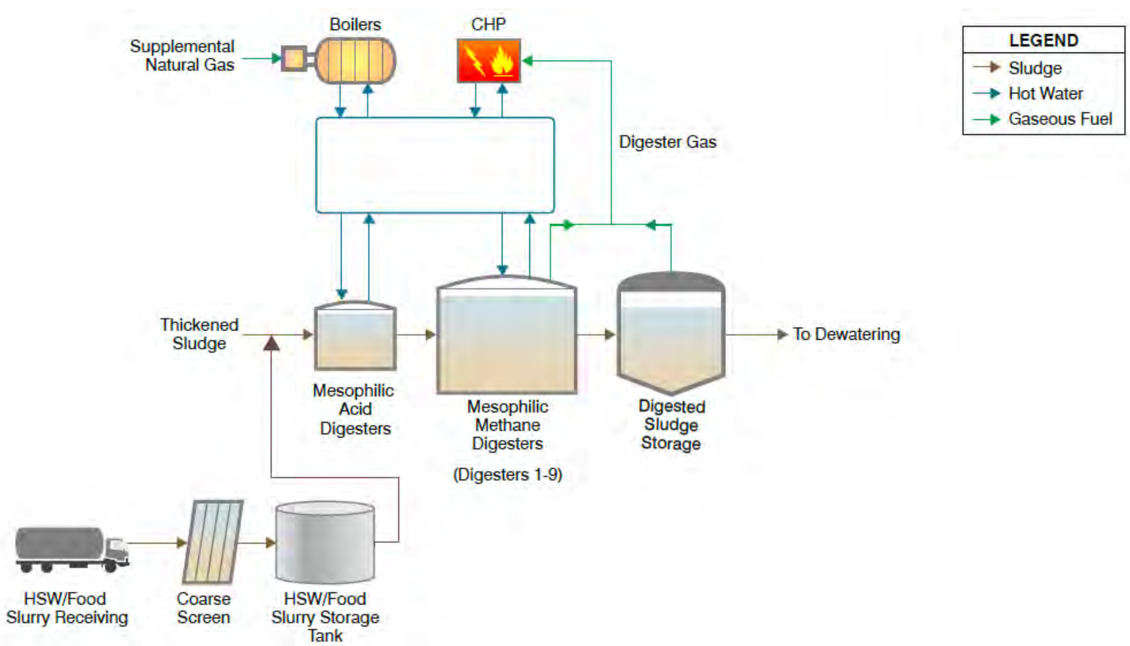


Figure 2.10 HSW/Food Slurry Receiving PFD

Due to the uncertain nature of the feedstock that would be received, it was assumed that the HSW/Food Slurry received would be preprocessed off-site by a waste management firm collaborating with the City of Madison. The system at NSWTP would be comprised of the following components:

- A receiving panel for registration/tracking of haulers.
- Coarse screens (bar screen with approximately 1.5-inch openings).
- Storage tank with 3 days of storage capacity; buried to avoid freezing.
- Mixers to keep solids in suspension within the storage tank.
- Macerators/positive displacement pumps to convey food slurry/HSW to the digesters.
- HSW storage tank heating.

As a preliminary estimate, it was determined that two (2) submersible mixers, each with 5 kilowatt (kW) motors, three (3) macerators, each with 7.5 horsepower (hp) motors, and three (3) positive displacement pumps, each with 7.5 hp motors would be needed. Additionally, somewhat significant paving improvements are likely needed in order to facilitate the requisite number of trucks needed to haul food slurry/HSW to the facility.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 2.94 out of 5.

Overall, this alternative is strategic if and when the HSW/food slurry feedstock becomes available. Major benefits include increased gas production for more onsite renewable energy production and diversion of waste from the treatment process and/or landfills. Major drawbacks include the potential variability and contamination in the HSW/food slurry received, the site improvements that would be needed to accept a large volume of hauled waste, potential digester foaming issues, and maintenance of equipment that handles HSW/food slurry.

2.3.2.6 Co-Digestion CD2 – Co-Digestion of FOG in All Digesters (Strategic)

Alternative Description

The term FOG typically refers to the layer of lipid-rich materials of animal or vegetable origin generated from restaurants, food processors, residences, or food-based industries. FOG waste streams typically have high bioenergy availability. By supplementing the existing PS+WAS digestion with FOG, biogas production can be substantially increased, but can also cause digester upset or even inhibit methanogenesis.

The FOG feedstock presently available represents about 6 percent of the total VS load that would go to the digesters in 2040.The threshold input of 30 percent (w/w) was analyzed to provide MMSD an idea of the potential benefits of co-digestion of FOG, if the feedstock becomes available in the future. As such, part of the analysis for this alternative is to determine the potential market for FOG feedstock for co-digestion.

Description of Modifications Required

Although it appears feedstocks are not currently available for maximal co-digestion of FOG, a hypothetical analysis of the modifications required at NSWTP to accommodate future co-digestion of FOG was performed. The modifications are very similar to those presented in for CD1. A PFD for the system is shown as Figure 2.10.

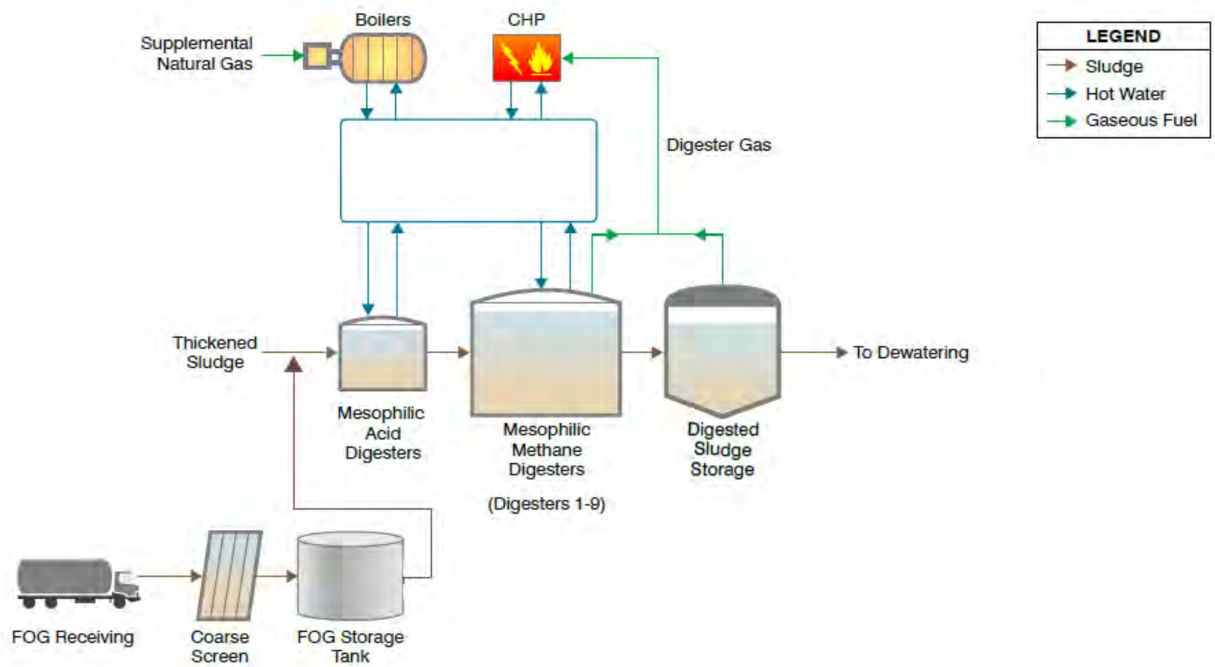


Figure 2.11 FOG Receiving PFD

The system would be comprised of the following components:

- A receiving panel for registration/tracking of haulers.
- Coarse screens (bar screen with approximately 1.5-inch openings).
- A storage tank with 3 days of storage capacity; buried to avoid freezing.
- Mixers to keep solids in suspension within the storage tank.
- Macerators/positive displacement pumps to convey FOG to the digester.
- FOG storage tank heating.

As a preliminary estimate, it was assumed that mixers, pumps, and macerators of the same size as alternative CD1 would be needed. Additionally, somewhat significant paving improvements are likely needed in order to facilitate the requisite number of trucks needed to deliver FOG to the facility.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 2.79 out of 5.

Currently, MMSD receives FOG from haulers at the plant headworks, which causes operational challenges downstream at NSWTP and has negative impacts on energy usage through increased aeration and on pumping and other equipment. Implementation of this alternative would be most strategic if the existing FOG received at the plant were diverted for co-digestion, first.

Major benefits include increased gas production and diversion of waste from the treatment process and/or landfills. Major drawbacks include the potential contaminants and variability in the FOG received, the site improvements that would be needed to accept a large volume of hauled waste, potential digester foaming issues, and maintenance of equipment that handles FOG slurry.

2.3.2.7 Effluent Pumping EP1 – Install VFDs and Optimize Pump Operations

Alternative Description

In this alternative, the pump controls would be modified to operate the pumps on VFDs to optimize pumping operation.

Description of Modifications Required

This alternative includes replacement of the existing effluent pump starters with VFDs, pump motors, and the addition of new controls to optimize pump operation.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 4.07 out of 5.

This alternative would improve operator control of effluent pumping and would allow a slight improvement in pumping efficiency. However, the significant capital cost associated with VFD installation would not be recouped with the anticipated energy savings. As such, this alternative would be best reserved for when current pumps reach the end of their useful life and need to be replaced. Implementation at this time can be offset the capital cost for the VFDs with the pump replacement cost spending that would be required anyways.

2.3.2.8 Effluent Pumping EP4 – Gravity Discharge to Nine Springs Creek

Alternative Description

This alternative includes replacement of the BFC and BMC effluent pumps with a gravity discharge to NSC. Based on current state statutes, it appears that the effluent quality would need to be close to background surface water quality prior to approval of an NSC discharge due to the downstream lakes. According to the WDNR, any permitted discharge to NSC would need to receive tertiary treatment and require limits that are less than the water quality criteria.

Description of Modifications Required

Significant political, social, and economic efforts are required to implement this alternative. The following project elements would be included:

- Potential modifications to Wisconsin State Statute 281.47.
- Tertiary treatment improvements to approximately achieve background surface water quality. The required effluent limits for an NSC discharge are unknown at this time.
- Removal of the BFC and BMC pumps.
- New pipe that intercepts the disinfected effluent pipe upstream of the storage reservoirs and conveys it to NSC.
- Modifications to the existing excess flow lagoon outfall to discharge effluent by gravity to NSC.
- Potential improvements to the drainage way between the existing excess flow lagoon outfall and NSC.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.45 out of 5.

Implementing this alternative eliminates effluent pumping and the associated energy use but will result in significant capital costs and the potential for an increase in energy use for tertiary treatment necessary for an NSC discharge.

2.3.2.9 Effluent Pumping EP7 – Eliminate Badger Mill Creek Discharge

Alternative Description

This alternative eliminates the BMC discharge, assuming that all flow will be pumped to the BFC outfall. Discontinuing the use of this outfall should be coordinated with WDNR and other stakeholders within the Sugar River watershed. Removing the BMC discharge would reduce effluent pumping costs and eliminate the impact from the proposed 0.075 milligrams per liter (mg/L) phosphorus limit for the BMC outfall. In addition, it would obviate the need to maintain the BMC force main and pumps, while saving on both O&M and lab labor.

Description of Modifications Required

This alternative includes removing the BMC pumps. All flow will be pumped to the BFC outfall, which can accommodate the additional BMC flow.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 4.38 out of 5.

Implementing this alternative results in lower energy use and avoidance of future capital costs associated with the BMC phosphorus limits.

2.3.2.10 Effluent Pumping EP8 – Hydroelectric Generation

Alternative Description

This alternative includes the addition of hydroelectric generation equipment to capture energy from flowing wastewater within the NSWTP. It may be feasible to utilize the available hydraulic drop at certain structures during average flow conditions to produce electricity using hydro turbines. There is approximately 3 to 4 feet of drop available at certain structures under average flow conditions. However, there is very little hydraulic drop available under peak flow conditions.

Description of Modifications Required

This alternative includes the installation of one or more hydroelectric turbines at locations with hydraulic drop available throughout the NSWTP, and connection of those turbines to the NSWTP electrical system. For the purposes of this evaluation, it was assumed that a 6.6 kW system is installed.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 2.54 out of 5.

Due to the minimal benefit of adding hydroelectric generation at NSWTP, this alternative did not warrant further consideration.

2.3.2.11 Effluent Pumping EP9 – Partnership or Incorporation with Sun Prairie WWTP

Alternative Description

This alternative includes pumping flow from PS 13 to the Sun Prairie WWTP. This would decrease the average flow to NSWTP by about 16 percent, while approximately doubling the flow to the Sun Prairie

WWTP. Pumping flow from the east side of Madison to Sun Prairie rather than to NSWTP would reduce overall pumping costs for MMSD.

Description of Modifications Required

This alternative includes construction of a new force main connecting PS 13 to the Sun Prairie WWTP. An evaluation of the Sun Prairie WWTP capacity and costs associated with a potential expansion was not included in this study. Using an approximate cost for an expansion in the range of $10-15/gallons per day (gpd), the resulting construction cost would be about $80 - $120 million depending on the capacity currently available. The conceptual route for the approximately 7-mile force main connecting PS 13 and the Sun Prairie WWTP is shown in Figure 2.11.

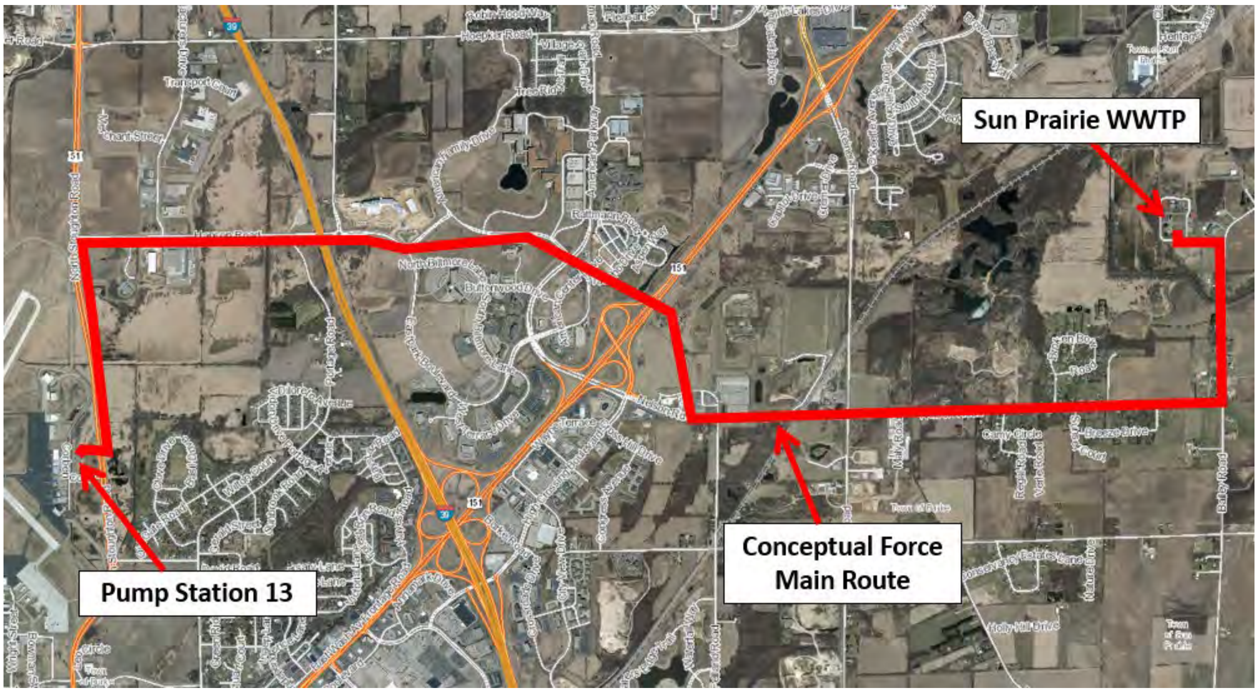


Figure 2.12 Conceptual Force Main Route Connecting PS 13 and Sun Prairie WWTP

Discussion and Considerations

The overall weighted non-economic score for this alternative is 2.07 out of 5.

Based on the substantial capital costs associated with PS 13 upgrades, construction of the force main, and major improvements required at the Sun Prairie WWTP, this alternative did not warrant further consideration. Additional energy would be required for pumping to Sun Prairie versus pumping from PS 13 to NSWTP. The energy saved at NSWTP from reduced flows would be required at the Sun Prairie WWTP for treatment.

2.3.2.12 Energy Storage ES1 – Battery Storage and Microgrid (Strategic)

Alternative Description

This alternative involves installation of battery storage and a microgrid system to increase MMSD's use of renewable energy sources, allow for peak shaving to reduce electrical costs, and to provide a short-term backup for power outages to increase resiliency.

For the purposes of this evaluation, alternative ES1 was combined with ES2, which included installation of a microgrid system and controls to reduce reliance on external electricity. A microgrid is a localized energy grid with multiple energy sources (utility electricity, cogeneration, solar) that can operate if connected or disconnected from the traditional electrical grid provided by MG&E.

Battery storage provides a buffer between the production of renewable energy (cogeneration and solar) and the NSWTP's energy consumption. The battery will supply electrical power when the renewable sources are insufficient to meet NSWTP's instantaneous energy needs and will store renewable energy during times of low energy use.

For the purposes of this evaluation, Carollo worked with Schneider Electric (who specializes in providing energy and automation solutions) to determine the capital costs and potential payback periods for three options:

- Option 1: Existing cogeneration + two 250 kW batteries.
- Option 2: Existing cogeneration + 500 kW solar + two 250 kW batteries.
- Option 3: Existing cogeneration + 1,000 kW additional cogeneration + 1,500 kW solar + two 250 kW batteries.

Description of Modifications Required

The following modifications are assumed to be required:

- Installation of battery storage and a microgrid system provided by a system integrator, such as Schneider Electric. This integrator provides intelligent software controls that allow the facility to automatically switch between the utility grid and the microgrid (i.e. cogeneration and solar) based on factors such as power reliability and cost efficiency.
- Battery tie-in point would be located downstream of 1,500 kilovolt-ampere (kVA) transformer in Unit Substation U3.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.21 out of 5.

Based on discussions with Schneider Electric, battery storage and microgrid systems are not yet cost effective for wastewater treatment plants where power costs are less than $0.10/kWh. In addition, it should be considered that batteries lose approximately 2.5 percent capacity each year, with battery life currently only at 13 years, which means that payback periods need to be a minimum of 10 to 12 years for this alternative to be economically attractive. Therefore, further consideration of microgrids was not recommended. This alternative may pencil out in the future if electricity costs increase and the capital cost of batteries continues to decrease.

2.3.2.13 Renewable Energy RE1 – Install Solar Power on Building Roofs (Strategic)

Alternative Description

This alternative includes installation of solar photovoltaic (PV) equipment on most buildings at NSWTP. Buildings with available roof space for a minimum 30 kW direct current (DC) will be included in this alternative. The location of each system identified in this alternative is presented in Figure 2.12.

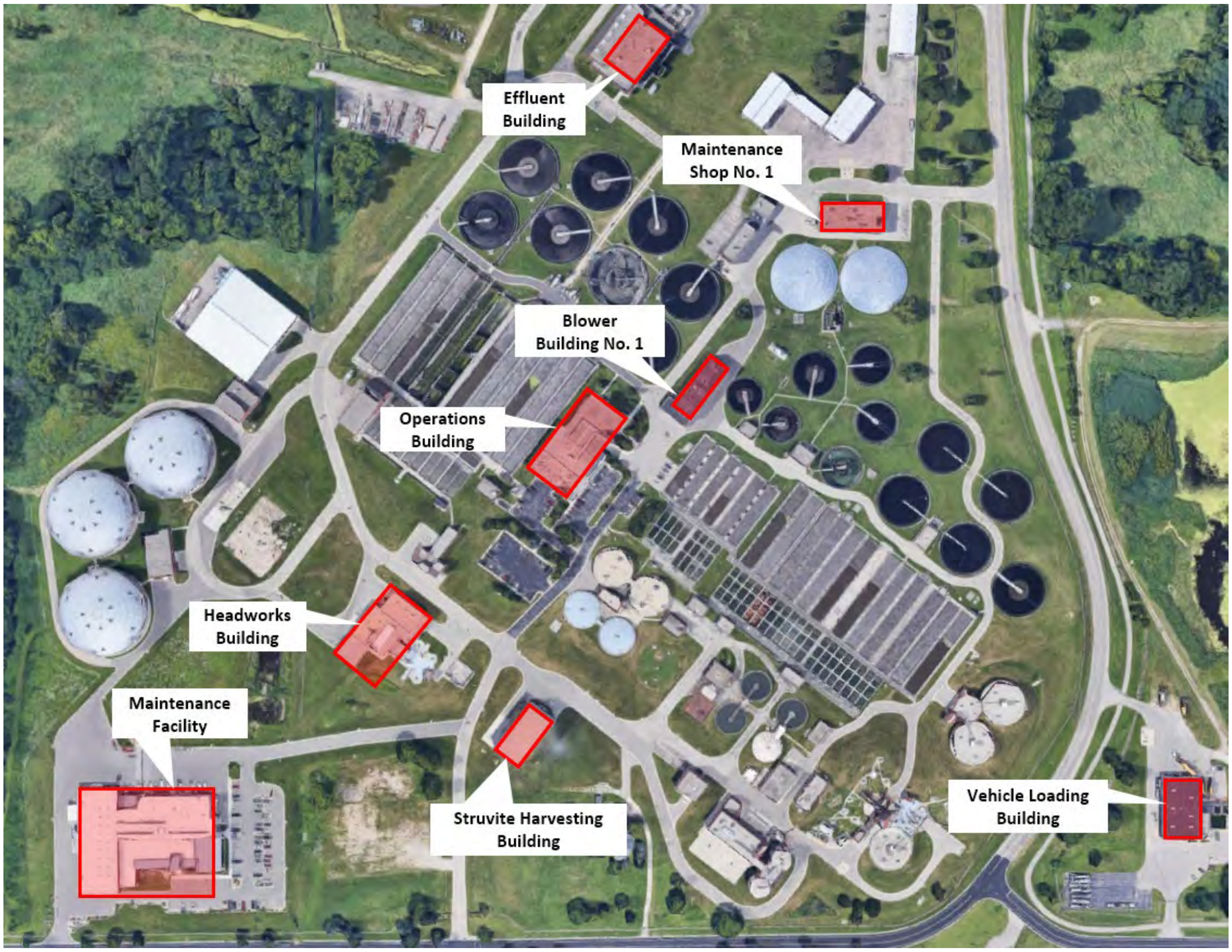


Figure 2.13 Roof-Mounted Solar PV System Locations

Description of Modifications Required

Prior to installation of a solar PV system on buildings at NSWTP, a detailed electrical and structural analysis should be completed to determine if each building's electrical infrastructure and building structure can support the addition of the solar PV equipment.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.24 out of 5.

To achieve the maximum production efficiency (kWh/kWp), solar PV modules should be oriented due south. The majority of the buildings at NSWTP are oriented such that, to maximize the number of solar PV modules, the modules would be oriented southeast or southwest, resulting in a production efficiency loss of approximately 4 percent when compared to buildings oriented due south.

Due to the reduced production efficiency, the small amount of energy produced relative to the amount of energy NSWTP uses, as well as the higher cost per watt when compared to larger ground-mounted systems, this alternative did not warrant further consideration.

2.3.2.14 Renewable Energy RE3 – Install Large-Scale Solar Array (Strategic)

Alternative Description

This alternative includes installation of a large-scale solar PV system on "Property 5," a 95-acre parcel owned by MMSD located southwest of NSWTP. Three large-scale system sizes that could be connected to NSWTP are presented, with the largest being limited by the approximate average plant demand of approximately 3.8 MW under current conditions. Additionally, a system is presented that could be connected to PS 11, which is located south of the parcel. The location and relative size of each system identified in this alternative are presented in Figure 2.13.

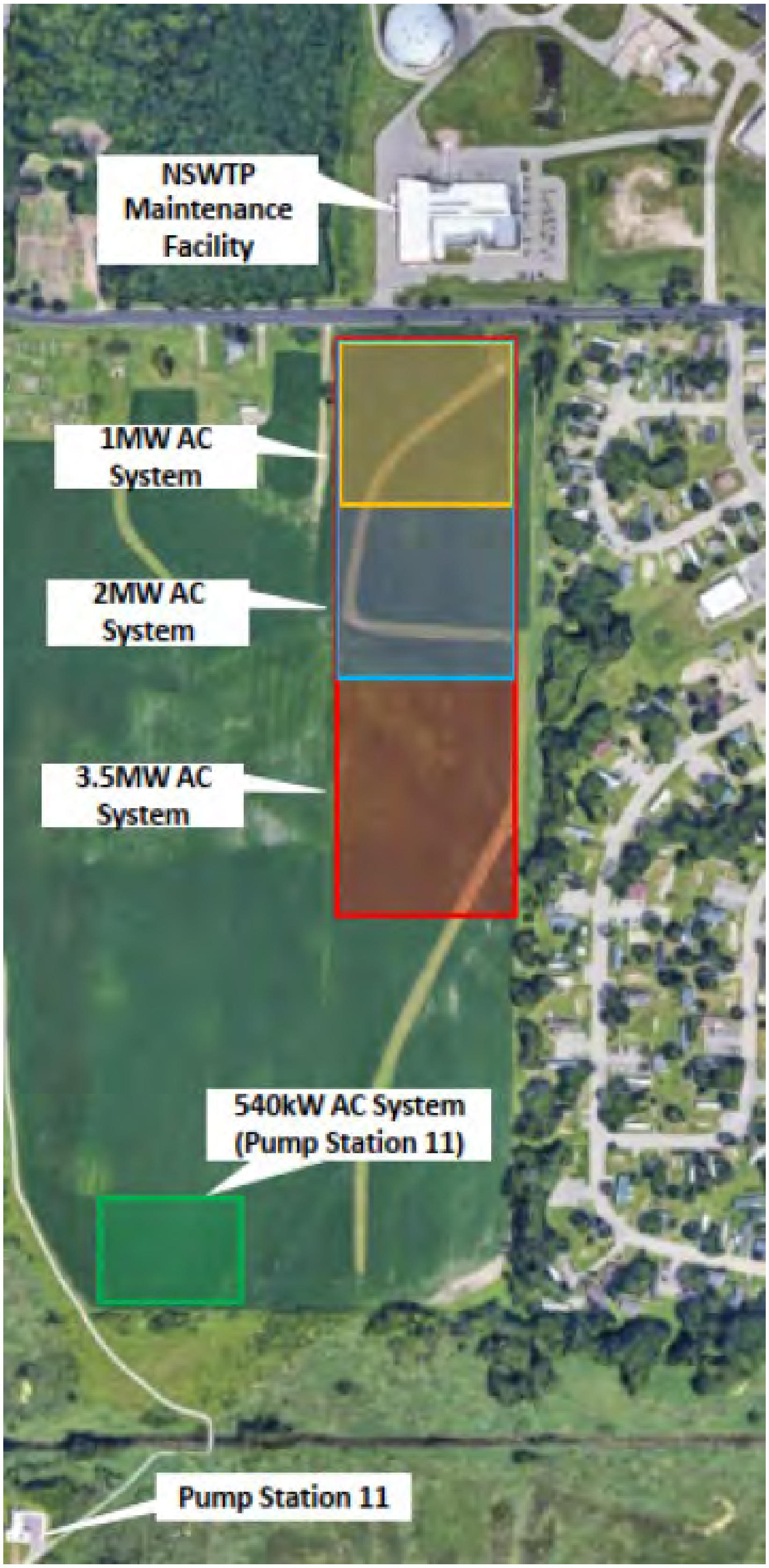


Figure 2.14 Large-Scale Solar PV System Locations

Description of Modifications Required

Prior to installation of a solar PV system, a detailed electrical analysis should be completed to determine the tie-in point for the solar PV equipment to the NSWTP electrical distribution system. Systems of this size would also require close coordination with the electric utility company, which would be part of a detailed design effort.

The proposed property is currently farmland that is leased out by MMSD and up to approximately 40 acres (7-8 acres per MW) would be taken out of production for installation of the new solar array for the NSWTP, depending on the selected array size.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.56 out of 5.

This alternative was recommended for further consideration. Implementing this alternative would result in a significant annual reduction of energy purchased from the utility company. If up-front capital is not available, alternative funding methods can be investigated, such as MG&E's RER program to reduce the initial capital investment.

2.3.2.15 Thermal Heating TH3 – Simplify Heat Loop (Feasible)

Alternative Description

This alternative includes potential changes to the hot water-based thermal heating system to address operational issues with heat distribution in conjunction with the replacement of equipment. The specific focus includes a more optimized heat distribution system and simplification of the overall hot water loop.

The NSWTP thermal heating system provides heat for the digesters, many buildings, and the struvite recovery dryers. It also supplies the heat necessary for operation of the adsorption chiller in the Operations Building. The heat sources for the thermal system include various hot water boilers, engine heat recovery systems, and steam boilers.

Heat demands were estimated for 2020 and 2040 to assess the thermal requirements for building heating/cooling, sludge heating for digestion as currently operated, digester tank losses, and struvite drying. Table 2.4 summarizes the total maximum and minimum thermal energy demand estimated by season in 2020 and 2040.

Table 2.4 Estimated Heat Demands by Season

Season	Steam (Btu/hr)(1)		Maximum Demand(2) Hot Water (Btu/hr)		Minimum Demand(3) Hot Water (Btu/hr)	
	2020	2040	2020	2040	2020	2040
Summer	2,450,000	2,880,000	6,190,000	6,240,000	1,690,000	1,740,000
Fall	3,340,000	3,930,000	11,730,000	11,780,000	1,980,000	2,030,000
Winter	4,230,000	4,990,000	15,510,000	15,560,000	6,710,000	6,760,000
Spring	3,340,000	3,930,000	12,630,000	12,680,000	1,950,000	2,000,000

Notes:

(1) Based on Applied Technologies' 2011 *Design Memorandum No. 5: 11th Addition to the NSWTP*, with modifications on sludge flows/loads to reflect digester feed flow of 215,000 gpd in 2020 and projected feed flow of 256,000 gpd in 2040. Summer and winter sludge heating based on summer and winter conditions for sludge heating as defined in the same memorandum. Sludge heating demands for spring and fall are estimated as averages between the summer and winter values because sludge-specific information was provided only for summer and winter in the referenced memorandum.

(2) Summer and winter sludge heating based on summer and winter conditions for sludge heating as defined in Applied Technologies' 2011 *Design Memorandum No. 5: 11th Addition to the NSWTP*. Methane phase mesophilic and thermophilic sludge heating demands for spring and fall are estimated as averages between the summer and winter values because sludge-specific information was provided only for summer and winter in the referenced memorandum. Digester tank losses are based on the values in this same memorandum, corrected for mesophilic operation in Digesters 4-9 and thermophilic operation in Digesters 1-3. Building heat demands are based on low air temperatures reflective of the 10th percentile of historic low temperatures in Madison, Wisconsin in each month. Also includes heating for struvite drying based on a heat demand, when operating, of 440,000 Btu/hr as determined from the required hot water flow and hot water inlet and outlet temperatures per an email from Derek Lycke to Bill Ericson and Paul Traeger on August 4, 2011.

(3) Based on summer sludge heating requirements and digester tank losses, no struvite drying, and minimal building heating or cooling requirements for conditions when ambient air is close to 60 deg. F.

Table 2.5 summarizes the annual heat energy estimated by season in 2020 and 2040.

Table 2.5 Estimated Annual Heat Energy

Season	Steam (MMBtu) (1)		Hot Water (MMBtu) (2)		Total (MMBtu)	
	2020	2040	2020	2040	2020	2040
Summer	5,400	6,300	9,000	9,400	14,400	15,700
Fall	7,300	8,600	9,900	10,200	17,200	18,800
Winter	9,300	10,900	23,700	24,100	33,000	35,000
Spring	7,300	8,600	12,200	12,600	19,500	21,200
Total	**29,300**	**34,400**	**54,800**	**56,300**	**84,100**	**90,700**

Notes:

(1) Based on applying estimated heat demands per season for the year.

(2) Based on applying estimated heat demands in varying conditions to an estimated frequency and length of each condition to determine total heat energy requirement. This includes application of struvite dryer run time based on data provided by MMSD and historic weather data for ambient air temperature to assess building heating/cooling energy requirements.

A schematic representation of the West, Central, and East hot water-based heat loops is shown in Figure 2.14. During winter conditions, the estimated heat demands on the west side of the plant are substantial and greater than the heat demands on the east side. However, the heat sources are concentrated on the east side. While the East, Central, and West loops are connected, only a single pump transfers heat from the East to the West/Central loops and this presents a conveyance limitation for heat transfer, leading to difficulty in maintaining required heat on the west side of the plant in the winter.

In the warmer months, when heat demand drops, excess heat is produced by the blower engine and the engine generators. The excess heat generated can become problematic because the engine radiators are unable to transfer enough heat away from the engines, instead using the methane-phase digesters as heat sinks, which can negatively affect digestion processes due to temperature fluctuation.

The actual configuration of the existing heat loops is complex, and this complexity also impacts the ability to move hot water in response to demand. The heat exchangers for the heat recovery system and the exhaust stacks for the engines have thermostatic three-way valves with no manual control or manual bypass. These three-way valves limit the system's ability to modulate as needed per heat demands and impact heat distribution within the system when in a partially or fully failed state.

Another operational limitation of this system is associated with the West boilers, which can be fueled only by biogas yet are the closest heat source other than the blower engine for the western heat demands. Availability of biogas and fluctuations in the biogas system pressure hamper the West boiler's operations when biogas is unavailable at sufficient pressure.

As noted in Chapter 1, the existing thermal heating system includes several aging components and is unable to provide the necessary heat distribution during certain times of the year. These components include the blower engine, cogen engine generators, and engine radiators, among other less urgent components. While devising approaches for replacing these aged components, it is prudent to simultaneously assess ways to simplify the heat loop system and address the operational issues described above to increase overall efficiency. The alternative proposed here is to replace the multi-loop system and its sub-loops with a true, single primary-secondary heat loop system.

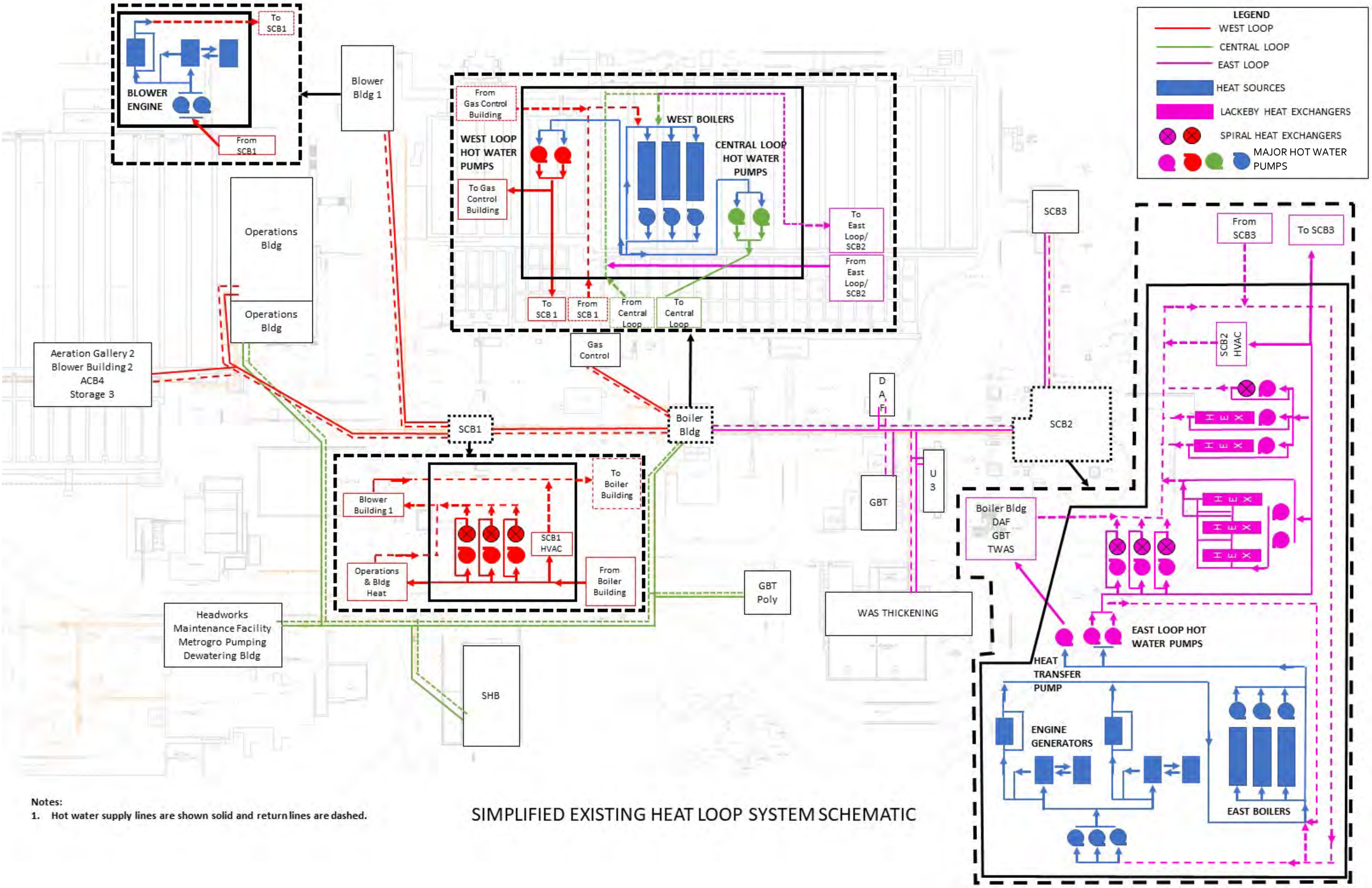


Figure 2.15 Existing NSWTP Hot Water-Based Heat Loop Schematic

Description of Modifications Required

The primary-secondary heat loop system proposed is shown in Figure 2.15. As shown in the figure, the loop would "start" downstream of new engine generators in SCB2. New primary heat loop pumps pump this very hot water (200-210 deg. F) into and around the primary loop. Heat supply sources are tied into the primary loop through individual secondary loops at different points of the primary loop such that sources are placed upstream of the large heat demand areas and processes.

Each supply source's secondary heat loop includes a dedicated secondary heat loop pump and three-way temperature control valve. The valve controls how much water from the supply unit's discharge enters the primary loop based on meeting temperature setpoints at various points within the primary heat loop. The source's secondary heat loop pump simply recirculates water within the secondary loop when the source is called to run based on overall heat demand within the primary loop.

Each major demand component is also tied into the primary heat loop via a secondary heat loop that includes a pump and three-way temperature control valve dedicated to that secondary loop. The three-way temperature control valves control the amount of water from the primary heat loop required to meet heat demands within their associated secondary loops. The secondary heat loop pumps recirculate water within the secondary loop when that loop is called to run.

This type of system simplifies the overall heating system by eliminating the crossties and multiple pumping systems and replacing them with a single set of pumps and a set of secondary loops configured in parallel off the primary loop, minimizing temperature reduction.

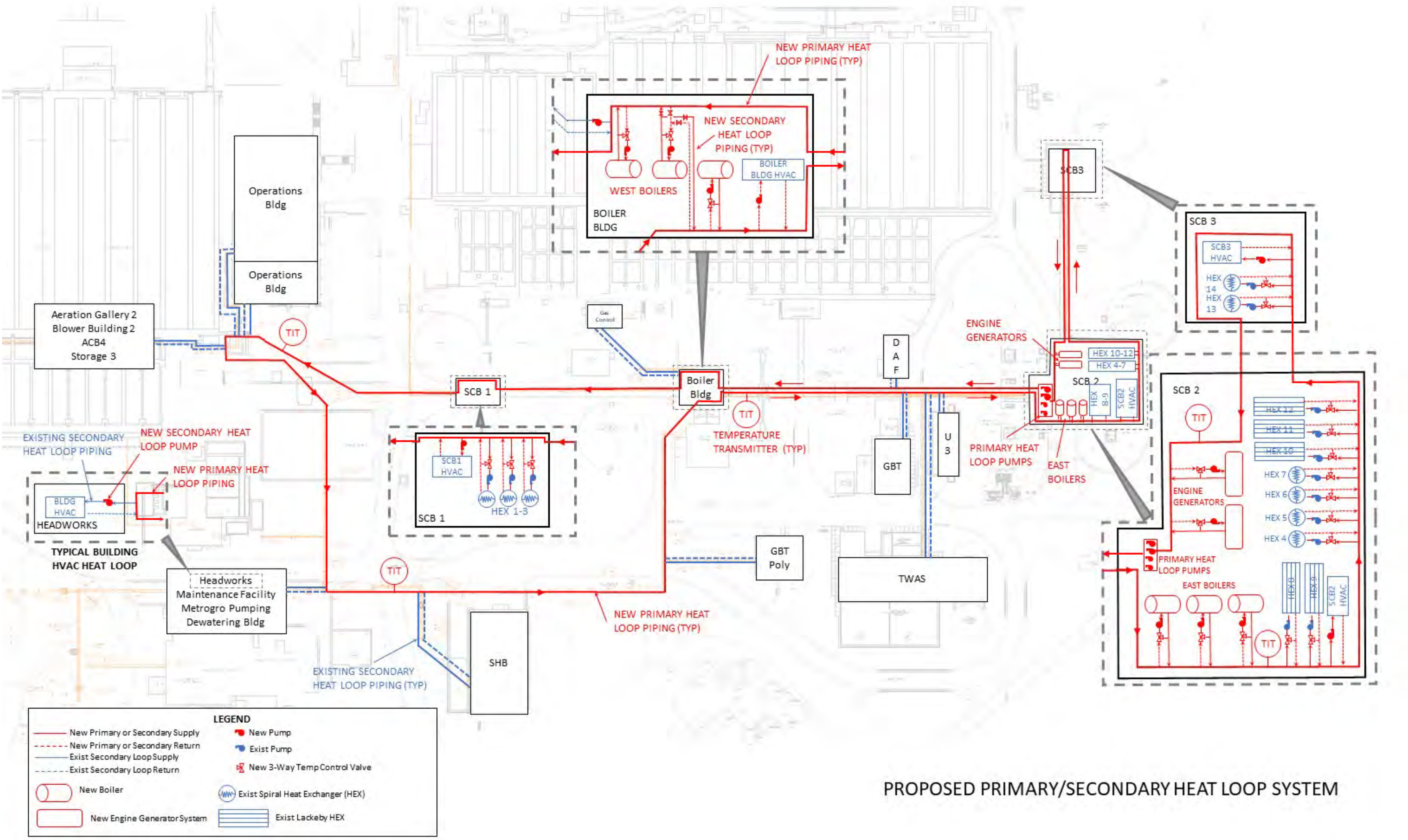


Figure 2.16 Proposed NSWTP Primary/Secondary Heat Loop System

The proposed routing of the primary loop is intended to follow the path of the current multi-loop system but would need to be upsized for optimal pipe velocity. The major changes to the heat loop to allow for 15.6 MMBtuh of heat to meet maximum demand at 2040 include:

- Two new engine generators, as described in BG6 which could produce a total of 9.6 MMBtuh of heat through recovery of the jacket and exhaust heat based on projected biogas availability in 2040.
- New engines' secondary heat loops consisting of new 6-inch piping (approximately 100 ft), dedicated three-way temperature control valves and new 500 gallons per minute (gpm) secondary heat loop pumps (2).
- All elements of the engine and engine heat recovery system would be replaced, including radiators, jacket water heat recovery, exhaust heat recovery, lubrication oil, and all associated pumps. Radiators would need to be sized for full engine thermal load to avoid operational disruptions currently plaguing the heat loop system and be used to disseminate excess heat.
- Three (2 duty, 1 standby) new 150 brake horsepower (bhp) West boilers, each capable of producing 5 MMBtuh of heat at full fire with a 4:1 turndown to produce 1.25 MMBtuh at low fire. The boilers' secondary heat loops would consist of new 6-inch piping (approximately 150 ft), dedicated three-way temperature control valves (3), and new 500 gpm secondary heat loop pumps (3).
- Three (2 duty, 1 standby) new 70 bhp East boilers, each capable of producing 2.3 MMBtuh of heat at full fire with a 4:1 turndown to produce 575 kilo British thermal units per hour (kBtu/hr) at low fire. The boilers' secondary heat loops would consist of new 4-inch piping (approximately 150 ft), dedicated three-way temperature control valves (3), and new 230 gpm secondary heat loop pumps (3).
- Four new primary heat loop pumps with variable frequency drives connected in parallel. Two of the pumps would be 800 gpm each and the other two would be 400 gpm each. Pump selection during preliminary design should be based on the best pump curves/characteristics to maximize flexibility within the primary loop pumping system.
- New 10-inch primary heat loop piping routed as shown in Figure 2.15, approximately 3500 ft total.
- New secondary heat loop piping and three-way temperature control valves for each individual digester heat exchanger. Approximately 350 ft of 3-inch piping and 250-ft of 4-inch piping is estimated.
- New secondary heat loop piping and new pumps for building HVAC connections within SCB1, Boiler Building, SCB2, and SCB3. In general, these pumps (4) will range from approximately 20-80 gpm depending on specific building heat demand. Approximately 200 ft of 3-inch piping is estimated.
- New recirculation pumps for other building HVAC loops. In general, these pumps (16) will range from approximately 5-200 gpm depending on specific building heat demand with most being 80 gpm or smaller.
- New temperature transmitters on the primary (5) and secondary loops (44).

Discussion and Considerations

The overall weighted non-economic score for this alternative is 4.36 out of 5.

Addressing the operational issues related to the thermal heating system and improving the ability to move heat to where it is needed is important. Because many of the components of the existing hot water heat loop system require replacement due to age, making the proposed improvements to the heat loop would address multiple objectives simultaneously. Replacement of the multi-loop system with a primary/secondary heat loop will not likely have a significant impact on the energy profile on its own. However, replacing the biogas utilization components will have significant impacts on the energy profile and O&M costs. If paired with other alternatives as noted above, this alternative could be incorporated into a larger project that improves the energy profile, produces a higher quality biosolids product, and/or addresses operational issues.

2.3.2.16 Emerging Technology ET6 – Biosolids Pyrolysis (Strategic)

Alternative Description

This alternative consists of implementation of a pyrolysis system to reduce the mass of biosolids hauled for land application. During pyrolysis, a controlled amount of heat, up to 1,300 deg. F is applied to dried sludge (90 percent cake) in an anaerobic environment, resulting in little to no combustion. The thermal decomposition of the 90 percent cake produces a biochar and a pyrogas.

Bioforcetech manufactures a system that includes a biodryer and pyrolysis reactor that has been in operation for 2 years in California. There is data from Bioforcetech that suggests destruction of per- and polyfluoroalkyl substances (PFAS) in the biochar, although this is unverified by a third party.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.16.

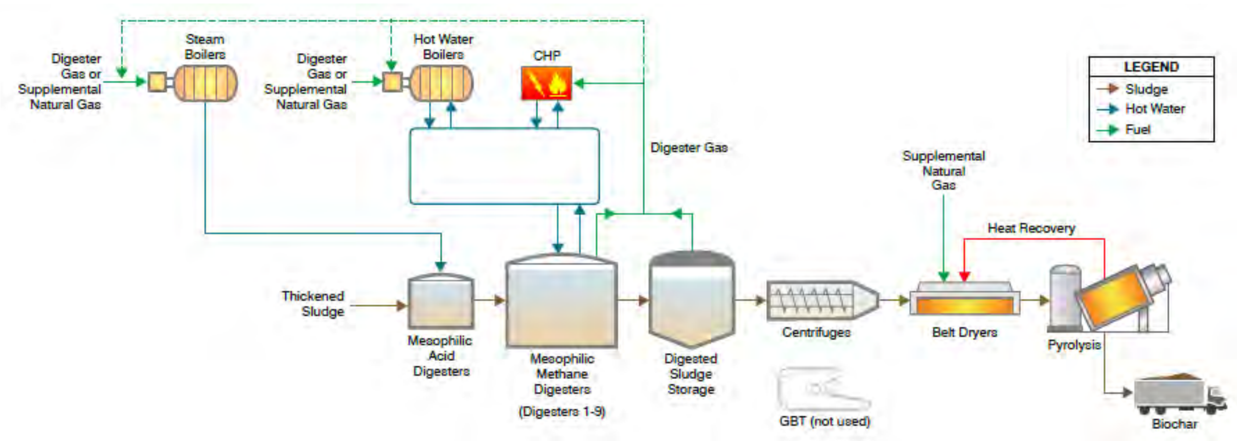


Figure 2.17 Pyrolysis PFD

For this alternative, MMSD would continue to use all digesters. Digesters 1-3 would be operated as mesophilic.

The following modifications are assumed to be required:

- Expansion of centrifuge dewatering to process 100 percent of the digested biosolids, within existing building.
- Addition of belt dryers and pyrolysis process and all ancillary equipment provided by Bioforcetech, in a new building.

The biochar product is assumed to be hauled and land applied. However, it may be possible to market and sell the biochar.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.2 out of 5.

At $109.7 million differential project cost and a reduction of $159,000 per year in O&M costs compared to the baseline, this alternative is significantly more expensive than baseline. This alternative does not provide

MMSD a net energy benefit, and instead, results in substantial increases in both power and heat demand. The lack of technology maturity and established markets for the biochar product are major concerns.

If stringent PFAS limits are established in the future, it may increase the viability of this alternative as it may be able to destroy PFAS through the high temperature reactor.

2.3.2.17 Emerging Technology ET15 – Biosolids Gasification (Strategic)

Alternative Description

The fluidized bed gasification process converts biosolids into biochar and syngas (a combustible synthetic gas) in an oxygen-deprived environment and controlled temperature (roughly 1500 deg. F). The syngas is typically returned to the thermal dryers upstream or could be used for renewable energy production.

Like pyrolysis, this process may destroy PFAS through the high temperature process, but this has not been verified by independent third-party researchers.

There are multiple manufacturers that market the gasification process within the US, including Ecoremedy Fluid Lift Gasification and Aries Clean Energy.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.17.

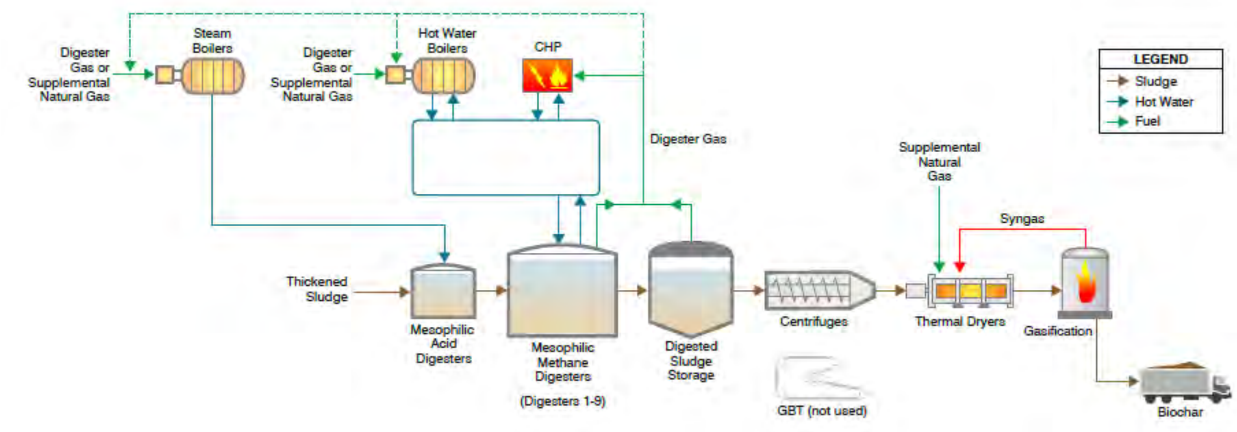


Figure 2.18 Gasification PFD

For this alternative, it was assumed that MMSD would continue use of all digesters. Digesters 1-3 would operate as mesophilic. Digestion volatile solids reduction (VSR) would be similar to existing.

The following modifications are assumed to be required:

- Expansion of centrifuge dewatering to process 100 percent of the digested biosolids, in existing building.
- Addition of single-vessel direct drying, pyrolysis, and gasification and associated ancillary equipment provided by Ecoremedy, in new building.

The biochar product is assumed to be hauled and land applied. However, it may be possible to market and sell the biochar.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.2 out of 5.

At $139.7 million differential project cost and a reduction of $824,000 per year in O&M costs compared to the baseline, this alternative is significantly more expensive than baseline. This alternative does not provide MMSD a net energy benefit, and instead, results in substantial increases in both power and heat demand. The lack of technology maturity and established markets for the biochar product are major concerns.

If stringent PFAS limits are established in the future, it may increase the viability of this alternative as it may be able to destroy PFAS through the high temperature reactor.

2.3.2.18 Biosolids BS2 – Non-Steam Based Thermal Hydrolysis (Strategic)

Alternative Description

This alternative consists of installation of a non-steam based thermal hydrolysis system to produce Class B biosolids, specifically Eliquo's LysoTherm process (licensed by Ovivo in the U.S.). Figure 2.18 shows a schematic of the process.

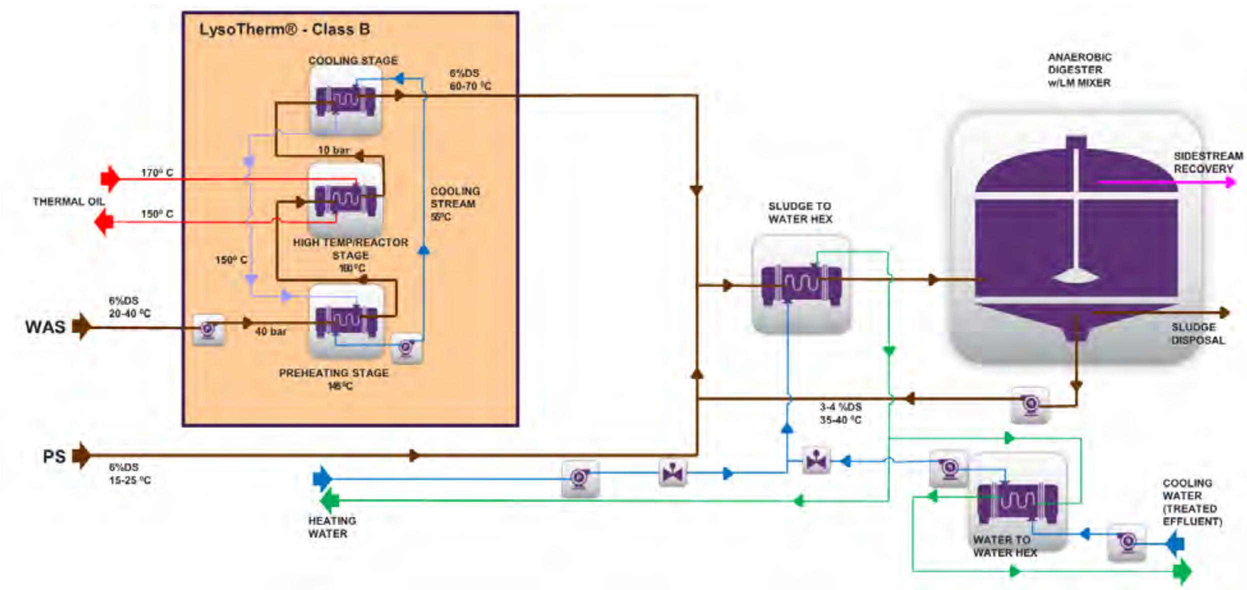


Figure 2.19 LysoTherm Process Schematic (courtesy of Ovivo)

During this process TWAS is pumped through a series of heat exchangers and heated to 316 deg. F and pressurized using a thermal oil heat loop. The thermal oil, at 338 deg. F causes thermal hydrolysis and the WAS biodegrades to improve digestibility and dewaterability which improves digestion performance. Once this process is complete, the TWAS is cooled before being fed into the digester.

This process has no effect on the PFAS content of the finished product.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.19.

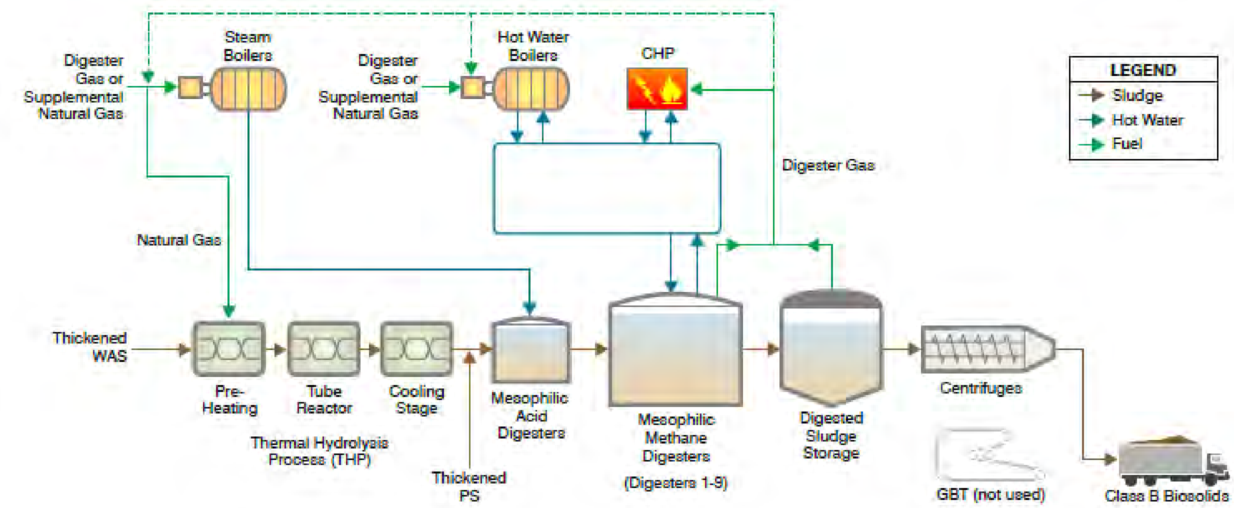


Figure 2.20 Non-Steam Based Thermal Hydrolysis PFD

The following modifications are assumed to be required:

- Addition of pre-digestion LysoTherm process provided by Ovivo, consisting of multistage heat exchanger system, and associated ancillary equipment.
- Expansion of centrifuge dewatering to process 100 percent of the digested biosolids, in existing building.

LysoTherm may increase both digestion and dewatering performance. It was assumed that the VSR increases by 5 percent from a baseline of 62 percent to 65 percent. It was assumed that a cake total solids (TS) concentration of 26 percent can be achieved post-Lysotherm. Class B biosolids cake is assumed to be hauled and land applied for beneficial use.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.9 out of 5.

At $38.2 million project cost and $982,000 operational savings per year compared to the baseline, this alternative is somewhat more expensive than baseline and cost savings may provide long-term payback.

2.3.2.19 Biosolids BS9 – Enhanced Primary Treatment (Feasible)

Alternative Description

Enhanced primary treatment consists of using either chemicals or mechanical methods to increase the efficiency of biochemical oxygen demand (BOD) and total suspended solids (TSS) removal in the primary clarifiers. CEPT specifically is a commonly used practice where chemicals such as aluminum or iron salts, and polymer are added to primary clarifiers to reduce loading to the secondary treatment process.

According to the 2014 Study, CEPT would reduce aeration by 5 to 10 percent due reduced BOD loading, in turn increasing biogas production by 15 to 20 percent and increasing solids production by 12,000 pounds per day (ppd). It was also noted that if CEPT was practiced at lower dose levels, it would detrimentally impact enhanced biological phosphorus removal and transition the facility to primarily chemical phosphorus removal. This would then inhibit phosphorus release needed for the Ostara process.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.20.

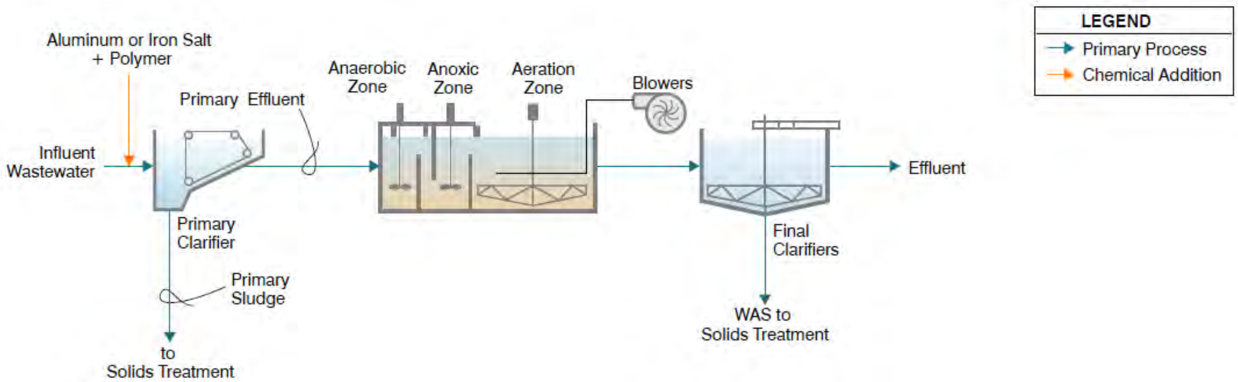


Figure 2.21 Enhanced Primary Treatment PFD

CEPT is relatively easy to integrate into the liquid stream process and would include the following modifications:

- The chemicals can be added directly to the influent to the primary clarifiers via chemical feed pumps and associated feed piping.
- A new chemical feed building would be required to house the chemical tanks and feed equipment.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 2.8 out of 5.

While there are some power savings that could be realized from implementing CEPT, the small savings were not justified due to the relatively high O&M costs and GHG footprint associated with the additional chemical use of this alternative. It could also have detrimental impacts on the facility's existing phosphorus removal and recovery process.

2.3.2.20 Biosolids BS14C – Anaerobic Digestion with Mesophilic Acid Phase/Thermophilic Methane Phase/Mesophilic 3rd Stage for Class A Biosolids Cake (Strategic)

Alternative Description

This alternative consists of implementation of TPAD to produce Class A biosolids as a dewatered cake. The existing digestion system was originally designed to operate as TPAD, but the process was discontinued due to several operational issues and no strong drivers for producing a Class A product.

For this alternative, operation of existing digesters would be reconfigured to include a mesophilic acid phase before the three methane TPAD phases, which include a thermophilic continuous phase, a thermophilic batch phase, and a mesophilic phase.

Following this digestion process, digested sludge would be dewatered to produce Class A biosolids cake.

This process has no effect on the PFAS content of the finished product.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.21.

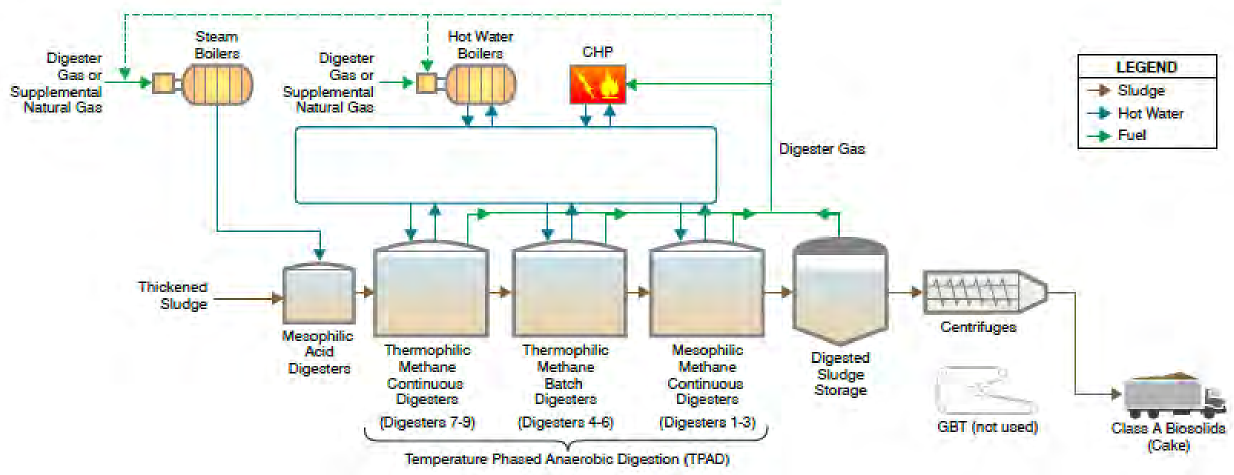


Figure 2.22 Anaerobic Digestion w/ Meso Acid/ Thermo Methane/ Meso 3rd Stage Cake PFD

The following modifications are assumed to be required:

- Continued used of all digesters. Modification of three of the methane phase digesters to thermophilic batch tanks, including addition of new sludge pumps and heat exchangers.
- Expansion of centrifuge dewatering to process 100 percent of the digested biosolids, in existing building.

This process produces Class A biosolids cake, which are assumed to be hauled and land applied for beneficial use.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.0 out of 5.

At $37.1 million project cost and $1,129,000 operational savings per year compared to the baseline, this alternative is somewhat more expensive than baseline, but was not carried forward. According to the findings of the BMP, the future need for Class A biosolids is beyond the 10-year planning horizon. Additionally, the viability of this alternative strongly depends on the market value of the Class A cake product.

2.3.2.21 Biosolids BS14L – Anaerobic Digestion with Mesophilic Acid Phase/Thermophilic Methane Phase/Mesophilic 3rd Stage for Class A Biosolids Liquid (Strategic)

Alternative Description

This alternative consists of the same TPAD modifications described in the previous alternative, BS14C. Following TPAD, digested sludge would be thickened using existing GBTs to produce Class A liquid biosolids.

This process has no effect on the PFAS content of the finished product.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.22.

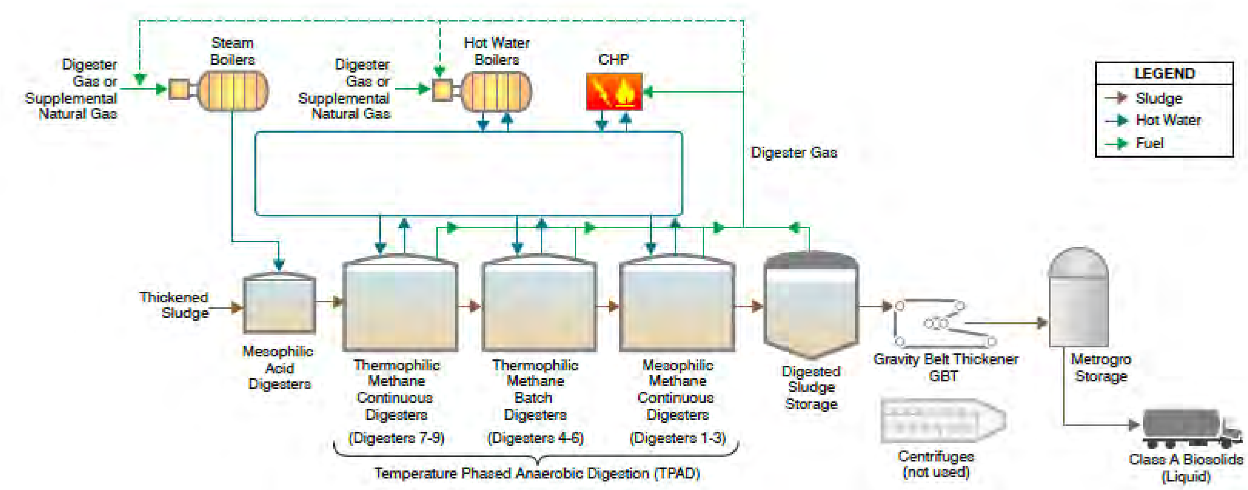


Figure 2.23 Anaerobic Digestion w/ Meso Acid/ Thermo Methane/ Meso 3rd Stage Liquid PFD

The following modifications are assumed to be required:

- Continued use of all digesters. Modification of three of the methane phase digesters to thermophilic batch tanks, including addition of new sludge pumps and heat exchangers.
- Construction of one additional Metrogro storage tank.

For this alternative, the GBTs would thicken 100 percent of the digested biosolids. No additional GBT capacity is needed. This process produces Class A liquid biosolids, which are assumed to be liquid hauled and land applied for beneficial use.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 2.2 out of 5.

At $6.6 million project cost and a $12,000 reduction in O&M costs per year compared to the baseline, this alternative is much less expensive than baseline. The viability of this alternative, though, strongly depends on the market value of the Class A liquid product.

2.3.2.22 Biosolids BS15C – Anaerobic Digestion with Mesophilic Acid Phase/Mesophilic Methane Phase for Class B Biosolids Cake (Feasible)

Alternative Description

This alternative consists of modifying existing digester operation by stopping thermophilic operation completely. Only mesophilic digestion would be utilized. Digested sludge would be dewatered to produce Class B biosolids cake.

This alternative reduces the need to rely on the heating system for thermophilic operation but does not improve the existing system.

This process has no effect on the PFAS content of the finished product.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.23.

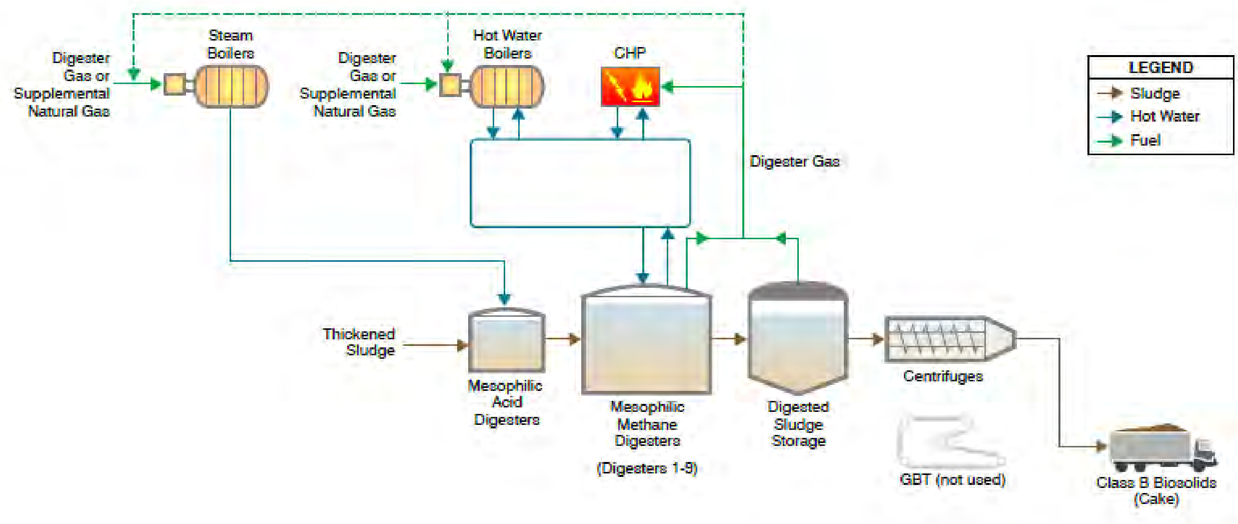


Figure 2.24 Anaerobic Digestion w/ Meso Acid/ Meso Methane Cake PFD

The following modifications are assumed to be required:

- Continued use of all digesters. Operate digesters 1-3 as mesophilic.
- Expansion of centrifuge dewatering to process 100 percent of the digested biosolids, in existing building.

This process produces Class B biosolids cake, which is assumed to be hauled and land applied for beneficial use.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 4.4 out of 5, highest of all biosolids alternatives evaluated.

At an increase in total project cost of $26,000,000 and $1,207,000 operational savings per year compared to the baseline, this alternative is less expensive than baseline and cost savings may provide long-term payback.

2.3.2.23 Biosolids BS15L – Anaerobic Digestion with Mesophilic Acid Phase/Mesophilic Methane Phase for Class B Biosolids Liquid (Feasible)

Alternative Description

This alternative consists of modifying existing digester operation by stopping thermophilic operation completely. Only mesophilic digestion would be utilized. Digested sludge would be thickened using GBTs to produce Class B liquid biosolids.

This alternative reduces the need to rely on the heating system for thermophilic operations but does not improve the existing system.

This process has no effect on the PFAS content of the finished product.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.24.

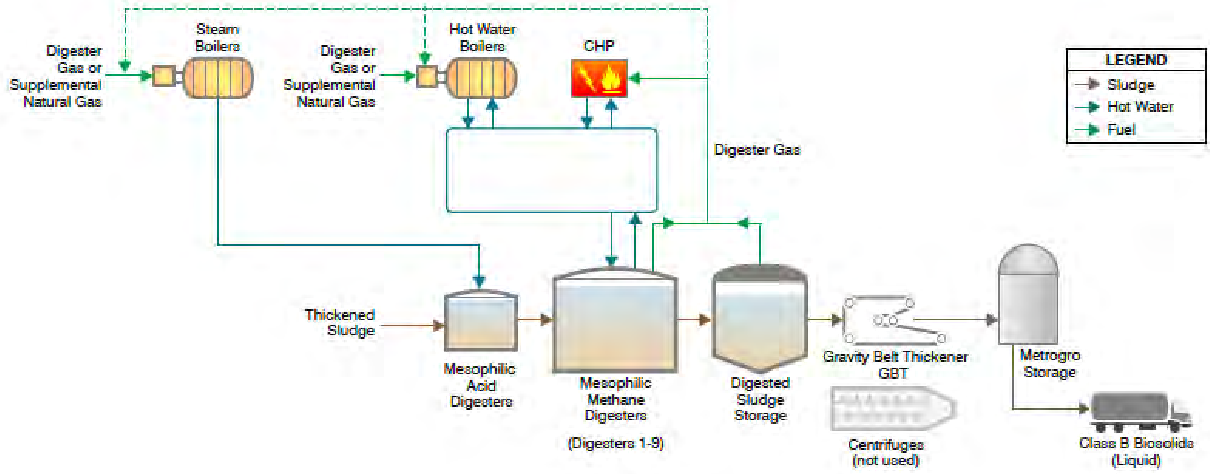


Figure 2.25 Anaerobic Digestion w/ Meso Acid/ Meso Methane Liquid PFD

The following modifications are assumed to be required:

- Continued use of all digesters. Operate digesters 1-3 as mesophilic.
- Construction of one additional Metrogro storage tank.

No additional GBT capacity is needed. This process produces Class B liquid biosolids, which are assumed to be liquid hauled and land applied for beneficial use.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.2 out of 5.

At $3,100,00 project cost below baseline and a reduction in O&M costs by $90,000 per year compared to the baseline, this alternative is much less expensive than baseline and cost savings may provide short-term payback.

2.3.2.24 Biosolids BS22 – Biosolids Dewatering to Produce Dewatered Cake (Feasible)

Alternative Description

This alternative includes converting from the current practice of dewatering approximately 3 percent of biosolids to dewatering all of the biosolids produced on-site, producing a Class A or B cake for land application.

This section includes an evaluation of the following three dewatering technologies for use at the NSWTP:

- Belt filter presses (BFPs).
  - Use moving porous belts and rollers to continuously dewater solids.
- Screw presses.
  - Use a rotating screw to continuously dewater solids.
  - Require a "plug" that provides dewatering pressure for the solids in the press.

- Centrifuges.
  - Use centrifugal force (up to 500 to 3,000 times the force of gravity) to separate solids from liquids in digested sludge.

A comparison between the three technologies is summarized in Table 2.6.

Table 2.6 Dewatering Equipment Comparison

Belt Filter Press	Screw Press	Centrifuge
• Potential safety/housekeeping issues from filtrate discharge. • Produces lower cake solids than centrifuge. • Highest odor and corrosion potential if an open design is selected. • Large amount of high-pressure spray water is needed. • Low power requirement.	• Enclosed design reduces odor concerns. • Can lose plug and cause housekeeping issues. • Produces lower cake solids than centrifuge. • Lowest solids capture rate. • Low power requirement.	• Enclosed design reduces odor concerns. • Produces high cake solids and high solids capture rate. • High power requirement.

The existing Dewatering Building at NSWTP could likely be reused for the centrifuge alternative, but that would not be feasible for the larger size of the BFP and screw press.

Description of Modifications Required

Digested sludge from the existing sludge storage tanks would be pumped into the new dewatering equipment. Dewatered cake will be conveyed to the existing cake storage facility for hauling and land application. Because the use of centrifuges for dewatering results in a significantly lower capital cost due to ability to reuse existing infrastructure, this equipment was used for further evaluation based on the screening criteria.

The following modifications are assumed to be required:

- Demolition of existing centrifuge and installation of two new centrifuges in existing Dewatering Building.
- Replacement of existing polymer system.
- Replacement of existing cake conveyors to accommodate increased capacity.
- Replacement or upgrades of ancillary systems as needed, including HVAC, electrical, instrumentation and control (EI&C). Structural modifications may also be required to handle the additional weight and rotational forces of the larger centrifuge units.
- Cake storage facility to provide adequate storage for dewatered cake storage prior to hauling for land application.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.98 out of 5.

While this alternative increases overall electricity use at the NSWTP, it has the benefit of significantly reducing O&M costs associated with hauling liquid biosolids and vehicle fuel consumption. At $28,000,000 capital cost above baseline and a $1,129,000 annual reduction in O&M costs, this alternative is less expensive than baseline. This alternative also has a significant benefit with several other alternatives considered herein that require dewatered cake.

2.3.2.25 Biosolids BS25 – Produce Class A Biosolids Through High-Temperature Mechanical Drying (Strategic)

Alternative Description

This alternative involves construction of a drum drying facility to produce Class A pellets. For this alternative, dewatered biosolids are dried using a convective rotary drum dryer. Following dewatering, biosolids would be fed into a triple pass rotary drum dryer that mixes the biosolids with hot air (heated with natural gas), evaporating water from the biosolids and producing a dried pellet.

This process has no effect on the PFAS content of the finished product.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.25.

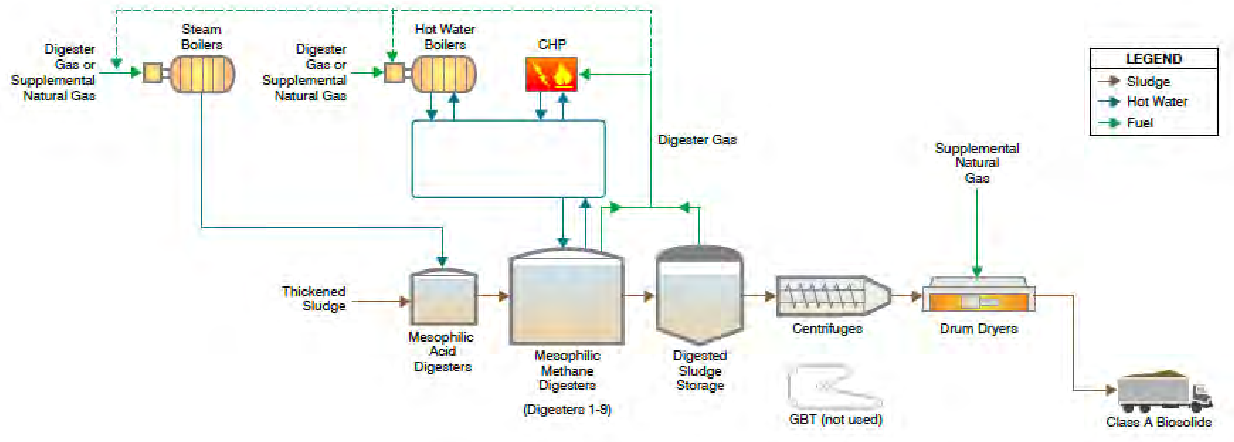


Figure 2.26 High-Temperature Drying PFD

For this alternative, MMSD would continue to use all digesters. Digesters 1-3 would be operated as mesophilic. Digestion VSR would remain the same as existing operation.

The following modifications are assumed to be required:

- Expansion of centrifuge dewatering to process 100 percent of the digested biosolids, in existing building.
- Addition of high temperature drum drying (correlates with the BMP) and associated ancillary equipment, in new building.
  - Drum dryer preferred by farmers and coordinates with the BMP.
  - Other dryer alternatives are more cost/energy efficient alternatives but do not produce as marketable of a product.

This alternative produces Class A dried biosolids product, which is assumed to be hauled and land applied for beneficial use. However, it may be possible to market and sell the dried product.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.1 out of 5.

At $69 million project cost and additional O&M costs of $169,000 per year compared to the baseline, this alternative is significantly more expensive than baseline. This alternative does not provide MMSD a net energy benefit, and instead, results in substantial increases in both power and natural gas use.

2.3.2.26 Biosolids BS27 – Produce Class A Liquid Fertilizer Through Thermo-Chemical Hydrolysis (Feasible)

Alternative Description

Post-digestion thermo-chemical hydrolysis (Lystek) is a process that uses a caustic chemical, relatively low temperature (compared to other biosolids processes), and high shear mixing to produce a liquid fertilizer. The process occurs after dewatering.

In this process, dewatered biosolids are fed into a storage hopper. The reactors are fed with low-pressure steam and caustic chemical. A mechanical blade in the reactor mixes and shears the solids. The pH, temperature and mixing conditions hydrolyze and shear the solids. The result is a homogenized pumpable liquid product with a solids concentration up to 16 percent.

This process has no effect on the PFAS content of the finished product.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.26.

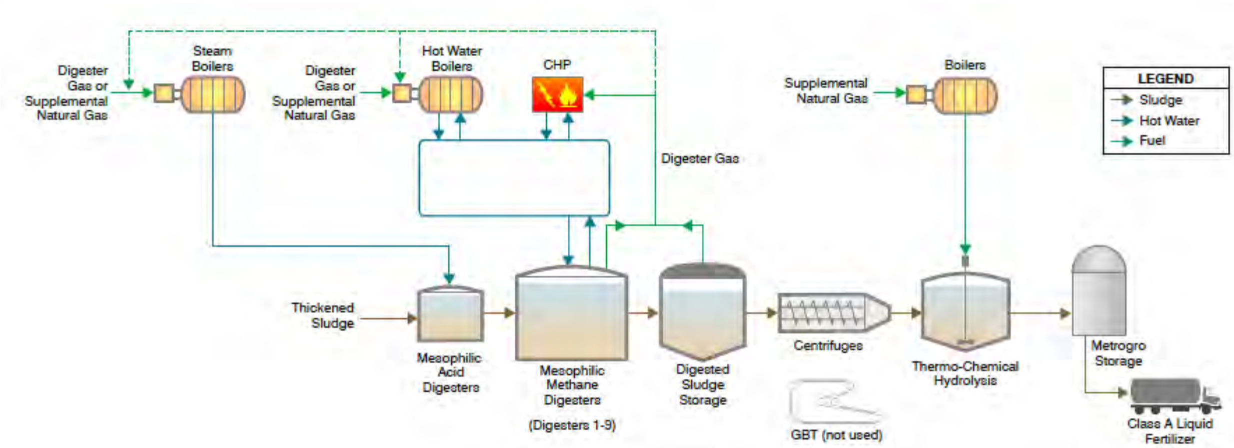


Figure 2.27 Liquid Fertilizer through Thermo-Chemical Hydrolysis PFD

For this alternative, MMSD would continue to use all digesters. Digesters 1-3 would be operated as mesophilic. Digestion VSR would remain the same as existing operation.

The following modifications are assumed to be required:

- Expansion of centrifuge dewatering to process 100 percent of the digested biosolids, in existing building.
- Dilution to 16 to 18 percent TS to feed Lystek process. Addition of Lystek thermo-chemical hydrolysis reactors and associated ancillary equipment in new building.

This process produces Class A liquid biosolids product, which are assumed to be hauled and land applied for beneficial use.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.5 out of 5.

At $29.2 million project cost and $703,000 operational savings per year compared to the baseline, this alternative is slightly less than baseline and cost savings may provide long-term payback. The viability of this alternative is strongly dependent on the market value of the Lystek product. Connecting the Lystek process to the existing hot water loop to make use of the excess engine heat could make this alternative more favorable.

In addition, the thermo-chemically hydrolyzed sludge can be recirculated to the anaerobic digesters to further increase the VSR and biogas production.

2.3.2.27 Biosolids BS29 – Implement Biosolids Incineration with Energy Recovery (Strategic)

Alternative Description

This alternative involves the installation of a fluidized biosolids incineration system to produce ash for landfill disposal. The incineration system utilizes multiple stages to dry and burn biosolids, greatly reducing the quantity of end use product that must be hauled offsite. There are potential regulatory risks concerning incineration and air pollutants.

This process may destroy PFAS through the high temperature process, but this has not been verified by independent third-party researchers.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.27.

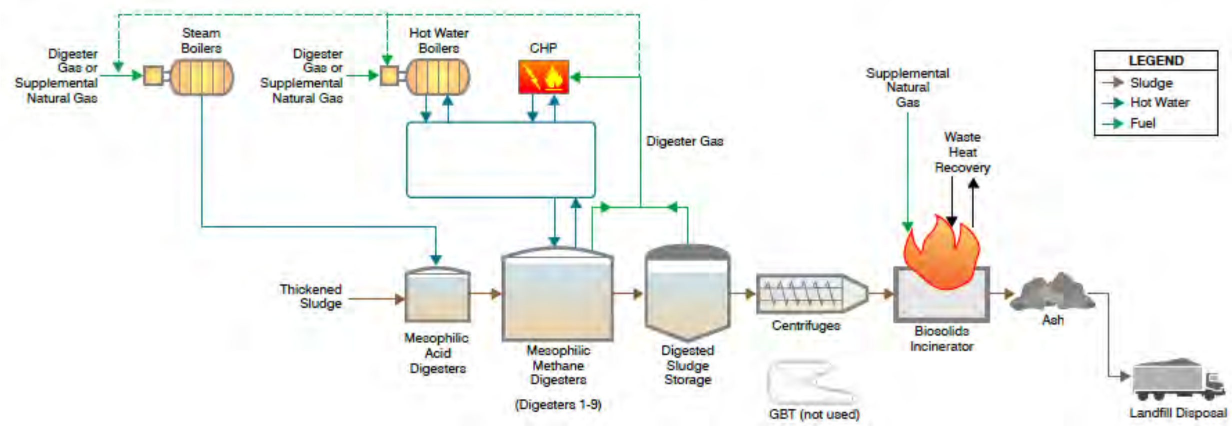


Figure 2.28 Biosolids Incineration w/ Energy Recovery PFD

For this alternative, MMSD would continue to use all digesters. Digesters 1-3 would be operated as mesophilic. Digestion VSR would be similar to existing.

The following modifications are assumed to be required:

- Expansion of centrifuge dewatering to process 100 percent of the digested biosolids, in existing building.
- Addition of biosolids incinerators and all ancillary equipment, in new building.

The incineration process produces ash and waste heat. The waste heat is assumed to be recovered internally to make the incineration process more efficient. The ash is assumed to be hauled to landfill for disposal.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 3.0 out of 5.

At $129.7 million project cost and an annual O&M cost $195,000 less compared to the baseline, this alternative is significantly more expensive than baseline. It also does not provide MMSD a net energy benefit, and instead, results in substantial increases in both power and natural gas use. Furthermore, incinerating biosolids eliminates the GHG benefits of biosolids land application.

If stringent PFAS limits are established in the future, it may increase the viability of this alternative as it may be able to destroy PFAS through the high temperature reactor.

2.3.2.28 Biosolids BS36 – Produce Class A Biosolids Through Composting on MMSD Property (Strategic)

Alternative Description

Composting is a solids stabilization process whereby aerobic organisms decompose organic matter. Solids are combined with a bulking agent, commonly woody waste, which raises initial solids content of the mixture and provides a carbon source for the organisms.

When composting is complete, the portion of the bulking agent that has not fully broken down is screened and recycled to be composted again, while the final product is allowed to cure for several days. The resulting material, similar to humus, can be used as a soil amendment.

A compost product may have a lower PFAS content due to dilution with other feedstocks.

Description of Modifications Required

A PFD illustrating this alternative is shown in Figure 2.28.

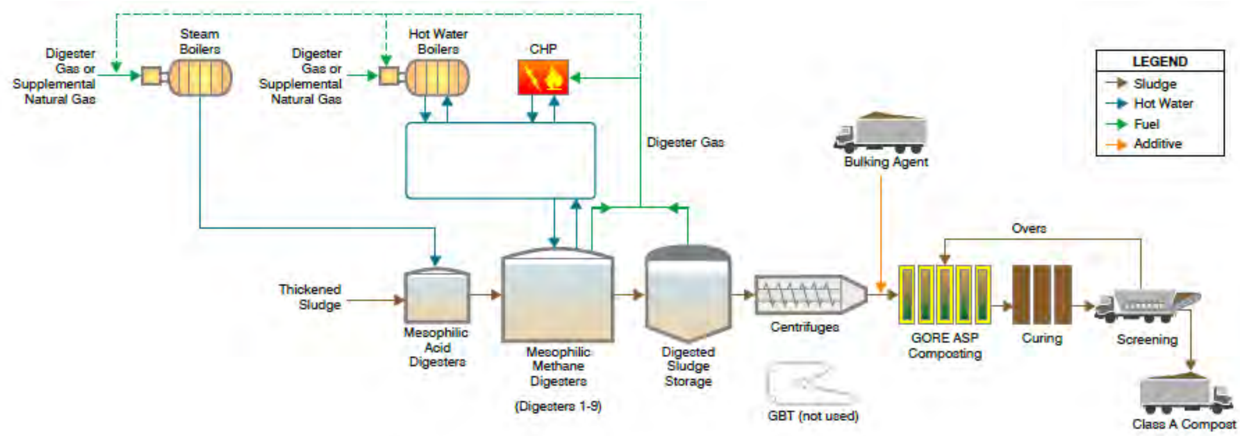


Figure 2.29 Biosolids Composting PFD

For this alternative, MMSD would continue to use all digesters. Digesters 1-3 would be operated as mesophilic. Digestion VSR would be similar to existing.

The following modifications are assumed to be required:

- Expansion of centrifuge dewatering to process 100 percent of the digested biosolids, in existing building.
- Addition of covered aerated static pile composting facility. Composting facility to include building for feedstock receiving, area for covered composting bunkers equipped with air blowers, mixing and screening machines, front end loaders and other ancillary equipment.

This alternative requires procurement of green waste or wood chips for use as bulking agent. This alternative produces a Class A compost product, which is assumed to be sold for beneficial use.

Discussion and Considerations

The overall weighted non-economic score for this alternative is 4.1 out of 5.

At $47.7 million project cost and an additional $995,000 operational costs per year compared to the baseline, this alternative is more expensive than baseline.

If stringent PFAS limits are established in the future, it may increase the viability of this alternative since the compost may have a lower PFAS concentration due to dilution with other feedstocks.

2.3.3 Summary of Alternative Analysis and Alternatives for Phase 4 Evaluation

After consideration of the capital and O&M cost differential, weighted non-economic score, and net energy differential, the alternatives that were recommended to be carried into Phase 4 for further evaluation are summarized in Table 2.7.

Table 2.7 Alternatives Recommended to be Carried Forward

Alternative	Capital Cost Differential	Annual O&M Cost Differential	Weighted Non-Economic Score	Net Electrical Energy Differential (kWh/yr)(1)	Net Thermal Energy Differential (MMBtu/yr) (1)	Additional Biogas Production (MMBtu/yr)
Biogas Alternatives						
BG6 – Status Quo Operation	$17,800,000	-$966,000	4.2	-11,751,000	-36,100	N/A
BG9 – Upgrade Cogen to Handle all NSWTP Needs (Option 1)	$36,600,000	-$1,272,000	4.9	-27,857,000	84,400	N/A
BG9 - Upgrade Cogen to Handle all NSWTP Needs (Option 2)	$42,900,000	-$2,672,000	4.9	-27,221,000	-67,700	N/A
BG14 – Pipeline Injection (Option 1A)	$31,200,000	-$2,072,000	4.2	11,430,000	-88,000	N/A
BG14 – Pipeline Injection (Option 1B)	$43,400,000	-$4,172,000	4.2	13,549,000	-223,200	N/A
BG14 – Pipeline Injection (Option 2A)	$19,500,000	-$1,072,000	4.2	11,855,000	-88,000	N/A
BG14 – Pipeline Injection (Option 2B)	$32,400,000	-$2,472,000	4.2	14,349,000	-223,200	N/A
Co-Digestion Alternatives						
CD1 – Co-digestion: Food Waste	$6,500,000	-$799,000	2.9	298,000	N/A	198,500
CD2 – Co-digestion: FOG	$7,500,000	-$1,600,000	2.8	293,000	N/A	182,600
Effluent Pumping Alternatives						
EP7 – Eliminate BMC Discharge	-$8,200,000	$21,000	4.4	-1,099,000	0	N/A
Renewable Energy Alternatives						
RE3 – Large Scale Solar (Option 1)	$2,900,000	-$111,000	3.6	-1,730,000	0	N/A
RE3 – Large Scale Solar (Option 2)	$5,700,000	-$222,000	3.6	-3,458,000	0	N/A
RE3 – Large Scale Solar (Option 3)	$7,700,000	-$387,000	3.6	-6,033,000	0	N/A
RE3 – Large Scale Solar (PS 11)	$1,800,000	-$62,000	3.6	-929,000	0	N/A

Alternative	Capital Cost Differential	Annual O&M Cost Differential	Weighted Non-Economic Score	Net Electrical Energy Differential (kWh/yr)(1)	Net Thermal Energy Differential (MMBtu/yr) (1)	Additional Biogas Production (MMBtu/yr)
Thermal Energy and Biosolids Alternatives						
TH3 – Simplify Heat Loop	$26,700,000	-$884,000	4.4	-10,397,000	-36,100	0
BS2 – Non-Steam Based THP	$38,200,000	-$982,000	3.9	1,384,000	1,200	9,208
BS14C – TPAD, Class A Cake	$37,100,000	-$1,117,000	3.0	1,144,000	15,700	0
BS15C – Meso, Class B Cake	$26,000,000	-$1,207,000	4.4	1,144,000	-2,400	0
BS15L – Meso, Class B Liquid	$0	-$90,000	3.2	-38,000	-2,400	0
BS22 – Dewatering	$28,000,000	-$1,117,000	4.0	1,144,000	0	0
BS27 – Class A Lystek	$29,200,000	-$703,000	3.5	1,814,000	12,200	0
BS36 – Class A Composting	$47,700,000	$995,000	4.1	1,394,000	14,900	0

Notes:

(1) Net electrical energy and thermal energy differential is the difference between the energy consumption of the new alternative less the energy consumption of the respective baseline configuration. A positive differential indicates the new alternative uses more energy than the baseline. A negative differential indicates the new alternative is using less energy than the baseline and/or producing more energy than the baseline.

Chapter 3

PHASE 3

3.1 Phase 3 Overview

Phase 3 included a review of the foreseeable future regulatory drivers potentially affecting MMSD's energy use for alternatives identified in this Project. It also covered non-traditional financing, funding, and business model alternatives available to MMSD to recover capital costs associated with the planning, design, and construction of the elements within the Project.

3.2 Technical Memorandum 3.1: Regulatory Drivers (TM 3.1)[1]

3.2.1 Current Air Permit Requirements

3.2.1.1 Existing Air Emissions Equipment

MMSD's current air permit outlines air pollution compliance requirements for emissions equipment at NSWTP. The main emissions equipment specifically addressed in the air permit are shown in Table 3.1, with other numerous insignificant emissions units not included.

Table 3.1 NSWTP Air Emissions Equipment

Air Permit Identification	Fuel	Air Permit Description
Process P10	Not Applicable	Anaerobic Digesters with Biogas Treatment System
Process P08	Biogas	Waste Gas Flare
Boiler B01	Biogas	East Boilers (Three 8.0 MMBtuh Hot Water Boilers)
Boiler B01	Natural Gas	East Boilers (Three 8.0 MMBtuh Hot Water Boilers)
Boiler B02	Biogas	West Boilers (Three 4.18 MMBtuh Hot Water Boilers)
Boiler B03	Natural Gas	Bryan Boilers (Three 1.45 MMBtuh Hot Water Boilers)
Process B04	Biogas	Biogas Fired Engine Generators (Two 580 bhp Waukesha Engines)
Process B05	Biogas	Blower Engine (One 580 bhp Waukesha Engine)
Boiler B06	Biogas	Fulton Boilers (Four 8.0 MMBtuh Steam Boilers)
Boiler B06	Natural Gas	Fulton Boilers (Four 8.0 MMBtuh Steam Boilers)
Process P06	Not Applicable	Wastewater Treatment Plant Operations (Fugitive Emissions)
Process P11	Diesel	Emergency Generator (402 hp Diesel Fired Engine)
Process P18	Diesel	Emergency Generator (2010 hp Diesel Fired Engine)

[1] See Appendix G for additional information.

3.2.1.2 Existing Air Pollution Control Equipment

Emissions of formaldehyde from the biogas blower engine (Process B05) must be controlled using an oxidation catalyst according to MMSD's air permit, which was determined to be the Best Available Control Technology (BACT) for this engine. The required BACT for the two biogas fired engine generators includes maintenance activities such as oil changes, spark plug inspections, and inspections of belts and hoses.

3.2.1.3 Current Air Emissions and Limitations

MMSD must estimate air emissions from NSWTP and report this data on an annual basis to the WDNR Air Management Program. Emissions are calculated for all major emissions equipment using standard emission factors and data from stack testing when available. Carbon monoxide (CO) and NO_x have facility-wide permit limitations of 198,000 lb/year for each of these pollutants. A summary of the average air emissions reported from 2015 through 2019 for CO and NO_x is shown in Table 3.2.

Table 3.2 Average NSWTP Air Emissions from 2015 through 2019

Air Permit Identification	Air Permit Description[1]	CO Emissions (lb/year)	NO_x Emissions (lb/year)
Process P08	Waste Gas Flare	3,700	300
Boiler B01 (Biogas)	East Boilers (Three 8.0 MMBtuh Hot Water Boilers)	100	100
Boiler B01 (Natural Gas)	East Boilers (Three 8.0 MMBtuh Hot Water Boilers)	1,000	1,200
Boiler B02 (Biogas)	West Boilers (Three 4.18 MMBtuh Hot Water Boilers)	1,600	1,100
Boiler B03 (Natural Gas)	Bryan Boilers (Three 1.45 MMBtuh Hot Water Boilers)	400	500
Process B04 (Biogas)	Biogas Fired Engine Generators (Two 580 bhp Waukesha Engines)	43,000	91,300
Process B05 (Biogas)	Blower Engine (One 580 bhp Waukesha Engine)	5,900	26,500
Boiler B06 (Biogas)	Fulton Boilers (Four 8.0 MMBtuh Steam Boilers)	900	600
Boiler B06 (Natural Gas)	Fulton Boilers (Four 8.0 MMBtuh Steam Boilers)	1,000	1,200
Total		**57,600**	**122,800**

Notes:
(1) Emissions are not reported for the anaerobic digesters, waste gas flare, and emergency generators.

3.2.2 Air Emissions Regulatory Considerations

3.2.2.1 Existing Air Emissions Capacity

As shown in Table 3.2, NO_x emissions average approximately 122,800 lb/year, which is about 62 percent of the allowable NO_x emissions (198,000 lb/year) under MMSD's current air permit. The majority of NO_x emissions, and pollutant emissions in general, are generated from the biogas blower engine and biogas engine generators. The CO and NO_x emissions limitations in MMSD's current air permit are due to the facility's classification as a synthetic minor source, meaning that emissions are capped below the major source threshold of 200,000 lb/year for any criteria pollutant (CO, NOx, sulfur dioxide, lead, ozone, and particulate matter). If emissions are anticipated to increase to levels at or above the major source threshold, MMSD will need to apply for a revised air permit as a major source, resulting in higher permit fees and different federal compliance requirements.

3.2.2.2 Future Air Pollution Regulatory Considerations

Future regulatory considerations are related to changes in emissions equipment and the potential increases in biogas production. There are no anticipated state regulations that would impact MMSD's current air permit, but this is subject to change upon permit reapplication.

Any changes to emissions equipment at NSWTP will result in changes to the facility wide emissions. New equipment such as internal combustion engines may have lower emission factors than existing equipment due to recent regulations such as New Source Performance Standards (NSPS). NSPS are federal standards required by the Clean Air Act that apply to specific categories of stationary sources.

Alternatives associated with accepting high-strength waste for codigestion will have an impact on air emissions. Both the biogas quantity and quality will be impacted by these alternatives. Biogas analysis is recommended during any pilot testing of high-strength waste codigestion to determine any changes in methane, hydrogen sulfide, oxides of nitrogen, and siloxane content. Implementing pipeline quality gas treatment would also impact air emissions due to the need for a thermal oxidizer for off-gas and the higher consequent demand of natural gas for additional heating.

Implementing incineration would have a significant impact on air permitting at NSWTP and likely would have local stakeholder and community considerations as well.

3.2.2.3 Future Air Permit Modifications

Air permitting requirements should be reviewed in detail and coordinated with the WDNR when proposing modifications to existing emissions equipment or construction of new emissions equipment. In general, an air pollution control construction permit will be required for the projects considered herein along with a revised operation permit. A thorough review of the existing compliance requirements is recommended if MMSD's air permit is revised. Future air permit modifications may require air dispersion modeling to demonstrate compliance with ambient air quality standards.

3.2.3 Current WPDES Permit Requirements

The NSWTP is presently operating under Wisconsin Pollutant Discharge Elimination System (WPDES) Permit No. WI-0024597-09-0 with a permit expiration date of March 31, 2025. Permit limits for BFC and BMC can be found in Appendix B of TM 3.1.

3.2.4 Nutrient Regulations

3.2.4.1 Phosphorus

Phosphorus rule revisions were passed by the Wisconsin State Legislature and became effective on December 1, 2010. These regulations established numeric water quality criteria for phosphorus. The criterion for BMC and BFC is 0.075 mg/L. Additional phosphorus compliance alternatives are available beyond treatment upgrades, including water quality trading (WQT), watershed adaptive management (AM), and the multidischarger variance (MDV).

MMSD has already determined, based on cost-effectiveness and triple bottom line considerations, to pursue AM for its BFC outfall compliance option. Watershed AM allows a WWTP to partner with other sources of phosphorus loading to make load reductions elsewhere in its watershed, often including nonpoint source load reductions. MMSD is collaborating with multiple partners in the Yahara River watershed on an AM program called Yahara Watershed Improvement Network (Yahara WINs) established in 2012. MMSD's current phosphorus effluent limit for the BFC outfall is 0.6 mg/L as a six-month average and is an interim limit associated with AM. The interim limit is anticipated to decrease to 0.5 mg/L for the second and third permit terms.

The current interim limit for the BMC outfall is 0.6 mg/L as a six-month average. MMSD will need to evaluate alternatives, such as those mentioned above or even discontinuing discharge to BMC completely, for compliance with an expected 0.075 mg/L six-month average and 0.225 mg/L monthly average limit for the BMC outfall in 2028. Implementation of AM at the BFC outfall is expected to have a minimal impact on energy use, while the energy impact of a compliance alternative at the BMC outfall could be significant.

3.2.4.2 Total Nitrogen (TN)

TN includes all forms of nitrogen: organic, ammonia, and inorganic forms like nitrite and nitrate. The WDNR's Triennial Standards Review states that WDNR does not believe there is sufficient data to calculate a scientifically defensible water quality standard for nitrogen. Phosphorus is generally understood to be the limiting nutrient for algal growth and, therefore, the nutrient that requires control in Wisconsin surface waters. Regardless, new TN effluent limits appear likely within approximately the next 10 to 20 years. For planning purposes, limits in the treatment technology-based range of 8 to 10 mg/L can be assumed. Future TN limits are anticipated to have minimal impact on the alternatives evaluation of this study.

3.2.4.3 Ammonia

The current Wisconsin water quality standards for ammonia are based primarily on toxicity to fish. The US EPA developed and adopted more stringent ammonia criteria for surface waters that have the ability to support mussels and snails, which are more sensitive to ammonia. State-level adoption is expected within approximately the next five to ten years. The WWTP currently discharges an average effluent ammonia concentration that is well below permit limits, and MMSD staff do not expect the new criteria and potential lower limits to be a major consideration.

3.2.4.4 Total Maximum Daily Load

The Rock River Basin phosphorus and sediment total maximum daily load (TMDL) affects the BFC discharge and would affect any future outfalls in the Yahara River Watershed of the Rock River Basin.

A. Phosphorus TMDL

MMSD's TMDL derived limits for total phosphorus at BFC range from 54 to 67 pounds per day. The Yahara WINs AM program will be used to meet phosphorus wasteload allocations.

B. Sediment/TSS TMDL

MMSD's TMDL derived limits for TSS range from 4,600 to 8,470 lb/day as a monthly average and 7,690 to 14,100 lb/day as a weekly average. MMSD should not need to implement any special provisions at the NSWTP to meet these TSS limits. The Yahara WINs AM program can be used to help meet TSS limits if needed.

3.2.5 Badger Mill Creek Outfall

Discontinuing the use of BMC outfall should be coordinated with the WDNR and other stakeholders within the Sugar River watershed because it will shift the water balance from the Sugar River watershed to the Rock River watershed. However, removing the BMC outfall has the regulatory advantage of eliminating additional phosphorus compliance strategies associated with the proposed 0.075 mg/L phosphorus limit and any future limits related to nitrogen or other pollutants, which would have a significant impact on the energy use at NSWTP. This alternative remains in the preliminary stages of conception and requires extensive further analysis, as well as community engagement and input. Though there is no regulatory requirement to maintain an effluent discharge; it would need to be closely coordinated with WDNR and other stakeholders within the Sugar River watershed to account for considerations other than energy savings.

3.2.6 Badfish Creek Outfall

Eliminating the BFC outfall (alternative EP4) through a gravity discharge to Lake Waubesa via NSC would have several regulatory implications. In accordance with Wisconsin State Statute 281.47 it is expected that the effluent quality would need to be close to background surface water quality prior to approval of a Lake Waubesa discharge. Per previous correspondence, the WDNR indicated that any permitted discharge to NSC would need to receive tertiary treatment and require limits that are less than the water quality criteria. Although there are significant regulatory obstacles associated with an NSC discharge, the potential energy reduction and resiliency improvements make this alternative strategic, but the need for tertiary treatment could nullify these benefits, making the alternative cost and resource prohibitive.

3.2.7 Chloride Regulations

Wisconsin's chloride standards are included in NR 105, and the acute and chronic standards are 757 mg/L and 395 mg/L, respectively. MMSD currently has chloride limits of 430 mg/L for the months of April through October and 465 mg/L for the months of November through March. The average chloride effluent concentration from 2015 through 2019 was 370 mg/L.

Chlorides are not removed through settling or biological processes and require treatment such as reverse osmosis for removal. Alternatives that impact the effluent chloride concentration should consider these chloride regulations. The evaluation of potential high strength waste feed stock for codigestion should include analysis for chlorides.

3.2.8 Recreational Standards

The US EPA's recommended recreational water quality criteria are based on the use of two bacterial indicators of fecal contamination, *E. coli* and enterococci. The WDNR has developed water quality standards based on the US EPA recommendations with *E. coli* limits of 126 colony forming units (CFU)/100 milliliters (mL) (geometric mean) and 410 CFU/100 mL (statistical threshold value) expressed on a calendar month basis. A new UV system that is designed to meet the new *E. coli* limits is being constructed and is scheduled to be in service prior to the 2021 disinfection season. The UV system average energy use is anticipated to decrease from 1,200 kwh/day to 900 kwh/day with the new equipment, though the system may need to run longer over the year than previously, which could decrease these energy savings.

3.2.9 Thermal Regulations

The State of Wisconsin has adopted thermal standard rule revisions in NR 102 and NR 106 of the Wisconsin Administrative Code. MMSD's permit application for reissuance, along with a request for Alternative Effluent Limits (AEL) for temperature for BMC, has been approved by the WDNR. There are no temperature limits for BFC because of its NR 104 variance status. Should the WDNR include stricter temperature limits in future permits, MMSD may have an opportunity to perform a dissipative cooling analysis on one, or both, of the receiving streams to determine if the limits are necessary. Alternatives in this study are not expected to have a measurable impact on effluent wastewater temperature, however, future limits could be a driver for additional effluent heat recovery.

3.2.10 Other Current or Upcoming Water Quality Regulations

3.2.10.1 PFAS

PFAS are a large group of chemicals that have been used in industry and consumer products since the 1950s. PFAS do not occur naturally but are now widespread in the environment due to human use. The EPA has established a health advisory level of 70 parts per trillion for PFAS in drinking water.

There are currently no effluent or biosolids standards related to PFAS in Wisconsin. However, WDNR is currently working to create human health surface water quality criteria that may result in new water quality based effluent limitations. Data for treatment of PFAS is limited, however it is likely that treatment technologies at the plant will be limited to advanced processes, though further study and evaluation of these developing technologies is needed. PFAS regulations, as a result, could significantly increase energy use at NSWTP, however there is high uncertainty at this time related to future PFAS treatment requirements for both effluent and biosolids.

3.2.10.2 Microplastics

Microplastics are defined as plastic particles less than 5 millimeters (mm) in size (although they can be much smaller) and are now widespread in the environment. Although there are no regulations related to microplastics in effluent and biosolids at this time, MMSD should continue to monitor this issue. Consideration regarding the cleanliness of potential high strength waste feedstocks is imperative.

3.2.10.3 Pharmaceuticals and Other Compounds of Emerging Concern

The WDNR does not currently have rules related to microconstituents like pharmaceuticals or compounds of emerging concern (CEC). MMSD has undertaken initiatives for pollution prevention and source reduction and these efforts may continue to be the best approach for these parameters during the facilities planning period. Similar to PFAs, though, possible future regulations would likely require advanced treatment technologies, such as incineration, which would significantly increase energy use at NSWTP.

3.2.11 Groundwater Discharge Requirements

Groundwater recharge using effluent is being practiced in several locations around the state, particularly in the Wisconsin River Valley and other locations where soils are sandy and thus conducive to infiltration. Some groundwater infiltration locations have been identified in Dane County but may not be cost effective due to the energy use associated with conveyance and additional treatment required compared to the volume recharged, as such groundwater recharge is not being evaluated in detail in this study.

3.2.12 Effluent Reuse Requirements

Wastewater effluent is being used for industrial noncontact cooling and other noncontact uses in some locations, particularly where fresh water is scarce. Wisconsin currently has no specific standards for the treatment of effluent for use in an industrial facility. MMSD effluent can be utilized for a number of purposes and reuse could be considered as an alternative to pumping to BFC or BMC to save energy, but to date uses do not appear sufficiently cost effective and beneficial at this time. While this could change in the future, effluent reuse is not being evaluated in detail in this study.

3.2.13 SSO and CMOM Regulatory Parameters

In August of 2013 the State of Wisconsin published administrative rule revisions at NR 210 that prohibit sanitary sewer overflows (SSOs) and contain provisions to develop a Compliance, Management, Operation, and Maintenance (CMOM) program. MMSD has been addressing these regulations including implementing projects to reduce infiltration/inflow (I/I) in its collection system and updating its sewer use ordinance (SUO). Reductions in I/I provide significant energy savings related to pumping in both the collection system and at NSWTP.

3.2.14 Biosolids Handling and Beneficial Reuse

Biosolids handling at NSWTP follows the requirements of Chapter NR 204, Domestic Sewage Sludge Management. MMSD generates biosolids that are land-applied mainly as liquid (Class B), although a portion is dewatered (Class A). WDNR does not require facilities to produce Class A biosolids, instead, the decision to do so is driven by local conditions and other economic factors and resiliency considerations. Producing Class A biosolids could provide the advantage of reduced energy for hauling as compared to Class B biosolids, however, it takes more energy onsite to produce Class A biosolids. This tradeoff was evaluated for the applicable alternatives in Phase 2.

Class A biosolids must have a fecal coliform concentration of less than 1,000 most probable number (MPN) per gram of total solids and meet one of several alternative treatment process standards. They also must meet high quality criteria for metals, and a process-based vector attraction reduction requirement, if they are to be labeled "exceptional quality." Biosolids that are considered "exceptional quality" have several advantages such as not needing to meet the lifetime cumulative metal loadings to be land applied, land application site evaluation reports would not be required, and more sites or other markets would potentially be available for the biosolids.

The USEPA periodically conducts surveys and investigations of biosolids content including metals, organics, inorganic ions, and other targeted pollutants to determine exposure and identify new target pollutants to be regulated. This assessment is ongoing and may eventually affect the way MMSD monitors pathogens and manages biosolids.

The WDNR and other states have also been considering requiring agronomic phosphorus application rates, which could make phosphorus the limiting nutrient for land application of biosolids instead of nitrogen. However, while working with WDNR in developing the Phosphorus Index (PI) for the state, University of Wisconsin (UW) agreed with WDNR that water extractable phosphorus (WEP) is the key concern for water quality. WEP in biosolids is considerably lower than all other forms of organic residuals. Using equations developed by UW, a municipality can insert their own WEP to determine their site-specific PI. This scientific approach is preferential to the alternative of considering all phosphorus equally available and restricting biosolids application to the amount of phosphorus required for plant growth. This restriction is intended to reduce the amount of phosphorus runoff from agricultural land into surface waters. The increasing concern over nutrients in surface water and groundwater could result in lower biosolids application rates in the future (meaning more land and longer hauling distances will be required), more careful selection of land application sites, and possibly installation of BMPs at biosolids application sites to reduce soil erosion and runoff. These requirements would likely result in higher future hauling fuel use and overall costs for biosolids reuse.

Concerns over PFAS and other CEC in biosolids could impact the way MMSD manages its biosolids in the future. Landfilling of dewatered biosolids may not be the long-term solution, since PFAS can migrate through the landfill and into the leachate. Instead, the potential need for advanced treatment processes to meet future effluent and biosolids regulations for both PFAs and CECs could significantly increase energy use at NSWTP.

Changing weather patterns and farming practices could also impact MMSD's biosolids land application program. Many agricultural producers have relatively small windows of time in the spring and fall when they will accept biosolids.

3.2.15 Summary of Potential Regulatory Impacts

A summary of the potential regulatory impacts for the alternatives considered feasible and strategic is shown in Table 3.3.

Table 3.3 Potential Regulatory Impact Summary for Feasible and Strategic Alternatives

Alt. ID	Alternative Name	Category	Potential Regulations Impacted	Overall Impact Category(1)
BG6	Status Quo Operation (Engine-Driven Blowers; Boilers; Cogen Engines) with replacement of aging equipment	Feasible	Air permitting	B
BG7	Replace cogen with microturbines	Feasible	Air permitting	B
EP1	Install VFDs and optimize pump operations	Feasible	Little or no impact on regulations	A
EP8	Hydroelectric generation	Feasible	Little or no impact on regulations	A
TH3	Simplify heat loop	Feasible	Little or no impact on regulations	A
BS9	Enhanced Primary Treatment	Feasible	Biosolids	A
BS15	Meso Acid/Meso Methane, Class B Biosolids	Feasible	Air permitting, biosolids, PFAS, CECs	B
BS22	Centrifuge Dewatered Cake	Feasible	Biosolids, PFAS, CECs	A
BS27	Class A Liquid Fertilizer	Feasible	Air permitting, biosolids, PFAS, CECs	B
BG9	Upgrade cogeneration to handle all NSWTP electricity needs (microgrid)	Strategic	Air permitting	B
BG14	Condition biogas for pipeline injection	Strategic	Air permitting	B
C1	Co-Digest Food Waste Slurry from Solid Waste (All Digesters)	Strategic	Air permitting, biosolids	B
C2	Co-Digest FOG (All Digesters)	Strategic	Air permitting, biosolids	B
EP4	Gravity discharge to NSC	Strategic	Significant WPDES and potentially statutory impacts, political considerations	C
EP7	Eliminate BMC discharge	Strategic	Not a regulatory issue, but coordination with WDNR required, local stakeholder and community considerations	B
EP9	Partnership or Incorporation with Sun Prairie WWTP	Strategic	Air permitting, biosolids, CMOM, political considerations	B
ES1	Battery storage	Strategic	Little or no impact on regulations	A
ET6	Pyrolysis	Strategic	Air permitting, biosolids, CECs	C

Alt. ID	Alternative Name	Category	Potential Regulations Impacted	Overall Impact Category(1)
ET15	Biosolids Gasification	Strategic	Air permitting, biosolids, PFAS, CECs	B
RE1	Rooftop solar	Strategic	Little or no impact on regulations	A
RE3	Large scale solar array (>1 MW)	Strategic	Little or no impact on regulations	A
BS2	Class B Non-Steam Based Thermal Hydrolysis	Strategic	Air permitting, biosolids, PFAS, CECs	B
BS14	Meso Acid/Thermo Methane Batch/Meso Methane, Class A Biosolids	Strategic	Air permitting, biosolids, PFAS, CECs	B
BS25	Class A Pellets - Low Temperature Drying	Strategic	Air permitting, biosolids, PFAS, CECs	B
BS29	Incineration with Energy Recovery	Strategic	Air permitting, biosolids	C
BS36	Class A with Onsite Composting	Strategic	Biosolids, PFAS, CECs	B

Notes:
(1) A = Little or no regulatory impact. B = Regulations will be a factor but considered during facility planning. C = Regulations will impact Energy Management Master Plan recommendations.

3.3 Technical Memorandum 3.2: Funding Opportunities[2]

3.3.1 Approach to Funding Opportunities

In terms of project financing, reducing the cost of revenue required for financing to the ratepayers is an important consideration for MMSD and a main factor guiding financing pursuits. As such, the funding approach practiced by MMSD is to secure low-cost financing for any project where it is needed. The primary financing options include loan and financing programs, as well as revenue models, both of which MMSD has previous experience with. Revenue models offer opportunities to generate additional sources of revenue while maintaining control over the infrastructure and project specifications. Low interest loan programs are versatile and can be combined with revenue models when used for the infrastructure needed. Less common options are non-traditional funding opportunities such as energy performance contracts and power purchase agreements. These opportunities typically result in higher effective interest payments than any of the loan programs and yield control of infrastructure, equipment, and project specifications to a third-party.

Grants and rebates provide an additional source of funding and generally, MMSD may apply for grant and rebate opportunities regardless of the main financing route. But due to their competitive nature they are not a guaranteed source of funding and therefore are kept separate from the other opportunities. Table 3.4 summarizes the various funding opportunities available to MMSD.

Table 3.4 Funding Opportunities Summary

Agency/Funding Opportunity	Opportunity Type	Engagement Requirement
Loans and Financing		
WDNR CWFP	Financing/Loan	Any
US EPA Water Infrastructure Finance and Innovation Act	Financing/Loan	Pre-design
Wisconsin BCPL	Financing/Loan	Pre-design
Public Finance Authority	Financing/Loan	Any
Grants and Rebates		
US EPA Sustainable Materials Management Anaerobic Digestion Funding Opportunity	Grant	By Application Deadline
US EPA Supporting Anaerobic Digestion in Communities	Grant	By Application Deadline
US EPA Wastewater Efficiency Grant Pilot Program	Grant	To Be Determined
FEMA BRIC	Grant	To Be Determined
US DOE Research and Development for Advanced Water Resource Recovery Systems	Grant	To Be Determined
US DOE Water Security Grand Challenge Resource Recovery Prize	Grant	To Be Determined
US EPA Clean Water Infrastructure Resiliency and Sustainability Program	Grant	To Be Determined
Focus on Energy - Energy Efficiency	Grant	Pre-Equipment Purchase

[2] See Appendix H for additional information.

Agency/Funding Opportunity	Opportunity Type	Engagement Requirement
Focus on Energy - RECIP	Grant	Pre-Equipment Purchase
Focus on Energy - Solar	Grant	Reservation Required
Non-traditional Revenue and Funding		
Wisconsin Sales Tax Exemption	Credit	Post-Implementation
Wisconsin Net Metering	Business Model	Pre-design
Energy Performance Contracts and Performance Contracting	Business Model	Pre-design
Renewable Natural Gas	Credit	Post-Implementation

Notes:
(1) Abbreviations: BCPL = Board of Commissioners of Public Lands, BRIC = Building Resilient Infrastructure and Communities, CWFP = Clean Water Fund Program, DOE = Department of Energy, FEMA = Federal Emergency Management Association, RECIP = Renewable Energy Competitive Incentive Program.

3.3.2 Loans and Financing Programs

3.3.2.1 Water Fund Program

The State of Wisconsin Environmental Improvement Fund's (EIF) CWFP provides financial assistance to municipalities for publicly owned wastewater and stormwater infrastructure projects in the form of low interest loans. Interest rates are determined at the beginning of each funding cycle and are locked for the duration of the cycle.

Funding can be used for a variety of purposes including loan/debt refinancing, project planning, engineering design, construction costs (pre- or during construction), or to reimburse municipal funds. Loan terms are variable depending on the project with fixed interest rates for long term loans.

Program Link: https://dnr.wi.gov/Aid/EIF.html

3.3.2.2 US EPA Water Infrastructure Finance and Innovation Act

The Water Infrastructure Finance and Innovation Act (WIFIA) of 2014 established a federal credit program to accelerate investments in water and wastewater infrastructure. The program complements existing financing options, providing low interest loans of up to 49 percent of eligible project costs for the planning/design and or construction of large dollar-value water and wastewater projects with project or bundle of projects costs of no less than $20 million.

Total federal assistance from WIFIA and other federal funding sources cannot exceed 80 percent of total project costs. The interest rate, which is established at the time of loan closure, is equal to the United States Treasury rate of a similar maturity plus one percentage point with a loan term of 35 years.

The WIFIA application process is a two-step process: letter of interest (LOI) and WIFIA Application (upon invitation to apply). The loan process and its steps are given in Figure 3.1.

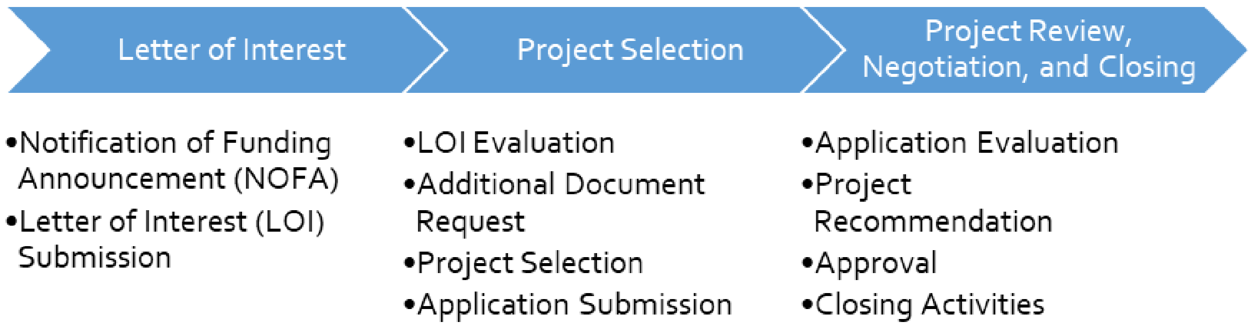


Figure 3.1 WIFIA Loan Process

Program Link: https://www.epa.gov/wifia

3.3.2.3 Wisconsin Board of Commissioners of Public Lands

The BCPL is a government agency specializing in financing, among other items, public sector infrastructure projects. The BCPL offers fixed rate loans with interest rates that are competitive with the bond market and other financial institutions. MMSD is eligible to apply for the State Trust Fund Loan Program, which consists of the General Obligation Loan and the Municipal Utility Revenue Obligation Loan.

General Obligation Loan

The General Obligation Loan allows for MMSD to finance capital projects, operations, and/or maintenance activities for loans of 10 or less years. Loans structured greater than 10 years are restricted to financing or refinancing of public purpose projects. Loan terms can be set from a 2 to 20-year fixed rate, with the rates dependent on the length of the loan terms. Loan availability: within 30-45 days from initial application.

Municipal Utility Revenue Obligation Loan

The Municipal Utility Revenue Obligation Loan is restricted to financing public purpose projects. Loan terms can be set from a 2 to 30-year fixed rate. The rate will vary depending on the risk assessment of MMSD and project during the transaction underwriting process, which includes the strength of the pledged revenues of MMSD. Loan availability: within 30-60 days from initial application.

The application process is similar for both loans, though Municipal Utility Revenue Obligation loans have greater documentation and information requirements. Funds are set aside at the time of application and thus must be requested when the project is certain to move forward.

3.3.2.4 Public Finance Authority

The Public Finance Authority (PFA) offers a water/wastewater pooled bond program that offers financing at AA rates. The PFA bundles borrower obligations and issues bonds with additional security provided by a bond insurer. Loan amounts range from $2 million to $30 million.

Program Link: https://www.pfauthority.org/finance-programs/waterwastewater-pooled-bond-program/

3.3.3 Grants and Rebates

3.3.3.1 Overview and Resources

Grant and rebate programs generally offer one-time award amounts to be used towards specific aspects of a project. Grants offer monetary awards at the start of the project or during the course of implementation. Rebate programs offer a reimbursement of costs after project implementation.

The State rebate programs have much simpler application processes that change little year-to-year, however they tend to offer lower total monetary awards. Federal and private-sector grant programs may require a significant upfront effort during the application process, but provide a much larger monetary award. Given the number of grants and rebate programs presented, Tables 3.5 and 3.6 showcase the various programs in order of likelihood of receipt.

Table 3.5 State Grants Ranked by Grant Amount and Likelihood of Receipt

Rank	State Grants, Low Amount High Likelihood
1	Focus on Energy - Energy Efficiency
2	Focus on Energy - RECIP
3	Focus on Energy - Solar

Table 3.6 Federal Grants Ranked by Grant Amount and Likelihood of Receipt

Rank	Federal Grants, High Amount Low Likelihood
1	US EPA Wastewater Efficiency Grant Pilot Program
2	US EPA Clean Water Infrastructure Resiliency and Sustainability Program
3	US EPA Sustainable Materials Management Anaerobic Digestion Funding Opportunity
4	US EPA Supporting Anaerobic Digestion in Communities
5	US DOE Water Security Grand Challenge Resource Recovery Prize
6	US DOE Research and Development for Advanced Water Resource Recovery Systems
7	FEMA BRIC

3.3.3.2 State Programs – Small-scale Grants and Rebates

Focus on Energy

The Focus on Energy program suite is funded by Wisconsin's investor-owned energy utilities and participating municipal and electric cooperative utilities. Program offerings take the form of grants, rebates, and energy studies.

Program Link: https://www.focusonenergy.com/business/water-and-wastewater-facilities

Energy Efficiency Incentives

The Focus on Energy program offers rebates on projects that result in a reduction of energy use. Incentive offerings are separated into two categories: the Standard Program and the Custom Program. The Standard Incentive Program offers set financial rebates for commonly installed energy efficiency equipment with a cap of $400,000 of incentive funding per year.

The Custom Program provides financial rebates to process-related projects that will result in the decrease of overall facility energy use and are based on the total amount of energy savings realized in the first year by the new equipment or process changes. The maximum funding allotment for the Custom Program is $300,000 per project, or 50 percent of the project cost, whichever is lower. Projects are required to have a simple payback between 1.5 to 10 years based on energy savings.

Renewable Energy Competitive Incentive Program

The RECIP offers funding for renewable energy projects through a competitive request for proposal (RFP) process. The RECIP offers grant funding for biogas, biomass, solar, thermal, and wind projects. Biogas that is injected into a pipeline or used as vehicle fuel does not qualify for RECIP funds. The program budget for the

2019-2021 program year was set to $700,000 and is awarded as a grant before construction on a first-come, first-served basis. The total amount awarded under RECIP is determined based on the estimated first year net energy production or energy offset created by the new system.

Solar Funding

Focus on Energy solar project funding is based on the size of the installed photovoltaic solar system and is granted as a rebate after the system is installed on a first-come, first-served basis.

3.3.3.3 Federal Grant Opportunities

US EPA Wastewater Efficiency Grant Pilot Program

The purpose of the grant pilot program is to award grants to publicly owned or operated treatment works that implement waste-to-energy projects, with grant payments up to $4,000,000. The program is expected to be competitive with the total amount of federal funds allocated to the program for fiscal years 2021 and 2022 at $17,500,000, which is disbursed on a first-come, first-served basis.

US EPA Clean Water Infrastructure Resiliency and Sustainability Program

The program is designed to assist treatment works in the planning, design, construction, implementation, operation, or maintenance of a program or project to increase the resiliency or adaptability of water systems to natural hazards. For each fiscal year 2021 through 2024, $5 million is being requested to be divided into individual grants for projects.

US EPA Sustainable Materials Management Anaerobic Digestion Funding Opportunity

This EPA funding opportunity is seeking projects to assist with diverting food waste from landfills by expanding overall anaerobic digestion capacity in the United States. The goal of the program is to accelerate the development of new or enhanced anaerobic digestion capacity and infrastructure. Individual project grants could be in the range of $50,000 to $300,000 for the funding period.

Program Link: https://www.epa.gov/sustainable-management-food/sustainable-materials-management-2020-anaerobic-digestion-funding

US EPA Supporting Anaerobic Digestion in Communities (Grant Identification Number: EPA-OLEM-ORCR-20-02)

The US EPA has a goal of reducing food and organic waste entering landfills. To support this effort the EPA developed a grant opportunity to install and improve anaerobic digesters for private and public facilities. This grant opportunity seeks to fund demonstration projects with project awards expected to be in the range of $50,000 - $300,000.

US DOE Water Security Grand Challenge Resource Recovery Prize

The DOE seeks multidisciplinary teams to develop pilot projects dedicated to resource recovery at wastewater treatment facilities through a two-phase prize competition with an anticipated award for winning submissions of $250,000.

US DOE Research and Development for Advanced Water Resource Recovery Systems (Grant Identification Number: DE-FOA-0002336)

Grant funds are provided for innovative research and development projects or pilot projects at wastewater treatment facilities that focus on resource recovery of captured wastewater. As part of the DOE's Water Security Grand Challenge (WSGC), several more funding opportunity announcements (FOAs) are expected to be released over the next several years.

FEMA Building Resilient Infrastructure and Communities

The goal of the program is to shift federal funds toward proactive investment in projects that improve a community's resiliency for disasters. Through the BRIC program, FEMA is placing an emphasis on funding infrastructure projects.

3.3.4 Non-traditional Revenue and Funding Opportunities

3.3.4.1 Net Metering with Local Utility

MG&E allows for Net Metering for the generation of renewable energy onsite. The production and distribution rates and charges depend on the generation capacity. The rate schedule will be determined by the agreement between MG&E and MMSD, but generally if an entity is considered a Net Seller (amount of energy sold exceeds the amount of energy used) then the entity is credited at MG&E's PG-1 rate.

3.3.4.2 Renewable Natural Gas

As part of the Federal Renewable Fuel Standard (RFS), administered by the US EPA, pipeline quality digester gas is considered a renewable natural gas that can be traded through the use of RINs. The market price for RINs is variable and can be traded either through the federal market or the voluntary market (directly to a consumer).

Typically, biogas is categorized under D3: Cellulosic Biofuel RIN, which allows it to count against compliance for D5 and D6 RINs. But a recent update by the EPA now devalues RINs to a D5 value when a wastewater treatment plant hauls in organic waste for co-digestion and converts the biogas to transportation fuel. It should be noted that many of the federal and state funding sources for biogas-production prefer biogas to be utilized as a fuel-source on premise, which could limit the available federal funding opportunities.

3.3.4.3 Energy Performance Contracting and Power Purchase Agreements

Energy Performance Contracting

Energy performance contracts (EPCs) typically are agreements in which the energy service company (ESCO) fronts the initial capital to implement an energy efficiency and/or renewable energy project then realized monetary savings from the project are used to finance the upfront capital over a set period of time. Energy performance contracts usually require the agency entering into the agreement to implement several (or large-scale) projects to ensure that the realized energy and monetary savings sufficiently cover the cost of project implementation.

Performance contracts may be preferred to bank loans since MMSD will only need to pay out realized monetary savings from any installed improvements. ESCOs are also able to take advantage of state or federal tax credits, rebate programs, or other available incentives to decrease the upfront or long-term costs of the project, some of which may not be available to a municipality.

Program Link: https://psc.wi.gov/Pages/Programs/OEI/MEETAP.aspx

Additional Resource Link: https://www.uww.edu/Documents/sustainability/performance_contracting.PDF

Power Purchase Agreement (PPA)

PPAs are contracts between a developer and a proposed supplier of excess electricity. The PPA developer is responsible for arranging to design, permit, finance, then install power generating equipment at MMSD. MMSD typically will pay little to no upfront costs for the project, instead agreeing to purchase the produced power from the developer at a fixed rate that should be less than the local power utility (MG&E) to be financially attractive.

Power purchase agreements are beneficial for areas of expertise that MMSD may not currently have, such as solar- and wind-powered electric generation. These agreements are also beneficial if MMSD has excess land or real estate that will not be used for a set period of time.

MG&E's RER Program is one such example of a PPA. In this program, MG&E would supply the funding, equipment, and a 30-year lease (or as negotiated) to build a solar field on MMSD property. MMSD would just initially be responsible for the electrical infrastructure to distribute the energy to NSWTP. Any excess energy produced by the solar field could also be credited against the electrical demand in the collection system.

3.3.5 Summary of Potential Funding Opportunities

Each of the funding opportunities presented have different requirements for application and are ideal for specific alternatives. The loan funding programs are very versatile and can be used for nearly all the feasible and strategic alternatives. Among these programs, the Clean Water Fund Program is considered the most advantageous by maintaining the lowest rates, along with MMSD's familiarity with the program, and the availability of funds from a large annual budget.

The grants and rebate programs tend to offer monetary awards that align with the particular mission of that program. Similarly, revenue models and non-traditional funding opportunities are ideal for specific alternatives. For example, net metering with a local utility would be applicable to alternatives that emphasize production of renewable energy on site, such as biogas alternatives that upgrade the cogeneration system or the solar power alternatives. While the opportunity to generate revenue from renewable natural gas production would be most applicable to alternative BG14 – Condition Biogas for Pipeline Quality.

Loans are considered the best and most common primary financing route and are the recommended path forward. Such funding programs provide readily available financing and have large annual budgets to support capital-intensive projects, while offering the best opportunity to minimize the cost-of-debt to rate payers. Grants should be explored and used to supplement loans with additional funding when available. Alternative funding opportunities can be utilized if other financial considerations arise such as the desire to avoid a large loan or in a case where it is denied.

Chapter 4

PHASE 4

4.1 Phase 4 Overview

The original purpose of Phase 4 was to develop and document capital improvement recommendations for the Plan. Due to the number of recommended projects and overall capital expenditure requirements, it became apparent that many of the recommended projects would project beyond the initial 10-year planning period, so this period was extended to 20-years.

The capital improvement recommendations provides a timeline for replacement, rehabilitation, or change of existing assets or group of assets within 20 years that prioritizes action based primarily on condition and criticality, but also considers balancing capital costs over multiple years. It was developed by first documenting business case evaluations for four varied combinations of complementary Strategic/Feasible alternatives that were carried forward from Phase 2. Based on the results of these business case evaluations, a suite of projects was recommended for inclusion in MMSD's capital improvements plan (CIP). It should be noted that this process is unique to this specific project and differs from MMSD's current overall CIP process.

4.2 Technical Memorandum 4.1: Business Case Evaluation (TM 4.1)[1]

4.2.1 Background

A total of 61 energy and biosolids alternatives were identified in Phase 2 and were sorted into four categories: Simple, Feasible, Difficult, and Strategic. The 26 alternatives deemed Feasible and Strategic were further evaluated against the eight screening criteria developed in Phase 1: Energy Impact, Capital Cost, O&M Cost, Operational Impacts/Flexibility, Aging Infrastructure, Synergistic Benefit, Maturity of Technology, and Greenhouse Gas Footprint.

Subsequent to the completion of Phase 2, the BMP recommended that MMSD investigate converting from their existing Class B liquid process to a Class B cake process. This project's Phase 2 analysis also showed that this was the highest scoring biosolids alternative, therefore, biosolids handling alternatives that produce a Class B cake product were carried forward.

Based on the evaluation from Phase 2 and the conclusions of the BMP, the following alternatives were recommended to be carried into Phase 4. Figure 4.1 presents these alternatives in a decision tree format. The first tier of bubbles refers to a particular plant process area which then branches to the second tier of bubbles that refer to the alternatives available to be chosen for that given process area.

[1] See Appendix I for additional information.

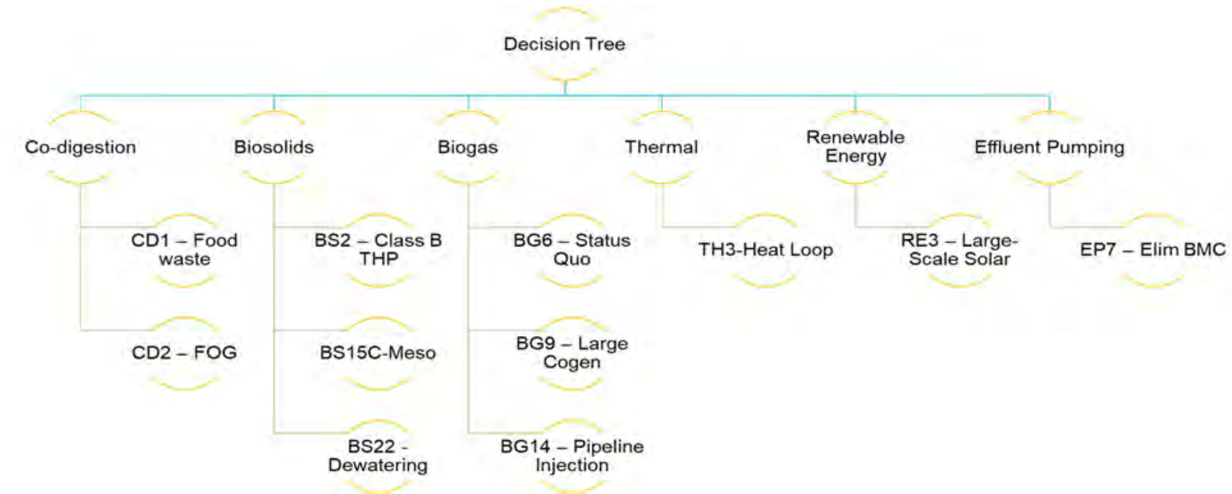


Figure 4.1 Alternatives Carried into Phase 4

4.2.2 Business Case Evaluations

The business case evaluations assessed four synergistic combinations developed from the alternatives carried forward from Phase 2. Each alternative combination was assessed against the same eight screening criteria that were used to evaluate the individual alternatives in Phase 2. Also like in Phase 2, cost estimates developed represent the AACE International criteria for a Class 5 Planning Level or Design Technical Feasibility Estimate.

Sensitivity analyses were performed on the alternative combinations to understand the impact of changing conditions (i.e., electricity costs, natural gas costs, maintenance costs, RIN pricing) on O&M costs. The sensitivity analyses focused on items that were differentiating between the alternative combinations (e.g., thermal hydrolysis, cogeneration, pipeline injection, and solar).

The business case evaluations and sensitivity analyses resulted in two alternative combinations being recommended to be carried forward for further evaluation of the following:

- The relative level of achievement relative to MMSD's stated goals for the project.
- Institute for Sustainable Infrastructure (ISI) Envision™ pre-assessment checklist.
- Impact of the estimated change in GHG emissions.

4.2.2.1 Alternative Combinations

The following four alternative combinations were designed for the development of business case evaluations and to address different questions that were posed as part of this project, as explained below.

1. Alternative Combination 1: Enhanced Baseline (BS15C + BS22 + BG6 + TH3 + EP7):
   a. This alternative represents the lowest capital cost combination of alternatives that can be incorporated to meet MMSD's energy and infrastructure project goals.
   b. Alternative Combination 1a includes the alternatives above plus solar (RE3).
2. Alternative Combination 2: Maximize Renewable Energy Production and Consumption (BS 2 + BS15C + BS22 + BG6/BG9 + TH3 + RE3 + EP7):
   a. This alternative maximizes on-site renewable energy production and consumption through the addition of thermal hydrolysis (TH3) and solar (RE3).

3. Alternative Combination 3: Energy Grid Resilience (BS15C + BS22 + BG9 + TH3 + EP7):
    a. This alternative seeks to understand the cost implications of increasing the size of on-site cogeneration. Natural gas is blended with biogas in the large engines to meet nearly all the NSWTP electricity needs.
4. Alternative Combination 4: Reduce Infrastructure Complexity (BS15C + BS22 + BG14 + TH3 + EP7):
    a. This alternative considers a combination of alternatives that reduce infrastructure complexity. Rather than replacing the existing cogeneration units, all the biogas on-site would be upgraded to RNG for pipeline injection.
    b. Alternative Combination 4a includes the alternatives above plus solar (RE3).

Each of the four alternative combinations included four common alternatives from Phase 2:

1. BS15C – Meso, Class B Cake, which eliminates thermophilic digestion and reduces thermal energy demands by 2,600 MMBtu/yr.
2. BS22 – Dewatering, which reduces the hauling costs associated with the production of liquid biosolids. This alternative also significantly reduces the fuel consumption associated with hauling liquid sludge.
3. EP7 – Eliminate BMC discharge, which translates to an energy savings of 2,010 kWh/day.
4. TH3 – Simplify the heat loop layout with a single primary-secondary heat loop system. Overall effects on the energy profile are dependent on the biogas alternative, but system reconfiguration would optimize heat distribution and operation and improve reliability.

4.2.2.2 Simple Alternatives

The 22 simple alternatives identified in Phase 2 were sorted into three categories:

1. Incorporate into alternative combinations.
2. Include as a standalone project.
3. Incorporate outside MMSD's CIP.

Table 4.1 presents the categorization of 21 of the simple alternatives.

Table 4.1 Categorization of Simple Alternatives

	Option ID	Option Name	Description
Incorporate into Alternative Combinations	AC2	Automation for process optimization	Digester instrumentation to measure health and/or gas production for optimized feeding of digesters.
	AC3	Automation for process optimization	Add automation for dewatering optimization.
	BG10	Replace engine-driven blower with electric blower	Increase biogas sent to cogeneration and boilers.
	TH7	Use heat to serve more process needs	Expand heat loop to provide process heat needs (i.e., polymer dilution, scum/grease separation, future co-digestion receiving station, enhanced WAS fermentation/phosphorous release).
	BS31	Reconfigure centrate pipeline	Redo centrate pipeline configuration for easier operation and alleviate gas accumulation.
	BS32	Optimize Location for Solids Processing Facilities	Place potential future solids processing facilities in closer proximity to each other to reduce needs for long sludge pipelines.
Include as Standalone Project	EP2	Replace existing pumps	Replace all 5 effluent pumps.
	HV1	Occupancy-Based HVAC and Lighting	Use smart systems to only heat/cool/light buildings or specific zones of buildings when occupied.
	HV9	Reduce Vehicle Loading Building loading bay heating	Consider solutions to reduce heating requirements in loading bay. Currently load bays are heated, but manual garage doors are left open all day.
	RE10	Electric vehicle charging stations	Install electric vehicle charging to support electric vehicle infrastructure.
	BS7	Alternative WAS thickening technology to dissolved air flotation	Rehabilitate or replace dissolved air flotation thickener system with alternative sludge concentration process.
	BS20	Ferric chloride pumping	Increase number of ferric pumps to improve reliability. Currently running into scenarios where there is no redundancy or inability to operate more than one process at a time.
	BS34	Sludge piping interconnections and redundancy	Add interconnections to provide operational flexibility to send sludge to various tanks/process areas and/or a secondary conveyance route for reliability. Add redundant sludge pipe from acid phase digester to methane phase digesters.

	Option ID	Option Name	Description
Incorporate outside MMSD's CIP	AC4	Energy decision management tools	Revisit/update energy standard operating procedure documentation. Develop intelligent energy models that recommends key operating setpoints, limits, and demands for various operating considerations such as ambient temperature, high flows, temporary loss of engine, etc. (Example: tool helps decide if it is better to spill to lagoon or increase effluent pumping output for a high flow event).
	EP5	Hydraulic equalization	Used to reduce pumping costs by pumping during low energy cost periods; Reduce peak power demand associated with effluent pumping; Utilize spilling to lagoon more frequently; Already incorporated in some capacity.
	HV2	Adjust lighting/temperature schedules	Adjust lighting schedules, and temperature setpoints and timing for heating/cooling in buildings.
	HV3	Reduced grounds lighting at night	Reduce energy demands for grounds lighting at night (focusing on lighting tower) and reduce light pollution.
	HV8	Allow continued/more remote work	Allow remote work to reduce energy from commuting and allow for less total office space to house district workforce each day.
	RE8	Purchase green power	For portion of power purchased from utility, opt into green power purchase program. Consider allowing customers to opt into higher rate structure to cover cost for green energy purchase or generation.
	RE12	Alternative energy vehicle fleet	Convert vehicle fleet to electric and/or compressed natural gas.
	BS33	Turn Off Metrogro storage tank mixers	Stop using Metrogro storage tank mixers as mixing does not appear to be necessary.

Capital costs for the six alternatives categorized as "Incorporated into Alternative Combinations" were included in the project costs presented in the following sections.

4.2.2.3 Baseline

Based on MMSD's asset registry, the expected baseline capital cost is approximately $40 million to upgrade existing aging equipment associated with the processes included in this study. Table 4.2 summarizes the total capital costs by process area for the baseline condition and avoided baseline costs (costs for the baseline condition that would not be realized or incurred) if any of the alternative combinations are selected.

Table 4.2 Baseline Capital Costs

Process Area	Baseline Capital Costs(1)	Avoided Baseline Costs
Biosolids	$31,200,000	$12,200,000
Biogas	$8,500,000	$8,500,000
Co-Digestion	$100,000	$100,000
Thermal Heat Loop	$200,000	$200,000
Grand Total	**$40,000,000**	**$21,000,000**

Notes:
(1) Cost adders were applied to MMSD's asset registry costs.

The baseline O&M cost for the processes included in this study is approximately $3.6 million per year, as presented in Table 4.3.

Table 4.3 Baseline O&M Costs

Process Area	Baseline Annual O&M
Biosolids	$3,806,000
Biogas	-$328,000
Thermal Heat Loop	$86,000
Grand Total	**$3,564,000**

Overall, the 20-year net present value (NPV) on O&M is approximately $53 million and the resulting total 20-year NPV (assuming a 50 percent estimating contingency on capital cost) is approximately $93 million.

4.2.2.4 Alternative Combination 1: Enhanced Baseline

Alternative Description

Alternative Combination 1 represents the lowest capital cost combination of alternatives that can be incorporated to advance MMSD's energy and infrastructure project goals. The major alternatives featured in the alternative combination are highlighted in Figure 4.2. A sub-alternative (Alternative Combination 1a) incorporates the large-scale solar array (RE3), indicated with the yellow circle, along with the rest of the major alternatives.

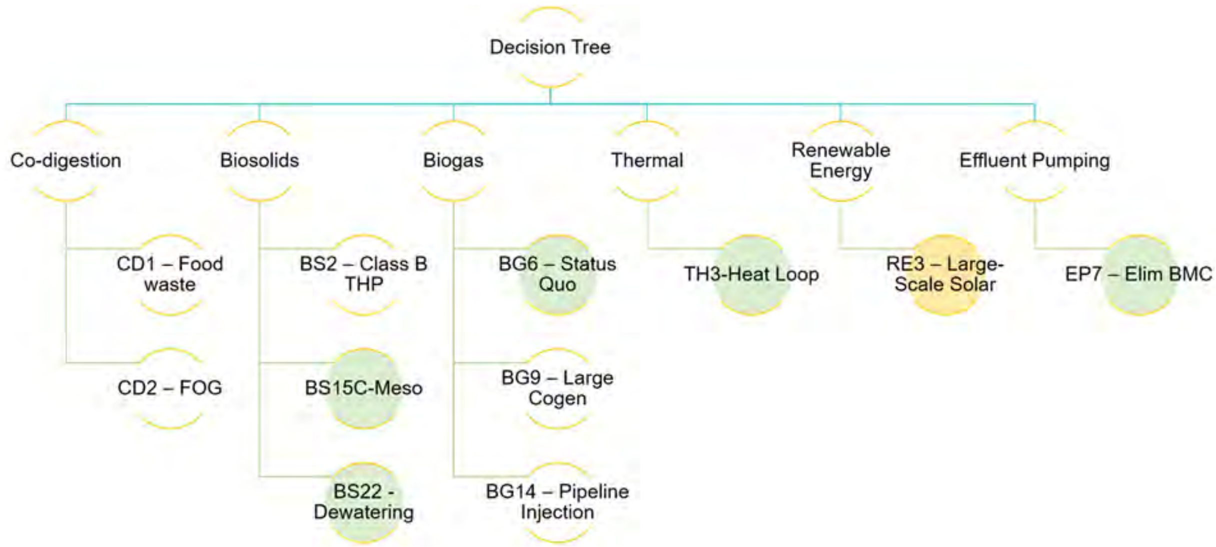


Figure 4.2 Alternative 1: Selected Combination of Options

The following simple alternatives are also included in Alternative Combination 1, refer to Table 4.1 for more information.

- AC2, BS31, AC3, TH7, and BG10.

Biosolids

- **BS15C** – All digesters will continue to be used but operation will be modified to mesophilic digestion only.
- **BS22** – Digested sludge will be pumped from the existing sludge storage tanks into two new centrifuges in the existing Dewatering Building, which will be able to process 100 percent of the digested biosolids to produce Class B biosolids cake.

Biogas

- **BG6** – Two new lean-burning, higher-efficiency, lower-emission engine-generators will replace the existing rich-burning engines that use biogas.

Thermal

- **TH3** – Optimize heat distribution and simplify the overall hot water loop with a true, single primary-secondary heat loop system.

Renewable Energy (Alternative 1a only)

- **RE3** – A large-scale solar PV system will be installed on an existing 95-acre parcel owned by MMSD and would be funded by the MG&E RER Program.

Effluent Pumping

- **EP7** – All effluent flow will be pumped to the BFC outfall, discontinuing the BMC discharge entirely.

A PFD illustrating Alternative Combination 1 is shown in Figure 4.3.

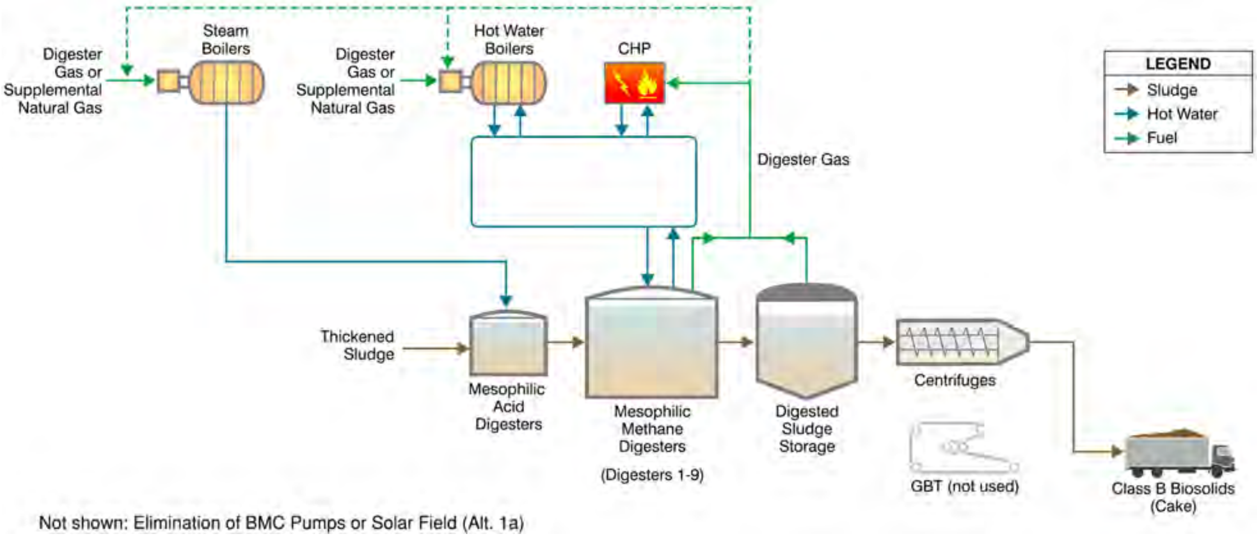


Figure 4.3 Alternative Combination 1 Process Flow Diagram

Business Case Evaluation

Refer to TM 4.1 for a full description of the business case evaluation performed on each alternative combination. Highlights are summarized below.

Energy Impact

Altogether, the electricity profile of Alternative Combination 1 and 1a are approximately 12.8 million kWh/yr and 18.9 million kWh/yr less than the baseline (Table 4.4).

Table 4.4 Electricity Profile of Alternative Combinations 1 and 1a Compared to Baseline

Description	Baseline (kWh/yr)	Alternative 1 (kWh/yr)	Alternative 1a (kWh/yr)
Biosolids	111,000	1,254,000(2)	1,254,000(2)
Biogas	-8,523,000	-20,292,000(3)	-20,292,000(3)
Thermal	-	-	-
Renewable Energy	-	-	-(4)
Effluent(1)		-1,099,000(5)	-1,099,000(5)
Total	**-8,412,000**	**-20,137,000**	**-26,170,000**

Notes:
(1) The elimination of the BMC discharge location eliminates the need for pumping and additional treatment and represents a power savings when compared to baseline.
(2) Includes BS15C and BS22. This represents an increase in electricity demand due to a change in operations.
(3) Includes BG6.This represents an increase in renewable electricity production.
(4) RE3 produces 6,033,000 kWh/yr solar power but is not included in this table as it is produced outside MMSD's electrical meter.
(5) Includes EP7. This represents an increase in electricity demand due to a change in operations.

Capital Cost

The total project cost for Alternative Combination 1 is approximately $72 million. These costs are broken down according to total direct cost, total estimated construction cost, and total project cost in Table 4.5. The total direct cost refers to the cost of installed equipment, material, and labor directly involved in construction. The total estimated construction cost refers to the sum of all costs, both direct and indirect, needed to convert a design plan into a project ready for startup. These costs including labor, supervision, administration, tools, field office expense, materials, equipment, and subcontracts. The total project cost includes engineering, legal, and administrative costs in addition to the total estimated construction cost.

Table 4.5 Project Cost of Alternative Combinations 1 and 1a

Process Area	Total Direct Cost	Total Est. Construction Cost(1)	Total Project Cost
BS15C (Meso)	$0	$0	$0
BS22 (Dewatering)	$16,351,000	$31,149,000	$38,936,000
BG6 (Status Quo)	$9,509,000	$18,116,000	$22,600,000
TH3 (Heatloop Improvements)	$4,280,000	$8,153,000	$10,200,000
RE3 (L. Scale Solar)	$0	$0	$0
EP7 (Eliminate BMC Discharge)	$0	$0	$0
Grand Total			**$71,736,000**

Notes:
(1) Alternative 1 and Alternative 1a share the same capital costs, since there are no capital costs associated with RE3.

O&M Costs

The O&M cost for Alternative Combinations 1 and 1a are approximately $1.5 million and $1.4 million per year, respectively, as presented in Table 4.6. On a 20-year NPV basis, this equates to a total O&M cost of approximately $23 million and $21 million for Alternative Combinations 1 and 1a, respectively.

Table 4.6 Alternative Combinations 1 and 1a Annual O&M Cost

Process Area	Alternative Combination 1 Annual O&M Cost	Alternative Combination 1a Annual O&M Cost
BS15C (Meso)	$0	$0
BS22 (Dewatering)	$2,611,000	$2,611,000
BG6 (Status Quo)	-$1,114,000	-$1,114,000
TH3 (Heatloop Improvements)	$2,000	$2,000
RE3 (L. Scale Solar)	$0	-$100,000
EP7 (Eliminate BMC Discharge)	$21,000	$21,000
Grand Total	**$1,520,000/year**	**$1,420,000/year**

Aging Infrastructure

Alternative Combination 1/1a affects aging infrastructure at the NSWTP site as follows:

- **BS15C** – May be able to discontinue using the East and West boilers.
- **BS22** – Replaces centrifuge and polymer system, discontinues use of GBTs which could then be used to replace DAF thickener, discontinues use of Metrogro storage tanks and vehicle loading.
- **BG6** – Replaces East and West boilers, waste gas burner, biogas conditioning equipment and associated ancillary components.
- **TH3** – Replaces 3-way valves, heat loop pumps, existing piping.
- **RE3** – No impact.
- **EP7** – Eliminates the need to replace BMC discharge equipment.

Sensitivity Analyses

The base assumptions and their adjustments used in the sensitivity analysis for Alternative Combination 1a O&M costs are as follows, with reasoning for the adjustments provided as needed:

- Cost of purchased electricity of $0.086/kWh. (change: $0.12/kWh)
  - The purchased electricity cost was increased to also allow MMSD to better understand the potential additional cost offset associated with an increase in utility electricity prices.
- Cogeneration engine electrical value of -21,400,000 kWh/yr. (change: 10 percent increase)
  - Cogeneration engine electrical value is increased to represent additional biogas production from running at full capacity, or to mimic FOG addition.
- Cogeneration engine maintenance cost of $0.025/kWh (change: $0.015/kWh - $0.035/kWh)

Figure 4.4 shows the result of the Alternative Combination 1a O&M sensitivity analysis on a 20-year NPV basis. The greatest decrease in O&M costs, by approximately $10 million, resulted from the change in the cost of purchased electricity. The greatest increase in O&M costs, by approximately $3.2 million, resulted from the increased cogeneration engine maintenance cost.

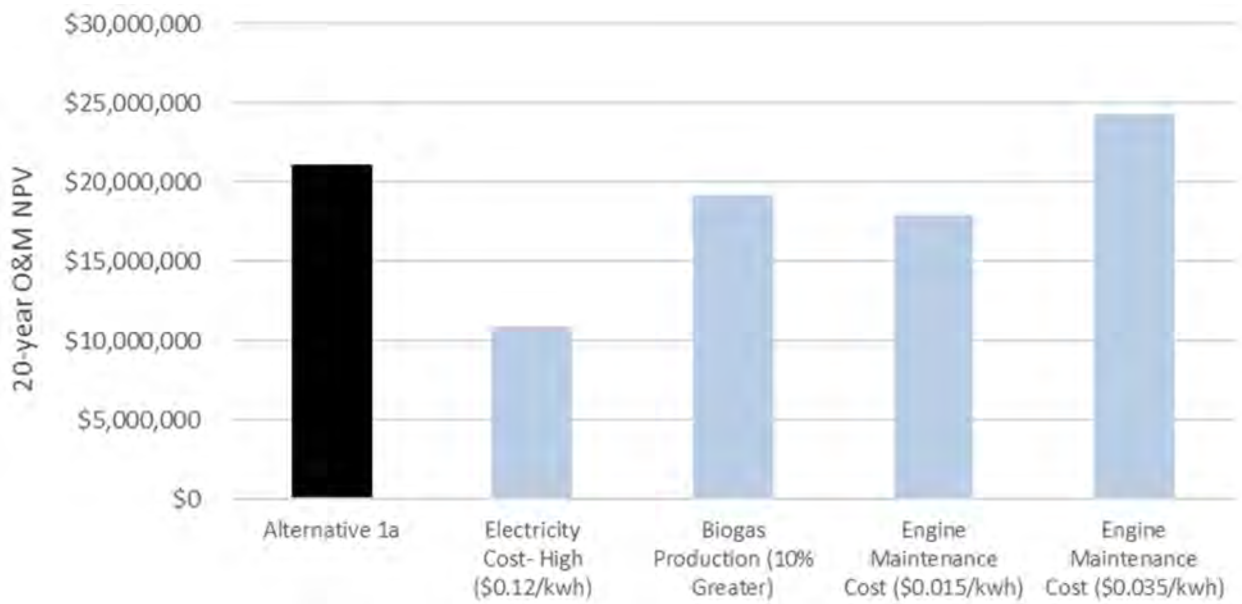


Figure 4.4 Alternative Combination 1a Sensitivity Analysis: 20-year O&M NPV

4.2.2.5 Alternative Combination 2: Maximize Renewable Energy Production and Consumption

Alternative Description

Alternative Combination 2 seeks to maximize on-site renewable energy production and consumption and includes the major alternatives highlighted in Figure 4.5. All the major alternatives included are the same as Alternative Combination 1a with the addition of BS2, Eliquo's LysoTherm process. The non-steam based thermal hydrolysis system is used to pre-treat WAS prior to anaerobic digestion.

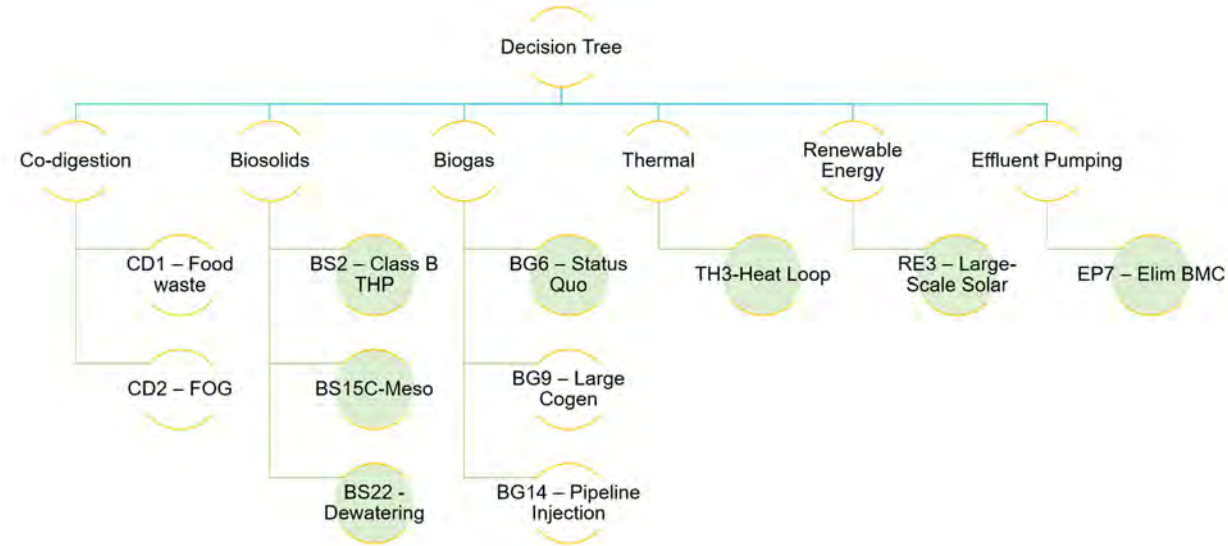


Figure 4.5 Alternative 2: Selected Combination of Options

The following simple alternatives, the same as Alternative Combination 1, are also included in Alternative Combination 2:

- AC2, BS31, AC3, TH7, and BG10.

A PFD illustrating Alternative Combination 2 is shown in Figure 4.6.

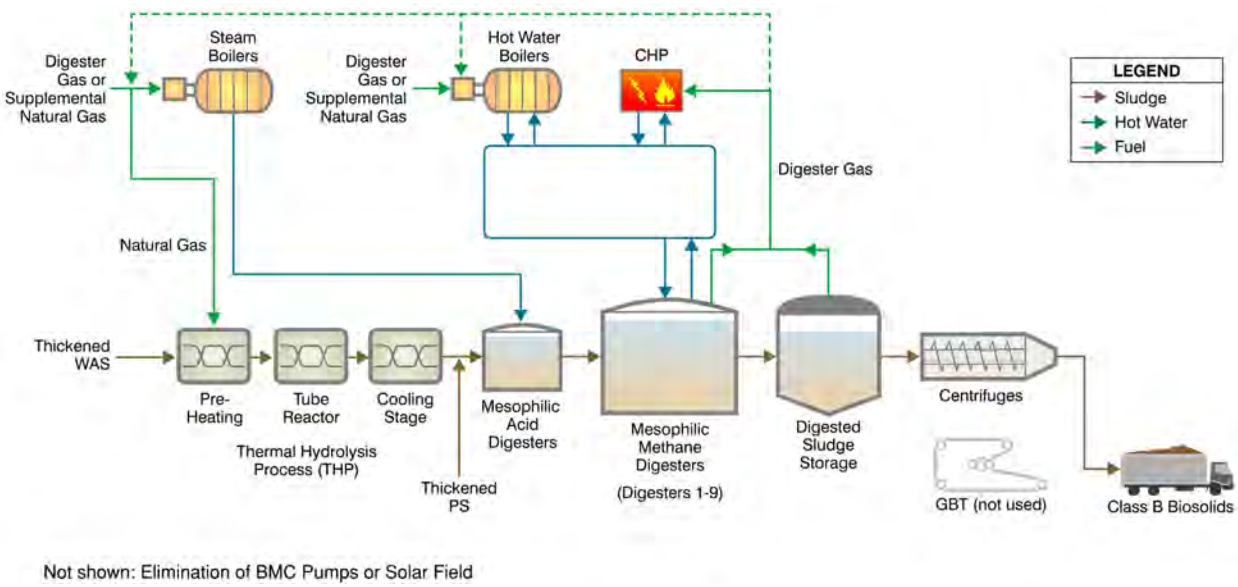


Figure 4.6 Alternative Combination 2 Process Flow Diagram

Business Case Evaluation

Refer to TM 4.1 for a full description of the business case evaluation performed on each alternative combination. Highlights are summarized below.

Energy Impact

Altogether, the electricity profile of Alternative Combination 2 is approximately 18.5 million kWh/yr less than the baseline (Table 4.7).

Table 4.7 Electricity Profile of Alternative Combination 2 Compared to Baseline

Description	Baseline (kWh/yr)	Alternative Combination 2 (kWh/yr)
Biosolids	111,000	1,495,000(2)
Biogas	-8,523,000	-21,316,000(3)
Thermal	-	-
Renewable Energy	-	- (4)
Effluent(1)	-	-1,099,000(5)
Total	**-8,412,000**	**-26,953,000**

Notes:
(1) The elimination of the BMC discharge location eliminates the need for pumping and additional treatment and represents a power savings when compared to baseline.
(2) Includes BS2, BS15C and BS22. This represents an increase in electricity demand due to a change in operations.
(3) Includes BG6. This represents an increase in renewable electricity production.
(4) RE3 produces 6,033,000 kWh/yr solar power but is not included in this table as it is produced outside MMSD's electrical meter.
(5) Includes EP7. This represents an increase in electricity demand due to a change in operations.

Capital Cost

The total project cost for Alternative Combination 2 is approximately $108 million. These costs are broken down in Table 4.8.

Table 4.8 Alternative Combination 2 Project Cost

Alternative Combination 2 - Capital Improvements	Total Direct Cost	Total Est. Construction Cost	Total Project Cost
BS2 (THP)	$15,401,000	$29,339,000	$36,700,000
BS15C (Meso)	$0	$0	$0
BS22 (Dewatering)	$16,271,000	$30,997,000	$38,746,000
BG6 (Status Quo)	$9,509,000	$18,116,000	$22,600,000
TH3 (Heatloop Improvements)	$4,280,000	$8,153,000	$10,200,000
RE3 (L. Scale Solar)	$0	$0	$0
EP7 (Eliminate BMC Discharge)	$0	$0	$0
Grand Total			**$108,246,000**

O&M Cost

The O&M cost for Alternative Combination 2 is approximately $1.7 million per year, as presented in Table 4.9. On a 20-year NPV basis, this equates to a total O&M cost of approximately $25 million.

Table 4.9 Alternative Combination 2 Annual O&M Cost

Alternative Combination 2 – O&M	Alternative Combination 2 Annual O&M Cost
BS2 (THP)	$549,300
BS15C (Meso)	$0
BS22 (Dewatering)	$2,406,000
BG6 (Status Quo)	-$1,176,000
TH3 (Heatloop Improvements)	$0
RE3 (L. Scale Solar)	-$100,000
EP7 (Eliminate BMC Discharge)	$21,000
Grand Total	**$1,700,300**

Aging Infrastructure

Alternative Combination 2 affects aging infrastructure at the NSWTP site as follows:

- **BS2** – Reduce the use of the existing steam boilers for heating the acid digesters.

Sensitivity Analyses

The base assumptions and their adjustments used in the sensitivity analysis for Alternative Combination 2 O&M costs are as follows, with reasoning for the adjustments provided as needed:

- Cost of purchased electricity of $0.086/kWh. (change: $0.12/kWh – same as Alternative Combination 1)
- Cake production of 42,300 wet tons/year. (change: 44,100 and 39,200 wet tons/year, 2 percent reduction and 5 percent increase in cake total solids, respectively)
- Cogeneration engine electrical value of -22,400,000 kWh/year. (change: 5 percent increase)
  - Represent additional biogas production from increased digester performance after LysoTherm THP.
- Cogeneration engine maintenance cost of $0.025/kWh. (change: $0.015/kWh - $0.035/kWh – same as Alternative Combination 1)

Figure 4.7 shows the result of the Alternative Combination 2 O&M sensitivity analysis on a 20-year NPV basis. The greatest decrease in O&M costs, by approximately $10.6 million, resulted from the change in the cost of purchased electricity and is due to avoided electricity costs. The greatest increase in O&M costs, by approximately $3.3 million, resulted from the increased cogeneration engine maintenance cost.

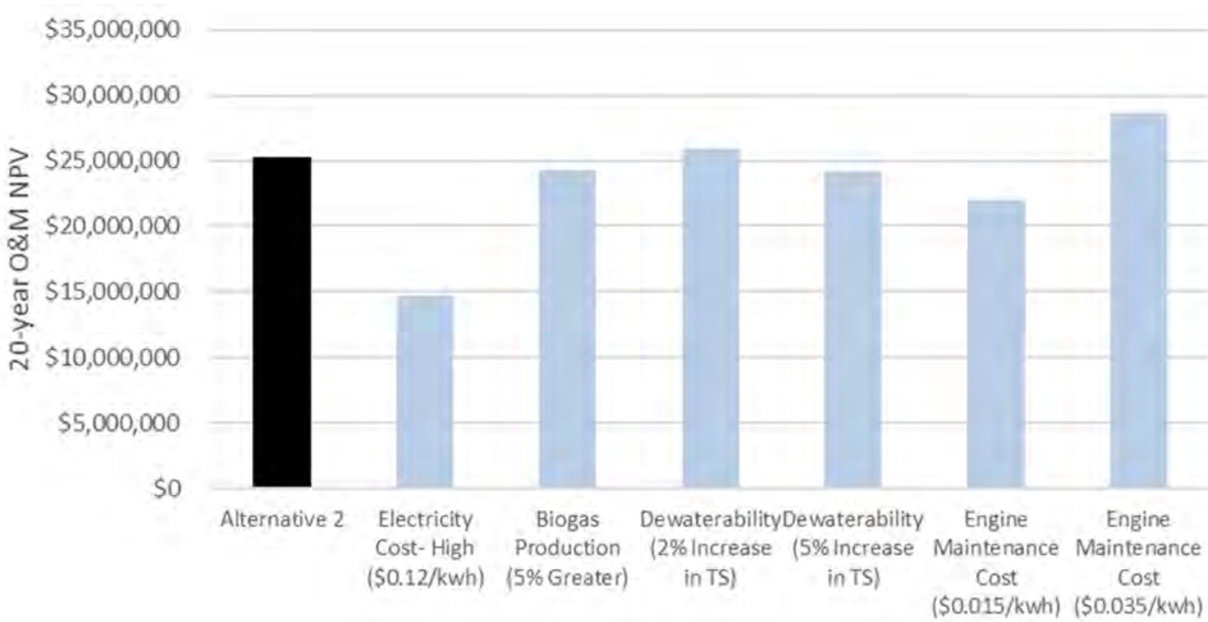


Figure 4.7 Alternative Combination 2 Sensitivity Analysis: 20-year O&M NPV

4.2.2.6 Alternative Combination 3: Energy Grid Resilience

Alternative Description

Alternative Combination 3 seeks to understand the cost and energy implications of increasing the size of on-site cogeneration. This alternative combination includes the major alternatives highlighted in Figure 4.8. All the major alternatives included are the same as Alternative Combination 1 except the BG9 alternative is chosen in place of BG6.

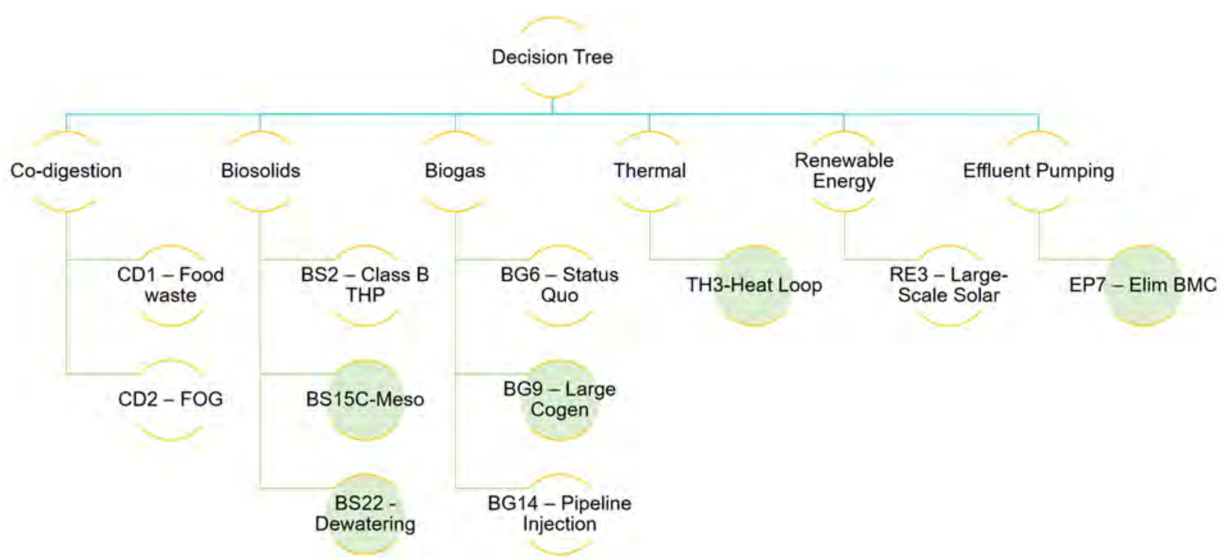


Figure 4.8 Alternative 3: Selected Combination of Options

Alternative BG9 replaces the existing rich-burning biogas engines with lean-burning, higher-efficiency, lower emission engine-generators. The new central internal combustion engine-based cogeneration system will use all biogas and supplemental natural gas to meet nearly all future NSWTP electricity demands.

The following simple alternatives, the same as Alternative Combination 1, are also included in Alternative Combination 3:

- AC2, BS31, AC3, TH7, and BG10.

A PFD illustrating Alternative Combination 3 is shown in Figure 4.9.

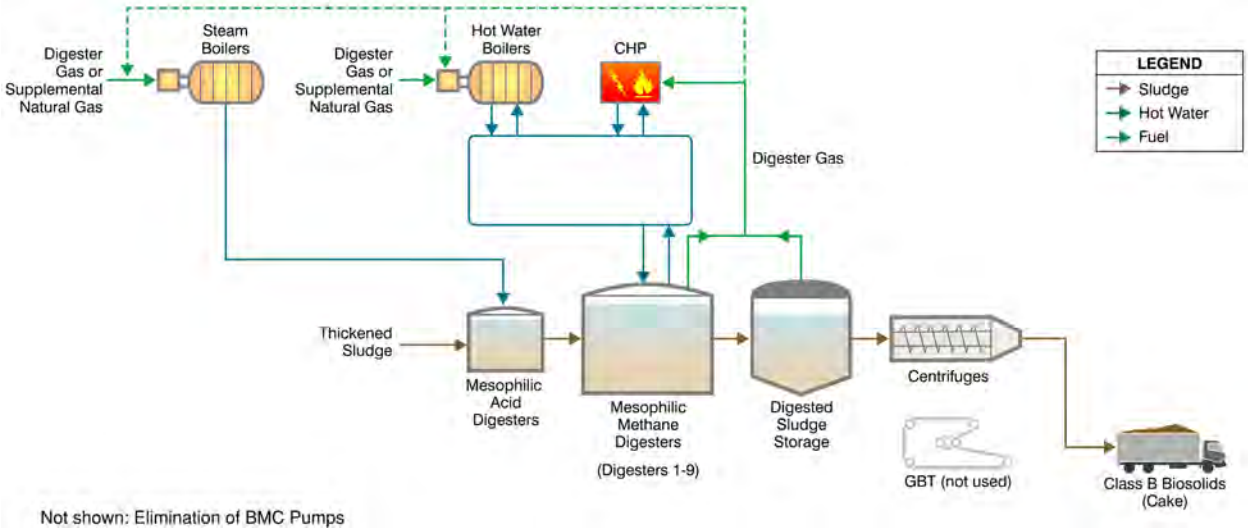


Figure 4.9 Alternative Combination 3 Process Flow Diagram

Business Case Evaluation

Refer to TM 4.1 for a full description of the business case evaluation performed on each alternative combination. Highlights are summarized below.

Energy Impact

Altogether, the electricity profile of Alternative Combination 3 is approximately 28 million kWh/yr less than baseline (Table 4.10).

Table 4.10 Electricity Profile of Alternative Combination 3 Compared to Baseline

Description	Baseline (kWh/yr)	Alternative Combination 3 (kWh/yr)
Biosolids	111,000	1,254,000(2)
Biogas	-8,523,000	-36,398,000(3)
Thermal	-	-
Effluent(1)		-1,099,000(4)
Total	**-8,412,000**	**-36,242,000**

Notes:
(1) The elimination of the BMC discharge location eliminates the need for pumping and additional treatment and represents a power savings when compared to baseline.
(2) Includes BS15C and BS22. This represents an increase in electricity demand due to a change in operations.
(3) Includes BG9. This represents an increase in renewable electricity production.
(4) Includes EP7. This represents an increase in electricity demand due to a change in operations.

Capital Cost

The total project cost for Alternative Combination 3 is approximately $86 million. These costs are broken down in Table 4.11.

Table 4.11 Alternative Combination 3 Project Cost

Alternative Combination 3 - Capital Improvements	Total Direct Cost	Total Est. Construction Cost	Total Project Cost
BS15C (Meso)	$0	$0	$0
BS22 (Dewatering)	$16,271,000	$30,997,000	$38,746,000
BG9 (Large Cogen)	$15,732,000	$29,970,000	$37,500,000
TH3 (Heatloop Improvements)	$4,281,000	$8,156,000	$10,200,000
EP7 (Eliminate BMC Discharge)	$0	$0	$0
Grand Total			**$86,446,000**

O&M Cost

The O&M cost for Alternative Combination 3 is approximately $1.1 million per year as presented in Table 4.12. On a 20-year NPV basis, this equates to a total O&M cost of approximately $17 million.

Table 4.12 Alternative Combination 3 Annual O&M Cost

Alternative Combination 3 – O&M	Alternative Combination 3 Annual O&M Cost
BS15C (Meso)	$ 0
BS22 (Dewatering)	$2,611,000
BG9 (Large Cogen)	-$1,500,000
TH3 (Heatloop Improvements)	$0
EP7 (Eliminate BMC Discharge)	$21,000
Grand Total	**$1,132,000**

Aging Infrastructure

Alternative Combination 3 affects aging infrastructure at the NSWTP site as follows:

- **BG9 –** Replaces East and West boilers, waste gas burner, biogas conditioning equipment and associated ancillary components.

Sensitivity Analyses

The base assumptions and their adjustments used in the sensitivity analysis for Alternative Combination 3 O&M costs are as follows, with reasoning for the adjustments provided as needed:

- Cost of purchased electricity of $0.086/kWh. (change: $0.12/kWh – same as Alternative Combination 1)
- Cogeneration engine maintenance cost of $0.025 /kWh. (change: $0.015/kWh - $0.035/kWh – same as Alternative Combination 1)
- Natural gas cost of $5/MMBtu. (change: increase to $7/MMBtu)

Figure 4.10 shows the result of the Alternative Combination 3 O&M sensitivity analysis on a 20-year NPV basis. The greatest decrease in O&M costs, by approximately $19 million, resulted from the change in the cost of purchased electricity and is due to avoided electricity costs. The greatest increase in O&M costs, by approximately $6 million, resulted from the increased cogeneration engine maintenance cost.

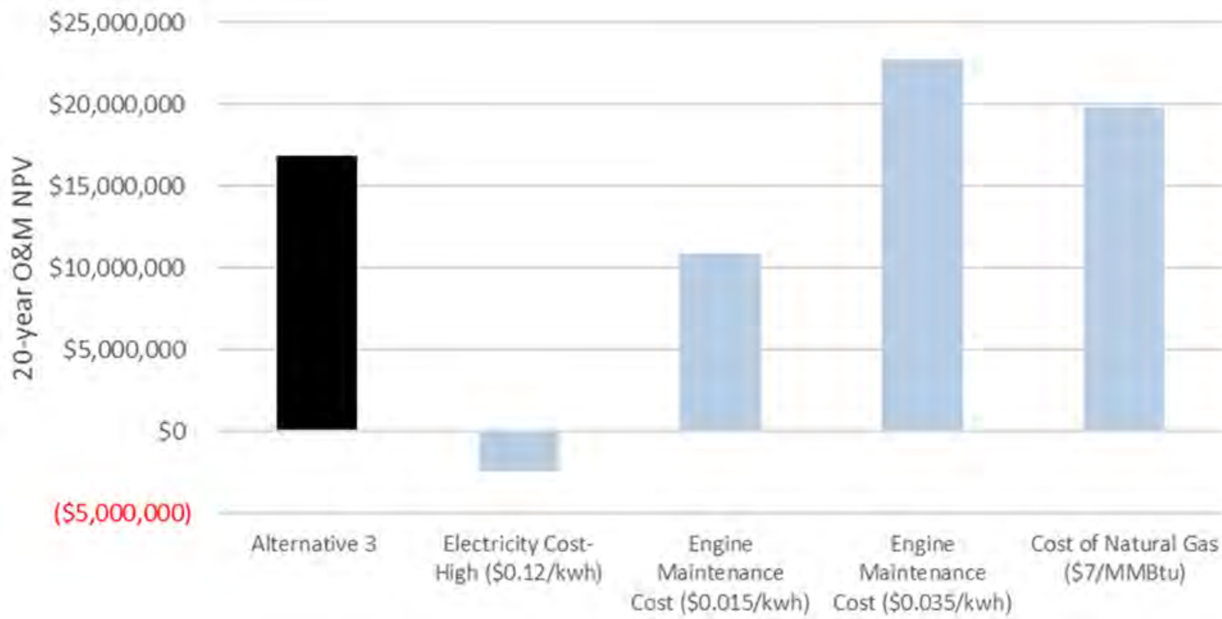


Figure 4.10 Alternative Combination 3 Sensitivity Analysis: 20-year O&M NPV

4.2.2.7 Alternative Combination 4: Reduce Infrastructure Complexity

Alternative Description

Alternative Combination 4 considers a combination of alternatives that reduce infrastructure complexity. Alternative Combination 4 improves system reliability by greatly simplifying the energy producing infrastructure from a combined heat and power system to a biogas upgrading and compression system. This alternative combination includes the major alternatives highlighted in Figure 4.11. A sub-alternative (Alternative Combination 4a) incorporates the large-scale solar array (RE3), indicated with the yellow circle, along with the rest of the major alternatives.

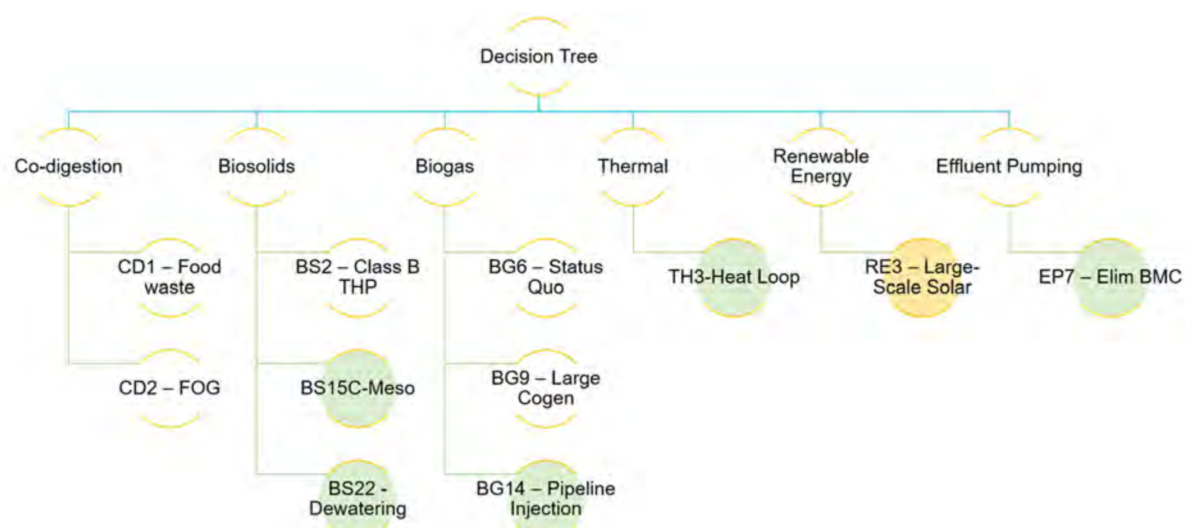


Figure 4.11 Alternative Combination 4: Selected Combination of Options

All the major alternatives included are the same as Alternative Combination 1 except the BG14 alternative is chosen in place of BG6. Alternative BG14 features a biogas conditioning system that will be used to treat biogas to pipeline quality, producing RNG. The produced RNG would either be injected into the ANR natural gas pipeline (requiring a 3-mile natural gas pipeline for connection), injected into MG&E's natural gas pipeline nearby, or trucked to a third-party facility with an existing pipeline connection. The RNG produced would generate D3 RINs for trading.

The following simple alternatives are also included in Alternative Combination 4:

- AC2, BS31, AC3, and BG10.

A PFD illustrating Alternative Combination 4 is shown in Figure 4.12.

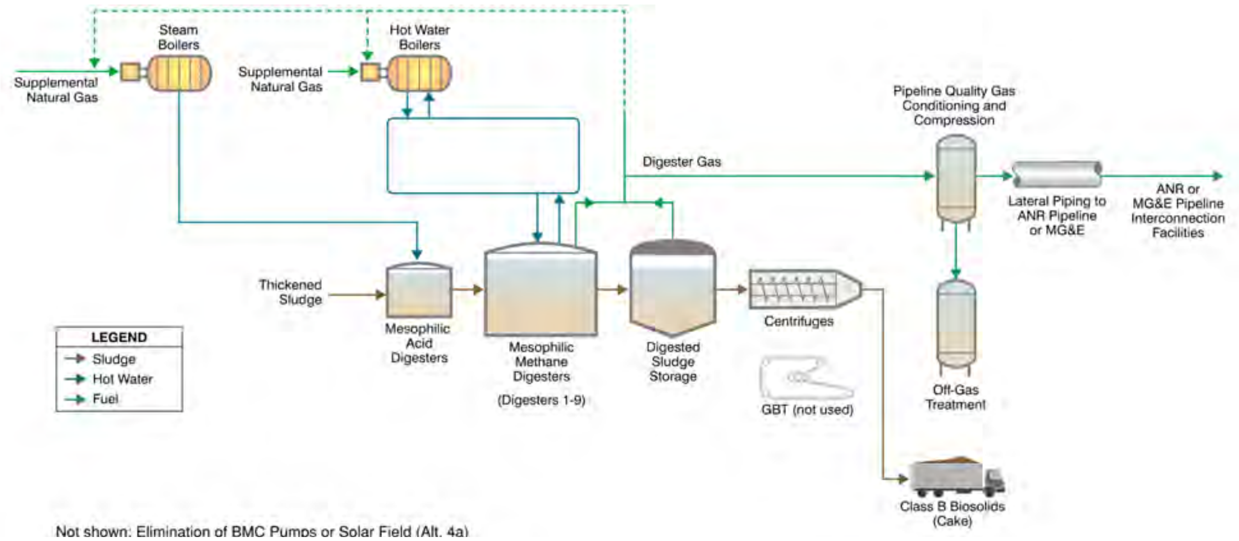


Figure 4.12 Alternative 4 Process Flow Diagram

Business Case Evaluation

Refer to TM 4.1 for a full description of the business case evaluation performed on each alternative combination. Highlights are summarized below.

Energy Impact

Altogether, the electricity profile of Alternative Combination 4 and 4a are approximately 11.5 million kWh/yr and 5.5 million kWh/yr greater than the baseline (Table 4.13).

Table 4.13 Electricity Profile of Alternative Combinations 4 and 4a Compared to Baseline

Description	Baseline (kWh/yr)	Alternative 4 (kWh/yr)	Alternative 4a (kWh/yr)
Biosolids	111,000	1,254,000(2)	1,254,000(2)
Biogas	-8,523,000	2,890,000(3)	2,890,000(3)
Thermal	-	-	-
Renewable Energy	-	-	- (4)
Effluent(1)		-1,099,000(5)	-1,099,000(5)
Total	**-8,412,000**	**3,045,000**	**-2,988,000**

Notes:
(1) The elimination of the BMC discharge location eliminates the need for pumping and additional treatment and represents a power savings when compared to baseline.
(2) Includes BS15C and BS22. This represents an increase in electricity demand due to a change in operations.
(3) Includes BG14. This represents an increase in electricity demand due to a change in operations.
(4) RE3 produces 6,033,000 kWh/yr solar power but is not included in this table as it is produced outside MMSD's electrical meter.
(5) Includes EP7. This represents an increase in electricity demand due to a change in operations.

Capital Cost

The total project cost for Alternative Combination 4 is approximately $75 million, not including the 3-mile pipeline to the ANR interconnection point. These costs are broken down in Table 4.14. With the 3-mile pipeline, the total project cost increases to approximately $85 million.

Table 4.14 Project Cost of Alternative Combinations 4 and 4a

Alternative 4 - Capital Improvements	Total Direct Cost	Total Est. Construction Cost(1)	Total Project Cost
BS15C (Meso)	$0	$0	$0
BS22 (Dewatering)	$16,271,000	$30,997,000	$38,746,000
BG14 (Pipeline Injection)(2)	$9,576,000	$18,243,000	$26,500,000
TH3 (Heatloop Improvements)	$3,966,000	$7,555,000	$9,400,000
RE3 (L. Scale Solar)	$0	$0	$0
EP7 (Eliminate BMC Discharge)	$0	$0	$0
Grand Total			**$74,646,000**

Notes:
(1) Alternative 4 and Alternative 4a share the same capital costs, since there are no capital costs associated with RE3.
(2) Does not include the construction cost of the 3-mile pipeline to the ANR pipeline but does include a one-time $5M fee for the interconnection facility.

O&M Cost

The O&M cost for Alternative Combinations 4 and 4a are approximately $207,000 and $107,000 per year, respectively, as presented in Table 4.15. On a 20-year NPV basis, this equates to a total O&M cost of approximately $3.1 million and $1.6 million for Alternative Combinations 4 and 4a, respectively.

Table 4.15 Alternative Combinations 4 and 4a Annual O&M Cost

Alternative Combination 4 – O&M	Alternative Combination 4 Annual O&M Cost	Alternative Combination 4a Annual O&M Cost
BS15C (Meso)	$0	$0
BS22 (Dewatering)	$2,611,000	$2,611,000
BG14 (Pipeline Injection)	-$2,800,000	-$2,800,000
TH3 (Heatloop Improvements)	$375,000	$375,000
RE3 (L. Scale Solar)	$0	-$100,000
EP7 (Eliminate BMC Discharge)	$21,000	$21,000
Grand Total	**$207,000/year**	**$107,000/year**

Aging Infrastructure

Alternative Combination 4/4a affects aging infrastructure at the NSWTP site as follows:

- **BG14 –** Replaces East and West boilers, waste gas burner, and biogas conditioning equipment with the added benefit of eliminating the need for biogas piping to the boiler system.

Sensitivity Analyses

The base assumptions and their adjustments used in the sensitivity analysis for Alternative Combination 4 O&M costs are as follows, with reasoning for the adjustments provided as needed:

- Cost of purchased electricity of $0.086/kWh. (change: $0.12/kWh – same as Alternative Combination 1)
- Natural gas cost of $5/MMBtu. (change: increase to $7/MMBtu)
- Annual gas conditioning O&M cost of $100,000 (change: $50,000 - $150,000)
- RIN value of $1.42/D3 RIN (revenue minus a 15 percent broker fee) (change: $1.00/D3 RIN - $2.50/D3 RIN)
  - The range of D3 RIN values is based on historical RIN market pricing. When D3 RINs were first introduced to the market in 2015, they had a value of approximately $1.00 per RIN. D3 RINs are currently trading for approximately $3.00 per RIN.

Figure 4.13 shows the result of the Alternative Combination 4 O&M sensitivity analysis on a 20-year NPV basis. The greatest decrease in O&M costs, by approximately $28 million, resulted from the high RIN value of $2.50/D3 due to revenue from trading RINs via the RFS program. The greatest increase in O&M costs, by approximately $12 million, resulted from the low RIN value of $1.00/D3 RIN which represents selling to the voluntary market.

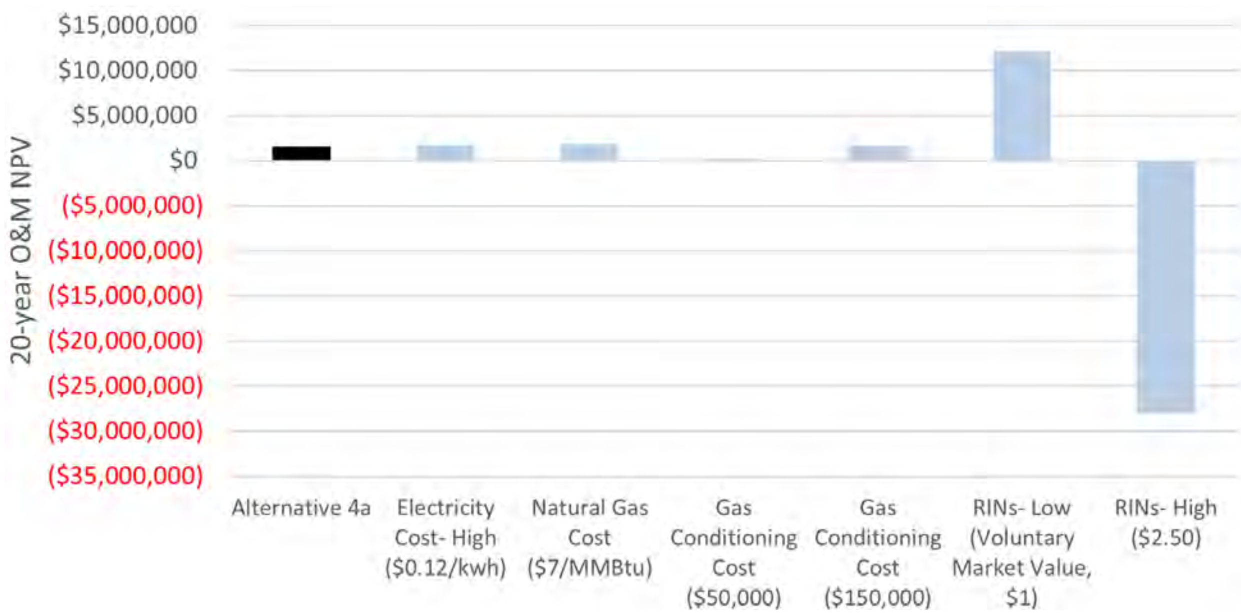


Figure 4.13 Alternative Combination 4 Sensitivity Analysis: 20-year O&M NPV

4.2.3 Comparison of Alternative Combinations

Each of the alternative combinations were compared against the baseline and each other to determine the selected alternative combinations to carry forward into the capital improvement recommendations. Table 4.16 presents the raw and weighted scores of each alternative combination for each of the six evaluation criteria. Some of the big picture takeaways based on the results include that all the alternative combinations outperformed baseline, scoring similarly overall, but each brings benefit via different means and with different priorities. In addition, they all successfully address aging infrastructure needs and all involve mature technologies.

The screening criteria scoring was used in combination with the costs, the sensitivity analyses, and other factors in the evaluation process to guide decision-making on the alternative combinations to ultimately carry forward for further consideration. Along these same lines, the prioritization and relative importance of the six evaluation criteria, reflected by their weighting, does not fully capture how MMSD's perspectives on each category have evolved according to greater insight and investigation. Such investigation has led the team to conclude that simplifying infrastructure and increasing renewable energy in some capacity are valuable features, but MMSD stops short of seeking to capture renewable energy at any cost and wants to avoid consuming more non-renewable energy.

Table 4.16 Summary of Screening Criteria

Alternative Combination	Total Weighted Score	Energy Impact	Operational Impacts/ Flexibility	Aging Infrastructure	Synergistic benefit	Maturity of technology	Greenhouse gas footprint
	100.0%	20.6%	14.9%	22.9%	22.9%	7.3%	11.5%
Baseline	2.7	3	3	1	3	5	3
1	4.3	4	4	5	4	5	4
1a	4.6	5	4	5	4	5	4.5
2	4.7	5	3	5	5	5	5
3	4.6	5	4	5	4	5	5
4	4.3	4	4	5	4	5	4
4a	4.6	5	4	5	4	5	4.5

Notes:

(1) Alternative Combination 1 = Enhanced Baseline, Alternative Combination 1a = Enhanced Baseline + Large Scale Solar.

(2) Alternative Combination 2 = Maximize Renewable Energy Production and Consumption.

(3) Alternative Combination 3 = Energy Grid Resilience.

(4) Alternative Combination 4 = Reduce Infrastructure Complexity, Alternative Combination 4a = Reduce Infrastructure Complexity + Large Scale Solar.

Figure 4.14 presents the net change in electricity consumption/production from baseline for each alternative combination. The baseline electricity production/consumption was set to zero so that the relative differences for each alternative can be seen. The net changes in electricity consumption/production do not reflect overall power demand, but instead show the surplus or deficit in purchased electricity for each Alternative Combination relative to baseline. This surplus or deficit would change in the amount of standard mix electricity MMSD would need to purchase. For Alternative Combinations 1, 1a, 2, and 3 more electricity is produced, thus less standard mix electricity would need to be purchased, while Alternative Combinations 4 and 4a would require purchase of more standard mix electricity as compared to baseline.

This graph shows that Alternative Combination 3 provides the highest electricity production of all the alternatives due to the larger engine sizing. In contrast, Alternative Combination 4 has the highest electricity consumption (assumes no on-site renewable electricity production from biogas since all biogas is converted to RNG for use off-site). The addition of a solar grid through MG&E's RER program (included in Alternatives 1a, 2, and 4a) provides approximately 6 million kilowatt-hour per year (kWh/yr) of renewable electricity which would account for about 15 percent of on-site energy demand.

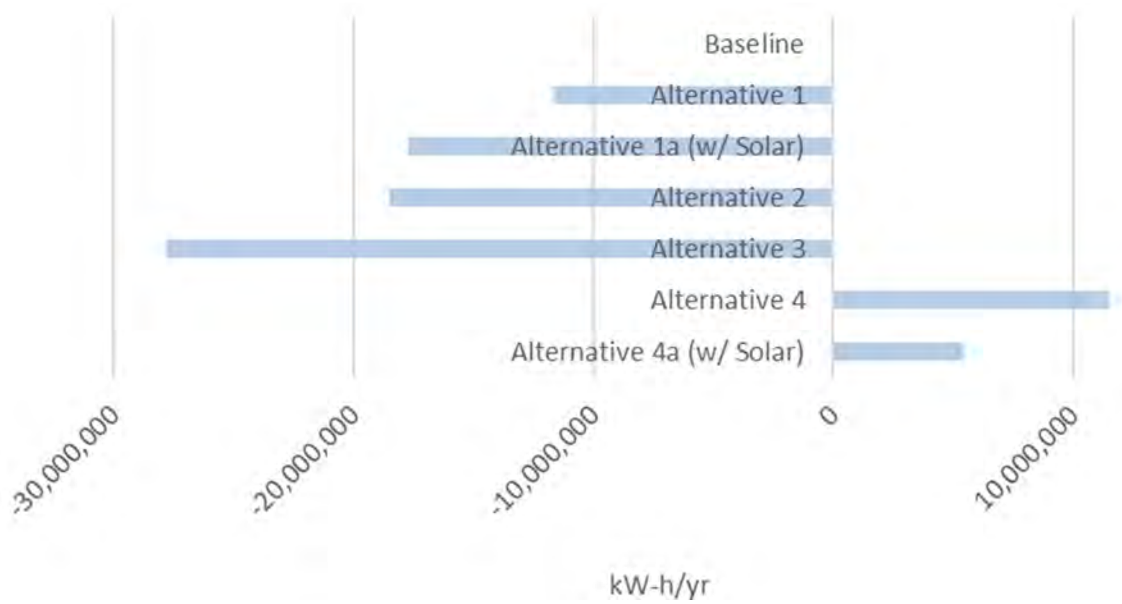


Figure 4.14 Net Change in Standard Mix Electricity Consumption

Figure 4.15 presents a summary of the project costs for each of the four alternative combinations compared to the baseline capital cost.

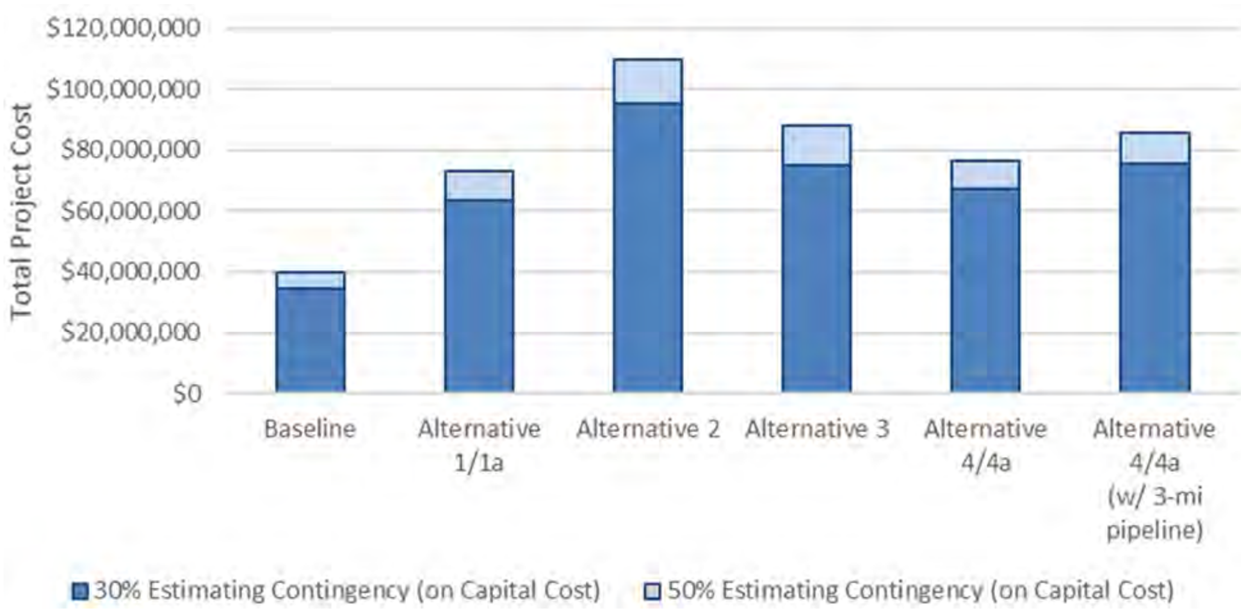


Figure 4.15 Summary of Project Costs

Figure 4.16 presents a breakdown of the annual O&M costs of each alternative combination as compared to the baseline.

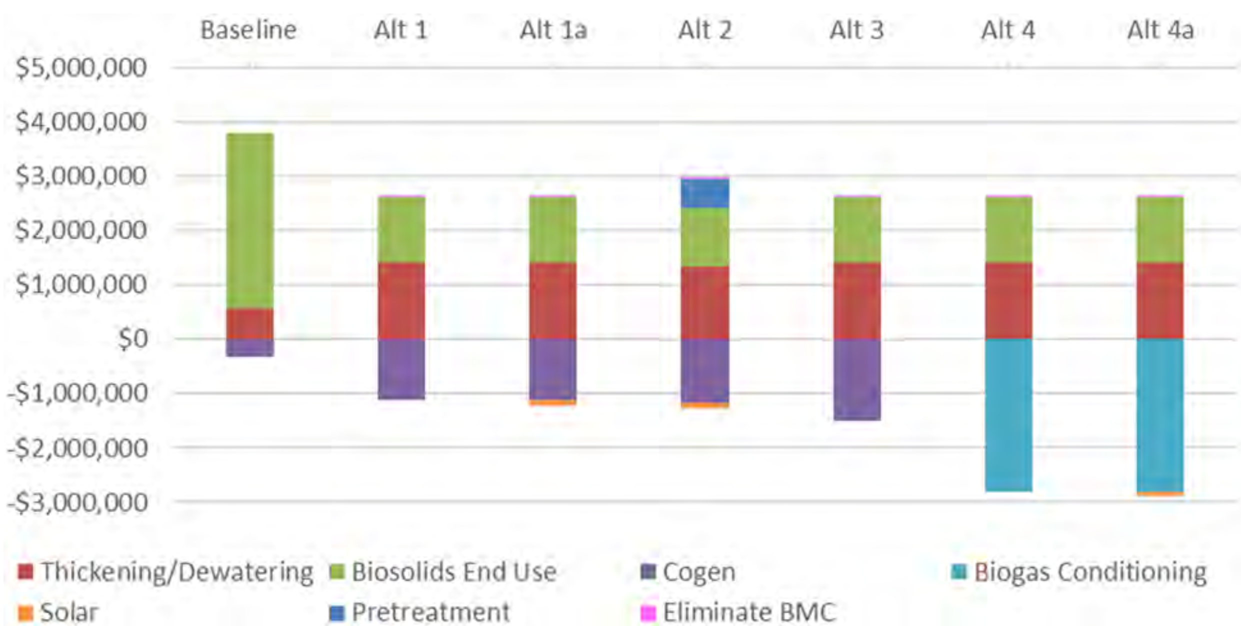


Figure 4.16 Summary of Annual O&M Costs

Figure 4.17 presents a summary of the total 20-year NPV of each alternative combination as compared to the baseline. The error bars shown for each alternative combination represent the range of sensitivity analyses performed on O&M costs, as noted in the sections above.

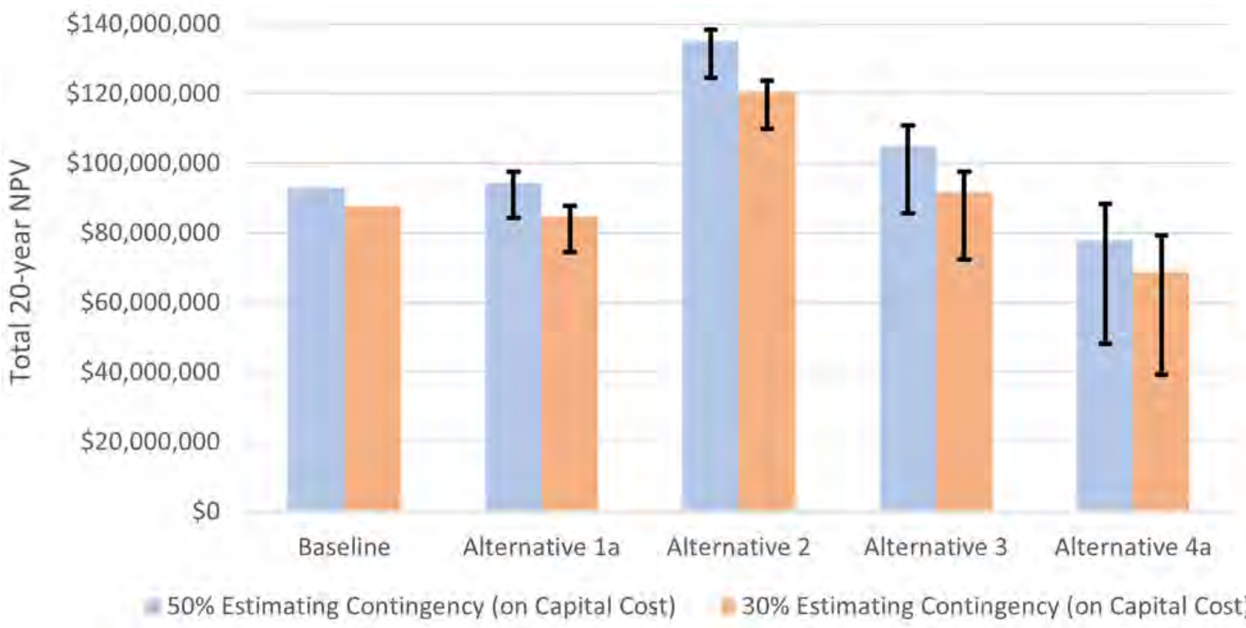


Figure 4.17 Sensitivity Analysis: Total 20-year NPV

4.2.3.1 Reliability

One of the stated goals of the Plan is to improve the reliability of energy using and consuming infrastructure. All four of the alternative combinations considered improve system reliability due to simplification of processes and replacement of aging infrastructure.

4.2.3.2 Resilience

Resilience is defined in TM 1.1 as the ability to adapt to and recover from a significant disruption by minimizing level of service failure magnitude and duration. For the purposes of the Plan, the project team defined resilience in terms of the power, gas, and thermal systems as follows, along with the extent to which the alternative combinations meet these goals provided:

- Utility Power: Ability to adapt to and recover from a utility power outage while maintaining adequate level of service.
  - **Goal Achievement:** The study could not identify alternatives that would cost-effectively provide resilience from a utility power outage. As such, none of the alternatives included in Alternative Combinations 1 through 4 increase utility power resilience in any significant way. Instead, it is recommended that MMSD pursue installation of a backup generator to provide the level of backup power desired.
- Utility Gas: Ability to adapt to and recover from a utility gas outage while maintaining adequate level of service.
  - **Goal Achievement:** Alternative Combinations 1 and 2 reduce the amount of natural gas purchased from the grid. Alternative Combination 4 increases the amount of natural gas purchased from the grid, but allows MMSD to use the RNG on-site in the event of a failure in natural gas supply. However, none of the alternative combinations considered improve MMSD's resilience to the utility gas grid, as all still require a connection to the grid and some amount of natural gas purchase.

- Thermal: Ability to adapt to and recover from an interruption of the heat loop while maintaining adequate level of service.
  - **Goal Achievement:** Alternative Combinations 1 through 4 do not improve thermal resilience due to heat loop modifications. While the heat loop will be simplified, this does not increase resiliency per the definition used herein. Alternative Combinations 1 thru 3 provide slightly increased thermal resilience due to the ability to produce heat on-site. For Alternative Combination 4, RNG can be used to supplement natural gas if the natural gas grid is compromised.

4.2.4 Summary of Recommended Projects

Based on the business case evaluations presented above, Alternative Combinations 1 and 4 were recommended to be carried forward for further consideration. These two alternative combinations provide significant benefit to MMSD based on each of the screening criteria, and had considerably lower capital and 20-year NPV costs as compared to Alternative Combinations 2 and 3. The following sections provide additional detail for Alternative Combinations 1 and 4 as it relates to GHG emissions, Envision™ scoring, updated energy baseline, and ability to meet MMSD's Plan goals.

4.2.4.1 GHG Evaluation

Table 4.17 presents a summary of the 2040 Projected GHG emissions for the three scenarios.

Table 4.17 2040 Projected Greenhouse Gas Emissions

Source	Baseline Projected (2040) MT CO_2e/Year[3]	Alternative Combination 1a (2040) MT CO_2e/Year	Alternative Combination 4a (2040) MT CO_2e/Year
NSWTP Electrical Demand	31,260	31,370	32,730
Pump Station Electrical Demand	8,000	8,000	8,000
Natural Gas	1,490	830	3,800
Diesel Fuel	310	120	120
Unleaded Gasoline	140	140	140
Biogas (Combustion)[1]	50	50	50
Acid Biogas Treatment (Aeration Basins)	140	140	140
Chemical Production[2]	200	530	530
Total Greenhouse Gas Emitted	*41,590*	*41,180*	*45,510*
Offset Electrical	(7,250)	(20,860)	(4,580)
Offset Diesel	0	0	(13,510)
Total Greenhouse Gas Emissions	**34,340**	**20,320**	**27,420**

Notes:
(1) The GHG emissions associated with biogas combustion represent the methane and nitrous oxide emissions from the ultimate combustion of the biogas, whether onsite in cogeneration engines or offsite downstream pipeline injection.
(2) GHG emissions from chemical production were not included in the GHG evaluation presented in TM 1.3 but have been added to account for the change in polymer usage due to dewatering all the biosolids.
(3) MT CO_2e = metric tons of carbon dioxide equivalent.

Compared to baseline, Alternative Combinations 1a and 4a are projected to potentially reduce GHG emissions by 41 percent and 20 percent, respectively, making Alternative Combination 1a the most favorable. In both cases, the GHG impact could be further offset with the purchase of electricity from renewable sources through MG&E's Green Power Tomorrow, which is capable of satisfying 100 percent of MMSD's energy needs.

4.2.4.2 ISI Envision™ Pre-Assessment

A preliminary Envision™ v3 Pre-Assessment Checklist was reviewed for the shortlisted Alternative Combinations 1a and 4a as an exercise for assessing each Alternative Combination's sustainability and resilience within the Envision™ framework. A conservative approach was taken in assessing MMSD's implementation approach of the alternatives including limited stakeholder engagement, etc. There are numerous opportunities to increase the number of possible points for nearly all the Envision™ categories, warranting further exploration as the planning/design is refined.

The total number of applicable points for Alternative 1a was determined to be 177, with 1,000 points possible to be achieved by pursuing the project. The total number of applicable points for Alternative 4a was determined to be 196, with 1,000 points possible to be achieved by pursuing the project. Based on the conservative approach to the checklists, neither alternative would have enough points to qualify for an award level. The relatively lower scores are related to the fact that the project includes land application of biosolids, which makes the project eligible for a number of "outside the fence" categories. MMSD would need to demonstrate more partnerships and stakeholder involvement with these "outside the fence" groups to increase the Envision score.

4.2.4.3 Update of 2040 Energy Baseline

This section provides an overview of annual energy use for the year 2040 baseline, Alternative Combination 1a, and Alternative Combination 4a conditions. Electrical use for Alternative Combination 1a is similar to the baseline condition. Electrical production is increased due to the larger, more efficient cogeneration engines and the addition of solar power. As for Alternative Combination 4a, total electrical use increases due to the additional electrical load for biogas compression required for pipeline quality gas. There is also a significant drop in electrical production due to eliminating cogeneration.

Table 4.18 Electrical Use Summary by Treatment Area

	Baseline (Year 2040) (kWh/day)	Alternative Combination 1a (Year 2040) (kWh/day)	Alternative Combination 4a (Year 2040) (kWh/day)
Collections System	28,800	28,800	28,800
Headworks	2,300	2,300	2,300
Primary Treatment	400	400	400
Secondary Treatment	46,600	46,600	46,600
Effluent Pumping and Disinfection	31,300	28,300	28,300
Thickening, Digestion and Post-Thickening	18,200	18,500	23,400
Metrogro Storage, Pumping and Dewatering	3,200	6,300	6,300
Operations Building	3,400	3,400	3,400
Unaccounted for Electrical Use	7,100	7,100	7,100
Total Electrical Use	141,300	141,700	146,600
Electrical Production	-26,100	-75,100	-16,500
Net Utility Electrical Use	115,200	66,600	130,100
Net Utility Electrical Use without Collection System	**86,400**	**37,800**	**101,300**

Table 4.19 summarizes the baseline (year 2040), and Alternative Combination 1 and 4 values for natural gas and biogas. There is a decrease in natural gas purchased for Alternative Combination 1 due to the heat loop improvements and larger engine capacity. Natural gas purchase increases significantly for Alternative 4 as all biogas is routed to the pipeline quality gas conditioning equipment.

Table 4.19 Current and Future Biogas and Natural Gas Baseline

	Baseline (Year 2040)	Alternative Combination 1 (Year 2040)	Alternative Combination 4 (Year 2040)
Biogas Production (MMBtu/yr)	190,300	190,300	190,300
Natural Gas Purchased (MMBtu/yr)	28,100	11,400	86,000
Total Biogas Production and Natural Gas Purchased (MMBtu/yr)	218,400	201,700	276,300
Average Biogas Flared (MMBtu/yr)(1)	24,200	0	12,200

Notes:

(1) Baseline is based on current overall thermal efficiency and current level of use in engine generators and blower engine. Alternative 1 assumes that biogas is routed to the boilers if an engine is out of service. Alternative 4 assumes that biogas is flared when the pipeline quality gas equipment is out of service for maintenance. Additional biogas may be flared if the biogas system is not operating under routine conditions.

4.2.4.4 MMSD Project Goals

Alternative Combinations 1 and 4 were further evaluated to document the relative level of achievement with regards to MMSD's stated goals for the project that summarize the minimum expectations for energy related improvements. It should be noted that these goals are specific to the Plan project and have not been established for the overall MMSD organization. For the purposes of this evaluation, it was assumed that the combination of projects within Alternatives 1 and 4 would be completed and operational within 20 years, an extension of the original 10-year timeframe.

GHG Reduction

Goal: Reduce fossil fuel based GHG emissions by a minimum of 10 percent.

Compared to baseline, Alternative Combinations 1a and 4a are projected to potentially reduce GHG emissions by 41 percent and 20 percent, respectively.

Peak Demand Costs

Goal: Reduce costs associated with peak electricity demand by a minimum of 5 percent.

Alternative Combination 1 is anticipated to reduce costs associated with peak electricity demand due to the significant increase in on-site electricity production. In contrast, Alternative Combination 4 would not meet the project goal, instead peak demand costs may increase.

Energy Efficiency

Goal: Reduce operational energy consumption by a minimum of 10 percent in MMBtu/mgd.

Total electrical use increases slightly for Alternative Combinations 1a and 4a due to dewatering all solids, but overall energy efficiency increases for both. Methods for reducing overall energy demands were explored, however the scope of the study included solids handling processes only, and areas for significant reduction could not be identified. Future activated sludge upgrades present a potential area to reduce overall energy demands if low dissolved oxygen operation can be used.

Renewable Energy

Goal: Use renewable energy sources to meet a minimum of 50 percent of total energy demands.

Alternative Combinations 1 and 1a would produce 54 percent and 70 percent of MMSD's electricity from renewable sources. In contrast, Alternative Combinations 4 and 4a would produce 0 and 15 percent of electricity from renewable sources. Although this goal is not directly met by renewable energy used by MMSD, the RNG produced would result in a global overall increase in renewable energy and Carollo believes this would indirectly meet the intent of the goal.

Energy for Biosolids Production

Goal: Reduce energy demands or produce a higher value biosolids product without significantly increasing energy demands.

Alternative Combinations 1 and 4 include a recommendation to dewater 100 percent of the biosolids produced on-site and land apply the Class B cake product. This would significantly reduce overall energy associated with truck hauling, but the use of centrifuges would increase on-site power use by 1,144,000 kWh/yr as compared to the baseline. Given this increase in on-site power use, alternative technologies should be explored as part of the facilities planning process.

Energy Sources

Goal: Improve reliability and resiliency of energy sources.

The reliability of the biogas and biosolids infrastructure will increase with Alternative Combinations 1 and 4 due to the replacement of aging infrastructure and simplification of existing processes. Neither Alternative Combination increases utility power or natural gas grid resilience.

Infrastructure

Goal: Improve reliability of energy using and consuming infrastructure.

Both Alternative Combination 1 and 4 significantly improve the reliability of energy using and consuming infrastructure due to simplification of processes and replacement of aging infrastructure. Alternative Combination 4 has the added benefit of simplifying operation and reducing infrastructure complexity by eliminating the cogeneration system.

Summary of Alternative Combination 1 and 4's Ability to Meet MMSD Project Goals

Table 4.20 presents a summary of the ability of Alternative Combination 1a and 4a to meet each of MMSD's stated project goals.

Table 4.20 Alternative Combination 1 and 4's Ability to Meet MMSD Project Goals

MMSD Project Goals	Alternative Combination 1a	Alternative Combination 4a
GHG Reduction	√√	√
Peak Demand Costs	√	--(1)
Energy Efficiency	√	√(2)
Renewable Energy(3)	√√	√
Energy for Biosolids Production	√	√
Energy Sources	√	√
Infrastructure	√	√√

Notes:
(1) Alternative Combination 4 does not meet the goal of decreasing peak demand costs since biogas is converted to RNG rather than on-site electricity. For Alternative Combination 4a (with solar), the net electricity production is less than for the baseline 2040 scenario.
(2) While both alternatives slightly increase the overall electricity used on-site, they both fully utilize all the biogas produced, as compared to the baseline scenario where some of biogas is flared due to the capacity limitations of the existing cogeneration system.
(3) Alternative Combination 1a produces more renewable energy for use on-site, but both alternatives meet the renewable energy goal.

4.2.5 Recommended Path Forward

Alternative Combinations 1a and 4a are both feasible alternatives that position MMSD to replace aging energy producing infrastructure and beneficially use biogas for either on-site electricity generation or production of RNG. Alternative Combinations 1a and 4a have relatively similar capital costs, though Alternative Combination 4a has the potential for higher revenue production depending on the value of RINs as part of the RFS program.

Alternative Combination 1a maintains an operational philosophy (i.e., cogeneration and renewable electricity production) that MMSD is familiar with and meets all MMSD's stated energy goals for the project.

Alternative Combination 4a has simpler infrastructure and lower operational complexity but does not meet MMSD's project goal of reducing peak demand costs, though projected RIN revenues would effectively offset the increase in peak demand costs.

Carollo recommends that MMSD continue to evaluate the merits of cogeneration versus pipeline injection. For the purposes of project planning, Alternative Combination 1a will be carried forward as a capital cost placeholder.

4.3 Technical Memorandum 4.2: Capital Improvement Recommendations (TM 4.2)[2]

4.3.1 Simple Alternatives to Include as Standalone Project

The simple alternatives that were identified as "Include as a Standalone Project" are as follows with associated estimated costs, refer to Table 4.1.1 for more information.

- EP2 Replace existing BFC pumps:
  - Project cost for this is estimated to be $6,428,000.
- HV1 Occupancy-Based HVAC and Lighting:
  - No cost for this simple alternative was included.
- HV9 Reduce Vehicle Loading Bay heating:
  - Project cost is estimated to be $100,000.
- RE10 Electric Vehicle Charging Stations:
  - Project cost is estimated to be $200,000.
- BS7 Alternative WAS Thickening Technology to DAF:
  - Rehabilitation of the existing DAF. Project cost for this is estimated to be $2,900,000.
- BS20 Ferric Chloride Pumping:
  - Project cost is estimated to be $400,000.
- BS34 Sludge Piping Interconnections and Redundancy:
  - Project cost is estimated to be $200,000.

4.3.2 Projects (Definition, Schedule, Staffing, Budget)

Below is a list of the biosolids and energy related infrastructure that MMSD would either discontinue using or would be replaced as part of the recommended projects described in Section 4.2.3. Infrastructure received a green (good condition), yellow (fair condition), and red (poor condition) rating in TM 1.2 based on average overall scores of less than or equal to 13, between 14 and 16, and above 17, respectively.

- Centrifuge dewatering system (green score).
- Gravity belt thickeners (green score).
- DAF infrastructure (red score).
- Heat loop (not included in TM 1.2 scoring).
- East and West Boilers (yellow score).
- Cogeneration system (red score).
- Gas conditioning system (red score).
- Waste gas burner (yellow score).
- Engine blower (red score).
- BMC effluent pumps (not included in TM 1.2 scoring):
  - MMSD's asset registry shows a remaining useful life of 13 to 22 years.
- BFC effluent pumps (not included in TM 1.2 scoring):
  - MMSD's asset registry shows a remaining useful life of 13 to 22 years.

[2] See Appendix J for additional information.

- Metrogro storage tanks and vehicle loading (yellow score).
- Cake storage facility (not included in TM 1.2 scoring).

Based on the condition of the various infrastructure that is being replaced, the recommended projects are listed below.

4.3.2.1 Cogeneration Improvements

This project replaces the three existing cogeneration engines (one engine-driven blower and two engine-generators) with two new lean-burning, higher-efficiency, lower-emission engine-generators. The two new engines will be sized based on the projected 2040 biogas production of 22 MMBtuh. The biogas engine blower is anticipated to be replaced with an electric blower within the next three to five years. At the facility planning level a modular cogeneration approach with additional smaller engines could be considered for increased reliability, though this approach will have a higher capital cost.

Due to the interconnectivity between the projects, it is recommended that initial facility planning for the cogeneration improvements should also include facility planning for the heat loop improvements. This facility planning step should also include a closer look at cogeneration versus pipeline injection to determine which option is the best fit for MMSD. The outcome of this facility planning effort should provide a recommendation on the phasing of design and construction for the respective projects.

This project replaces the following aging assets:

- Cogeneration engines.
- Engine secondary loop pumps, piping, and 3-way valves.
- Gas conditioning equipment.
- Waste gas burner.
- Switchgear.

Project Driver(s): Asset replacement and energy optimization.

Schedule: Begin planning in 2022.

Budget: $22,600,000.

4.3.2.2 Heat Loop Improvements

This project replaces the existing complex multi-loop heat system with a true, single primary-secondary heat loop system. This project replaces the following aging assets:

- East and west boilers.
- East and west boiler secondary loop pumps, piping, and 3-way valves.
- Primary heat loop pumps, piping, and 3-way valves.
- HVAC heat loop pumps, piping, and 3-way valves.
- Engine blower:
  - Replaced with an electric blower.

In addition to replacing the above assets, this project includes construction of a new secondary heat loop for polymer and waste activated sludge fermentation.

Project Driver(s): Asset replacement and energy optimization.

Schedule: Begin planning in 2026.

Budget: $10,200,000.

4.3.2.3 Dewatering and Cake Storage Improvements

This project includes installation of new dewatering centrifuges located in the existing dewatering building to process 100 percent of the digested biosolids to produce Class B biosolids cake, which will be hauled and land applied for beneficial use. A new cake storage facility will be constructed to provide adequate storage for dewatered cake storage prior to hauling for land application. The project also includes addition of digester instrumentation and automation and replacement and simplification of centrate piping.

This project replaces the following aging assets:

- Centrifuge.
- Dewatering polymer system.
- Cake conveyance.
- Metrogro storage tanks and vehicle loading.
- Cake storage facility.

With this project, the following assets would be discontinued:

- GBT and polymer system.
- Metrogro storage tanks, loading stations, trailers, and applicator equipment.
- Cake storage facility.

Project Driver(s): Asset Replacement, Operations Cost Savings.

Schedule: Begin planning in 2030.

Budget: $38,936,000.

4.3.2.4 Madison Gas and Electric Renewable Energy Rider Solar Program

This project includes installation of a large-scale solar PV system on an existing 95-acre parcel owned by MMSD. The proposed 10 MW system would be funded by the MG&E RER Program. MG&E would supply the funding, equipment, and a 30-year lease (or as negotiated). It is anticipated that 5 MW would be allocated for NSWTP and MMSD's pumping stations and 5 MW would be allocated by MG&E to other entities. The total amount of power MMSD would require through the RER program and its distribution will require discussion with MG&E and a study of energy use patterns at the NSWTP and in the collection system. This project does not replace any aging assets, but implementation would allow for the purchase of electricity from a renewable energy source, lowering overall electricity costs in the process.

In concert with the RER solar program discussions, MMSD intends to engage MG&E in discussions regarding installation of a backup generator that will be owned by MG&E and leased by MMSD. For planning purposes, $200,000 of administrative costs and $200,000 for construction of a concrete pad for the leased generator have been included.

Project Driver(s): Renewable energy production.

Schedule: Begin planning in 2022.

Budget: $400,000.

4.3.2.5 Prioritization of Simple Alternatives

Several of the simple alternatives are projects that could be incorporated into one of the large projects to reduce overhead costs. However, for the purpose of developing capital improvement recommendations, each of these projects are listed separately. The projects are listed below in order of implementation based on their overall cost and ability to replace aging assets, improve reliability and operational flexibility, and/or reduce energy consumption.

1. Ferric chloride pumping.
2. Vehicle Loading Building loading bay heating.
3. Sludge piping modifications.
4. Electric vehicle charging stations.
5. WAS thickening improvements.
6. Effluent pump replacement.

Carollo recommends that MMSD plan for a separate facility planning step to address WAS thickening improvements and sludge piping modifications to define the scope of these projects more clearly.

4.3.3 Capital Improvement Recommendations

The total capital expenditures for the 20-year period (assuming a 50 percent estimating contingency on capital cost) are $82,364,000. The costs are represented as the total project costs, which include expenditures for engineering, construction, and other allowances or contingencies. All costs shown are represented in 2020 dollars. Refer to TM 4.2 for additional background.

Figure 4.18 illustrates the annual capital expenditures anticipated for the 20-year period. Figure 4.19 shows the various project development phases from study to design through construction and commissioning. The design phase includes preliminary and final design efforts, as well as the bidding phase. The schedule was developed assuming that a conventional design-bid-build procurement approach would be used for each project. Figure 4.20 presents a bar chart of the total project cost expenditures by year. Figure 4.21 presents a bar chart of the estimated full-time equivalents of project management staff by year.

4.3.4 Conclusion

The 2020 Energy Management Master Plan serves to identify and prioritize targeted improvements to the NSWTP's energy infrastructure and energy-management approaches over the next 20 years. With this Project, MMSD set minimum goal expectations instead of hard targets in order to understand and compare the costs and benefits of alternatives at different levels of achievement. Throughout this process, the approach and perspective on the Project goals evolved according to new information and discoveries as the evaluation process progressed and priorities subsequently changed.

This project started with an evaluation of the condition of existing assets that handle biosolids, use biogas, and produce thermal energy, with a priority on replacement of assets that were deemed to be at or nearing the end of useful life. Common themes and challenges across the systems were observed during the asset evaluation:

- Individual Asset and System Capacities:
  - Imbalance in the capacities of individual assets compared to the systems as a whole creates a challenge, with some processes underloaded, while other process demands match or exceed capacity of individual assets.

- Physical Location Challenges:
  - The systems are physically distant, which presents challenges with the biogas and thermal energy distribution.
- Complexity and Interdependency:
  - Each of the systems is complex and highly interconnected; therefore, the efficiency of one system is dependent on the operation of other assets and process systems, with issues in one system propagating to other systems.

Current and projected energy use in the NSWTP and collection system was also documented as a starting point to determine each alternative's impact on the energy baseline. Electrical energy use was shown to hold relatively steady across the time period reviewed (2007 to 2019) with on-site electrical generation gradually increasing (up to system capacity limitations), while in an inverse fashion, purchased electricity gradually decreased. This suggests that MMSD has already begun trending towards greater energy independence, but as initial gains have become stagnant, there exists room for expansion and an opportunity to extend these efforts even further.

According to surveys and studies, the average energy intensity (i.e. energy use per treated flow) at NSWTP is in line with other wastewater treatment plants and when it comes to energy recovery, NSWTP is above average. With NSWTP in line with or better than other wastewater treatment plants in most energy use categories, there is not a clear and obvious initial step to take or assets to replace that would offer a short payback and immediate improvement. The process areas demanding of the greatest attention, though, are the heat and power infrastructure and the solids handling processes given the significant energy impact of each area, and these are the areas where NSWTP underperforms most relative to other plants.

Looking to the future, an increase in electrical energy use of 20 percent at NSWTP is projected by year 2040 under the status quo conditions. The updated baseline and breakdown of energy consumption helped target potential savings opportunities and assist in evaluating potential energy optimization alternatives.

A comprehensive screening process was used to narrow 133 unique energy-related alternatives into a suite of capital improvement recommendations. The selection process considered cost, present and future regulations, technological flexibility, and the alternative's ability to meet MMSD's project goals. The capital improvement recommendations provide a timeline for replacement, rehabilitation, or change of existing assets or group of assets within 20 years that prioritizes action based primarily on condition and criticality, but also considers balancing capital costs over multiple years. Ultimately, this 2020 Energy Management Master Plan recommended the following projects be implemented by MMSD through 2041:

- Cogeneration improvements.
- Heat loop improvements.
- Dewatering and cake storage improvements.
- Participation in the Madison Gas and Electric Renewable Energy Rider Solar Program.
- Ferric chloride pumping improvements.
- Vehicle Loading Building loading bay heating improvements.
- Sludge piping modifications.
- Add electric vehicle charging stations.
- WAS thickening improvements.
- Effluent pump replacement.

Together, these projects achieve a 50 percent reduction in net utility electricity purchase over baseline operation, position MMSD to replace the NSWTP's aging energy infrastructure, and beneficially use biogas for on-site electricity generation.

In the end, potentially the most consequential recommendation of this project is to continue to evaluate the merits of cogeneration (as listed above) versus pipeline injection. While the Cogeneration Improvements successfully meet MMSD's biogas related project goals, the production of RNG for pipeline injection deserves further consideration as part of the facilities planning process due to simplified infrastructure, reduced operational complexity, and the ability to produce new revenue streams through the sale of RINs. In the facility planning process, MMSD will engage stakeholders and community partners to earn their support in developing effective, responsible, and transparent projects that bring value to the community.

Projects	Design/ Administration Cost	Construction Cost	Project Cost	Priority	Project Duration (months)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Dewatering and Cake Storage	$ 7,787,000	$ 31,149,000	$ 38,936,000	2	60									$ 1,946,800	$ 3,893,600
Cogeneration Improvements	$ 4,484,000	$ 18,116,000	$ 22,600,000	1	60	$ 1,130,000	$ 2,260,000	$ 6,780,000	$ 7,910,000	$ 4,520,000					
Heat Loop Improvements	$ 2,047,000	$ 8,153,000	$ 10,200,000	1	48					$ 1,020,000	$ 2,550,000	$ 3,570,000	$ 3,060,000		
MG&E Solar (RER)/Standby Generator	$ 200,000	$ 200,000	$ 400,000	1	48	$ 25,000	$ 75,000	$ 150,000	$ 150,000						
Effluent Pump Replacement	$ 1,286,000	$ 5,142,000	$ 6,428,000	3	36										
VLB Loading Bay Heating	$ 48,000	$ 52,000	$ 100,000	5	12			$ 100,000							
Electric Vehicle Charging Stations	$ 79,500	$ 120,500	$ 200,000	5	12										
WAS Thickening Improvements	$ 614,000	$ 2,286,000	$ 2,900,000	2	24										
Ferric Chloride Pumping	$ 104,000	$ 296,000	$ 400,000	5	12		$ 400,000								
Sludge Piping Modifications	$ 9,000	$ 191,000	$ 200,000	5	12									$ 200,000	
Grand Total			**$ 82,364,000**			**$ 1,155,000**	**$ 2,735,000**	**$ 7,030,000**	**$ 8,060,000**	**$ 5,540,000**	**$ 2,550,000**	**$ 3,570,000**	**$ 3,060,000**	**$ 2,146,800**	**$ 3,893,600**

Projects	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Dewatering and Cake Storage	$ 11,680,800	$ 13,627,600	$ 7,787,200							
Cogeneration Improvements										
Heat Loop Improvements										
MG&E Solar (RER)/Standby Generator										
Effluent Pump Replacement								$ 1,285,600	$ 1,928,400	$ 3,214,000
VLB Loading Bay Heating										
Electric Vehicle Charging Stations				$ 200,000						
WAS Thickening Improvements				$ 870,000	$ 2,030,000					
Ferric Chloride Pumping										
Sludge Piping Modifications										
Grand Total	**$ 11,680,800**	**$ 13,627,600**	**$ 7,787,200**	**$ 1,070,000**	**$ 2,030,000**	**$ -**	**$ -**	**$ 1,285,600**	**$ 1,928,400**	**$ 3,214,000**

Figure 4.18 Summarized Capital Improvement Recommendations by Year

Projects	Project Cost	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Dewatering and Cake Storage Improvements	$ 38,936,000																				
Cogeneration Improvements	$ 22,600,000																				
Heat Loop Improvements	$ 10,200,000																				
MG&E Solar (RER Program)/Standby Generator	$ 400,000																				
Effluent Pump Replacement	$ 6,428,000																				
VLB Loading Bay Heating	$ 100,000																				
Electric Vehicle Charging Stations	$ 200,000																				
WAS Thickening Improvements	$ 2,900,000																				
Ferric Chloride Pumping	$ 400,000																				
Sludge Piping Modifications	$ 200,000																				

Legend: Project Development Phases

Facility Planning, Design, Bidding

Construction and Commissioning

Figure 4.19 Implementation Schedule for Capital Improvement Recommendations

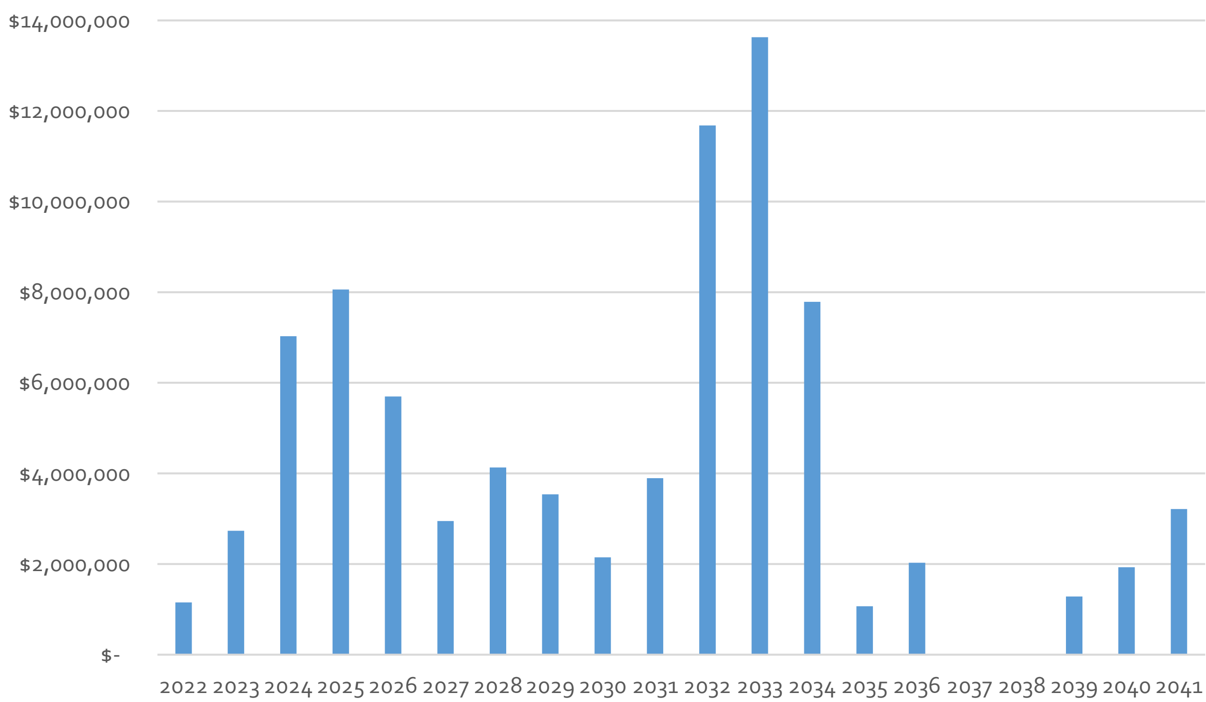


Figure 4.20 Capital Improvement Recommendations Annual Expenditure

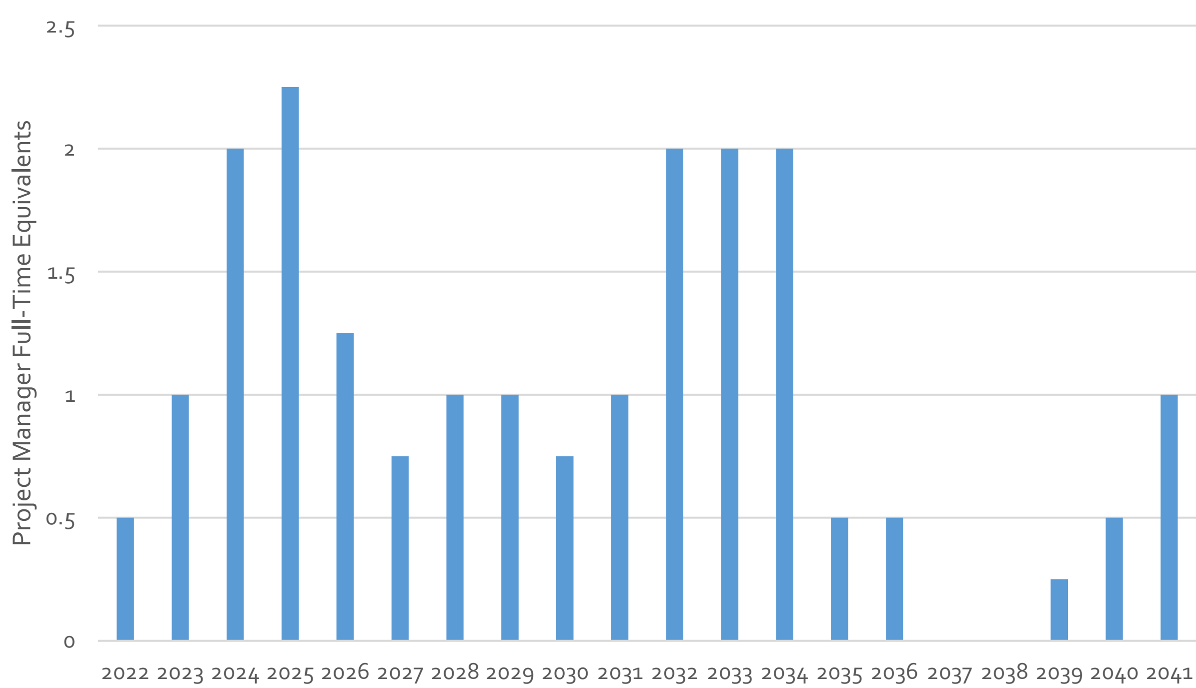


Figure 4.21 Project Manager Staffing Estimate