Feasibility of BioEnergy Generation at the Springfield Regional Wastewater Treatment Facility

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

°F	degrees Fahrenheit
$	dollar(s)
$/gal	dollars per gallon
$/hr	dollars per hour
$/wt	dollars per wet ton
Avg.	average
BC	Brown and Caldwell
Btu	British thermal units
Btu/scf	British thermal units per standard cubic feet
CFR	Code of Federal Regulations
CHP	combined heat and power
Commission	Springfield Water and Sewer Commission’s
d	day
dt	dry ton
EPA	Environmental Protection Agency
EPBR	enhanced biological phosphorus removal
FOG	fats, oil, and grease
ft	foot/feet
ft^3	square feet
gal	gallon(s)
gpd	gallons per day
gpm	gallons per minute
H_2S	hydrogen sulfide
hr	hour(s)
HRT	hydraulic residence time
HSOW	high-strength organic wastes
IC	internal combustion
kW	kilowatt(s)
kWh	kilowatt hour
lb	pound(s)
lb/hr	pounds per hour
lb-TS/d	pounds total solids per day
lb-VS/ft^3-d	pounds volatile solids per square foot per day
lb-VS/lb-TS	pounds volatile solids per pounds total solids
MACT	Maximum Achievable Control Technology
MassCEC	Massachusetts Clean Energy Center
Mass DOER	Massachusetts Department of Energy Resources
MG	million gallons
MW	megawatt(s)
NEBRA	North East Biosolids & Residuals Association
NECEC	Northeast Clean Energy Council
NFPA	National Fire Protection Association
NPV	net present value
OLR	organic loading rate
O&M	operations and maintenance
POTW	publicly owned treatment works
PS	primary sludge
RPS	Renewable Portfolio Standards
R&R	replacement and residual
RTO	regenerative thermal oxidizer
scfm	standard cubic feet per minute
SSO	source-separated organics
SWSC	Springfield Water and Sewer Commission
TCHP	thermochemical hydrolysis process
THP	thermal hydrolysis process
TN	total nitrogen
TP	total phosphorus
TS	total solids
TWAS	thickened waste activated sludge
VAR	vector attraction reduction
VS	volatile solids
WAS	waste activated sludge
WPCF	Water Pollution Control Facility
wt	wet ton
wtpd	wet tons per day
WWTF	wastewater treatment facility
WWTP	wastewater treatment plant

Executive Summary

The Springfield Water and Sewer Commission's (Commission) Regional Wastewater Treatment Facility (WWTF) treats an average flow of 36 million gallons per day (mgd) from the City of Springfield and the Commission's six-member communities. The Commission is interested in determining the economic viability of generating renewable energy from the solids (sludge) produced during the wastewater treatment process through anaerobic digestion. For anaerobic digestion-based systems the primary economic factors impacting feasibility have typically been energy revenues and residuals management. This report summarizes the feasibility study conducted to evaluate the financial costs and benefits of undertaking the construction and operation of an anaerobic digestion system at the Springfield Regional WWTF.

The feasibility study included various operating configurations believed to have potential benefit to the Commission and participating entities. These operating configurations includes:

- Operating the anaerobic digesters processing the Commission's solids only, and as a merchant facility, taking in solids from other publicly owned treatment works (POTWs) in the region, as well as with and without the addition of high strength organic wastes (HSOW) from industrial generators.
- Production of a Class B biosolids cake product or production of a thermally dried product to provide further cost control of solids hauling and disposition costs.

This study sought to understand the underlying fundamentals of these potential opportunities by addressing the following questions:

- Is it more financially attractive to generate renewable energy from anaerobic digestion and CHP over the 20-year planning period or does the status quo represent the better model for cost and rate control?
- Can sufficient revenues be generated via electricity production and imported feedstock tip fees to justify the investment for the import of regional sludge and HSOW; such as fats, oils and grease (FOG)?
- Does drying the digested solids reduce solids hauling and disposition costs enough to justify installation and operation of a drying facility?

Process Baseline Definition

The study considered annual WWTF operating data, regional population projections, and a preliminary high-level inventory assessment of nearby POTWs to develop solids projections to serve as the basis of all system evaluations. Table ES-1 provides a summary of the projected solids loadings developed based on the underlying assumptions.

Table ES-1. Summary of Feasibility Study Projected Solids Loading Estimates and Operating Conditions

	Current Load	20-year Projected Loads [a, b, c]			
Parameter	WWTF PS + WAS	WWTF PS + WAS	HSOW	Imported Wastewater Cake	Imported Liq Wastewater Sludge
Annual Average Load					
Total Solids (TS), pound per day	66,190	71,200	17,640	28,800	4,000

Table ES-1. Summary of Feasibility Study Projected Solids Loading Estimates and Operating Conditions

	Current Load	20-year Projected Loads [a, b, c]			
Parameter	WWTF PS + WAS	WWTF PS + WAS	HSOW	Imported Wastewater Cake	Imported Liq Wastewater Sludge
Volatile Solids (VS), pound per day	55,330	59,590	14,990	23,040	3,200
TS concentration, lb-TS/lb-sludge	4.3%	4.3%	5%	20%	5%

Basis of Evaluation

The feasibility study alternatives were developed from the different digester feedstock scenarios and solids management strategies described above. The equipment was sized to accommodate future growth conditions during the 20-year planning period using Brown and Caldwell (BC) design experience. The alternatives' major construction elements and project considerations are summarized below in Table ES-2.

Table ES-2 Summary of Feasibility Study Alternatives

	Status Quo	BioEnergy Alternatives (includes anaerobic digestion and IC engine CHP system)				
Parameter	Planning Baseline	Alt 1: WWTF Solids Only	Alt 2: +Imported WW Solids	Alt 3: +Imported WW Solids + Dryer	Alt 4: +Imported WW Solids + HSOW	Alt 5: +HSOW
Imported Feedstocks, trucks/day	-	-	7-9	7-9	17-29	10-20
Anaerobic Digesters, (quantity), million gallons	-	(4) 1.4 MG	(4) 1.5 MG	(4) 1.5 MG	(4) 1.8 MG	(4) 1.6 MG
CHP System, (quantity), megawatt	-	(1) 1.5 MW	(2) 1.1 MW	(2) 1.1 MW	(3) 1.1 MW	(2) 1.1 MW
Dryer, (quantity), wet tons per day	-	-	-	(2) 53 WTPD		
Digested Solids Hauled, trucks/day	6-7	3-4	5-6	1-2	5-6	4-5

Economic Evaluation of Alternatives

BC created a custom model to combine mass and energy balances to evaluate both technical performance and capital and operational costs for the new systems under consideration. Conceptual capital cost estimates developed for the alternatives are presented in Table ES-3. The capital costs are based on Class 5 conceptual cost estimates per the Association for the Advancement of Cost Engineering International (AACEI).

Table ES-3: Initial Project Costs for Feasibility Study Alternatives in Millions of Dollars

	Status Quo	BioEnergy Alternatives (includes anaerobic digestion and IC engine CHP system)				
Parameter	Planning Baseline	Alt 1: WWTF Solids Only	Alt 2: +Imported WW Solids	Alt 3: +Imported WW Solids + Dryer	Alt 4: +Imported WW Solids + HSOW	Alt 5: +HSOW
Imported Liquid Sludge Receiving	-	-	$0.4M	$0.4M	$0.4M	-
Imported Dewatered Cake Receiving	-	-	$3.7M	$3.7M	$3.7M	-
HSOW Receiving	-	-	-	-	$2.4M	$2.4M
Anaerobic Digestion	-	$46.2M	$48.5M	$48.5M	$55.1M	$50.7M
Drying	-	-	-	$22.5M	-	-
CHP System	-	$14.7M	$22.0M	$22.0M	$30.0M	$22.0M
Total Capital	**-**	**$60.9M**	**$74.6M**	**$97.2M**	**$91.6M**	**$75.2M**

Where an equipment vendor quote was obtained the equipment, cost was multiplied by the following factors to develop a project cost: 100% for installation cost, 20% for general conditions and overhead and profit, 20% for engineering and capital program administration, and 25% for an undefined details design allowance.

The capital investment required for each alternative (Table ES-3), and associated operating costs and revenues, are combined to generate a net present value (NPV) of lifecycle costs for each alternative. Table ES-4 shows the results of the NPV evaluation conducted for the feasibility study alternatives. Note that the extrapolated operating and maintenance (O&M) costs reflect historical cost factors based on actual costs incurred by the Commission for fiscal year 2017.

Table ES-4: Estimated Net Present Value Costs for Feasibility Study Alternatives

	Status Quo	BioEnergy Alternatives (includes anaerobic digestion and IC engine CHP system)				
Parameter	Planning Baseline	Alt 1: WWTF Solids Only	Alt 2: +Imported WW Solids	Alt 3: +Imported WW Solids + Dryer	Alt 4: +Imported WW Solids + HSOW	Alt 5: +HSOW
Total Capital Costs	-	$69,400,000	$85,000,000	$110,700,000	$104,300,000	$85,700,000
Revenue	-	-$29,600,000	-$78,400,000	-$78,400,000	-$109,400,000	-$59,200,000
Total O&M Costs	$111,300,000	$67,600,000	$101,400,000	$76,400,000	$111,700,000	$82,600,000
20-year NPV Cost	**$111,300,000**	**$107,400,000**	**$108,000,000**	**$108,700,000**	**$106,600,000**	**$109,100,000**

Capital costs include a 15% factor at year-15 to account for mechanical equipment replacement. These are planning-level estimates based on experience. The ultimate values may vary a little or moderately depending on regulatory impacts, inflation or local impacts.

Summary and Recommendations

Based in the underlying assumptions, data available, and processes selected for this analysis the 20 year NPV of all alternatives ranged from a low of $106 million to a high of $111 million. At the current level of analysis (design, cost estimating, market assessment, energy use profile, incentives, grants, etc.) the data show that there is no significant financial benefit from implementing anaerobic digestion, but there is not a significant detriment either. The preliminary analysis demonstrates that the Commission can invest in the infrastructure needed to convert its sludge and the sludges of other regional POTWs to generate renewable electrical energy at the same cost it would incur if it were to simply continue current solids management practices, which does not recover any energy.

Environmental Benefits

Moving forward with a solids-to-energy project at the Commission, depending on scope (see Figure ES-1 at the conclusion of this section), can provide the following range of energy and positive environmental attributes:

- Onsite-Renewable Power Generation: 1.2 MW to 2.1 MW, or approximately 57 to 100 percent of average electrical demand of the plant including new facilities. This results in an annual savings of $1.3M to $2.3M in the plant's electrical bill, represented as electrical offset in Section 6. In addition, Massachusetts energy program incentives (Renewable and Alternative Energy Certificates) are projected to provide $0.3M to $0.6M in annual revenue.
- Equivalent Carbon Emissions (power and natural gas only): 1,600 to 8,900 tons of CO_2e per year relative to a status quo rate of 6,700 tons CO_2e per year.

Risk Management

Further, risk mitigation factors should be considered in the decision to proceed or not with different process configurations. A key advantage of implementing anaerobic digestion is that it has the potential to reduce solids hauling and disposition costs by approximately 57% on an annual basis (~$2.7M/yr) under the cost factors assumed for the study. Given that wastewater solids disposal and end-use options are growing increasingly constrained in the region, this represents a significant ability to protect the Commission from the risk of climbing solids disposal fees. Likely impacts associated with a tightening biosolids management market would be either increased haul distance and/or increased fees at disposal points. Both of which are lessened by the mass reduction from digestion and further reduced with drying (Alternative 3).

Imported Organics

The import of additional feedstock, HSOW and/or outside wastewater sludges, has the potential to generate additional revenue, provide needed regional service, and increase the total energy production from a Commission digestion process. At the current level of analysis, the addition of imported feedstocks demonstrated little additional benefit from an economic standpoint, based on the current understanding of the market and associated assumptions. While from a purely economic standpoint of significantly reduced operating costs, each alternative showed little relative difference in overall cost of ownership (capital and operating costs) making risk reduction and additional environmental benefit the primary drivers for decision making, based on the current information.

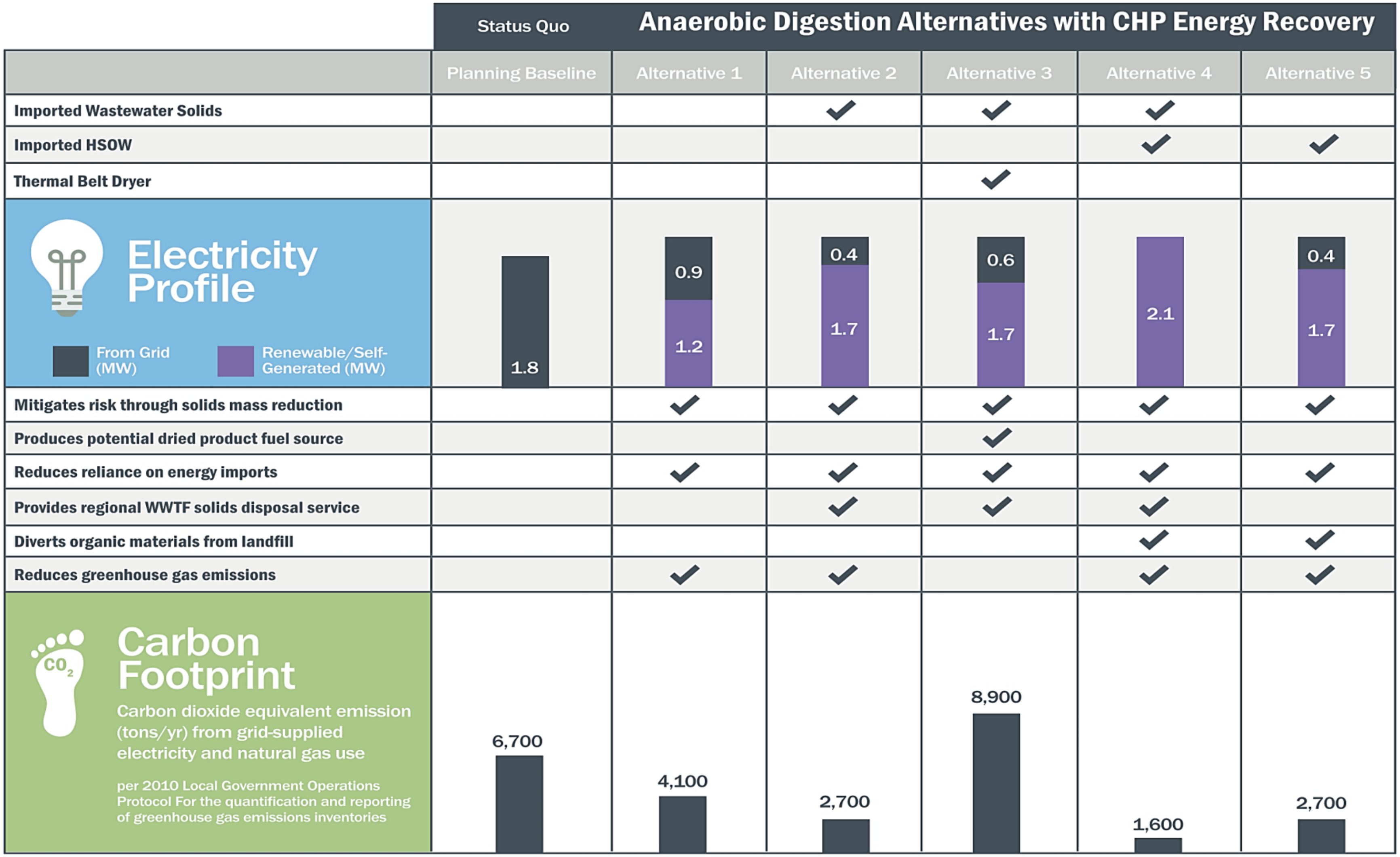
Core Assumptions Evaluation

Based on an evaluation of the data, underlying assumptions and the specific sensitivities of this analysis several areas were noted that have the potential to improve the overall financial benefit to the Commission. These include:

- Energy Production: for this analysis combined heat and power (CHP) was selected as the model energy system. Exploration of high value renewables such as renewable compressed vehicle fuel could generate significantly more revenue given to the value of Renewable Identification Numbers.
- Wastewater Sludge Disposal Fees: given a detailed market assessment of current sludge disposal costs from regional generators and a market-based assessment of potential tipping fees, the market demand for a regional digestion facility may demonstrate better cost factors than assumed in this study.
- High Strength Organic Wastes: given a more detailed market assessment surrounding the quantity and characteristics of available HSOW in the market, local tip fee limits and their potential for capital and operating cost recovery could be determined.

- Non-Waste Fuel Source: the potential to supply a dried product to nearby incinerators or biomass boilers with energy recovery systems and corresponding tipping fees could be demonstrated through additional outreach efforts. If viable combustion end uses are identified, regulators would be engaged to identify the steps required to classify the dried product as a non-waste, combustion fuel source.
- Grants and Incentives: exploration of low cost or no-cost capital grants should be explored along with any additional energy incentives that may prove relevant for electricity or other renewable energy production.

In summary, anaerobic digestion with CHP will likely be no more costly than continued operation under the current process model, raw sludge incineration and landfilling. There appears to be some marginal benefit associated with the digestion of imported wastewater solids and HSOW, though not beyond the tolerances of this analysis. However, in-terms of risk management, specifically long-term cost controls, and the associated environmental benefits of the renewable power production and carbon emissions reductions, in most cases, the digestion options are superior to the current practice of raw sludge management. The Commission would be best served by further developing these alternatives and refining value-added elements to further optimize the balance of financial and operations risks specific to their market. These tasks are a part of the due diligence necessary in the progression from initial feasibility study (this study) to the design, construction and operation of Commission located facility.



	Status Quo	Anaerobic Digestion Alternatives with CHP Energy Recovery				
	Planning Baseline	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Imported Wastewater Solids			✓	✓	✓	
Imported HSOW					✓	✓
Thermal Belt Dryer				✓		
Electricity Profile ⬛ From Grid (MW) 🟪 Renewable/Self-Generated (MW)	⬛ 1.8	⬛ 0.9 🟪 1.2	⬛ 0.4 🟪 1.7	⬛ 0.6 🟪 1.7	🟪 2.1	⬛ 0.4 🟪 1.7
Mitigates risk through solids mass reduction		✓	✓	✓	✓	✓
Produces potential dried product fuel source				✓		
Reduces reliance on energy imports		✓	✓	✓	✓	✓
Provides regional WWTF solids disposal service			✓	✓	✓	
Diverts organic materials from landfill					✓	✓
Reduces greenhouse gas emissions		✓	✓		✓	✓
Carbon Footprint Carbon dioxide equivalent emission (tons/yr) from grid-supplied electricity and natural gas use per 2010 Local Government Operations Protocol For the quantification and reporting of greenhouse gas emissions inventories	6,700	4,100	2,700	8,900	1,600	2,700

Figure ES-1. Summary of major elements, energy profile and carbon footprint of evaluated alternatives

Section 1

Introduction

This report presents the findings of the Feasibility Study of BioEnergy Generation at the Springfield Regional Wastewater Treatment Facility (WWTF). The Springfield Regional WWTF at Bondi's Island is owned by the Springfield Water and Sewer Commission (Commission) and treats wastewater collected from the City of Springfield and its six-member communities: Agawam, West Springfield, Longmeadow, East Longmeadow, Wilbraham, and Ludlow. The Commission is interested in determining the economic viability of generating energy from the solids (sludge) produced during the wastewater treatment process through anaerobic digestion.

Anaerobic digestion is a solids processing technology that employs microbes to break down solids and produce an energy rich biogas. The biogas can be combusted on site using combined heat and power (CHP), also known as cogeneration), energy recovery systems that produce usable electricity and heat, offsetting utility purchase costs. Additionally, anaerobic digestion reduces solids volume, creating less material to be managed, and reduces solids odor generation potential.

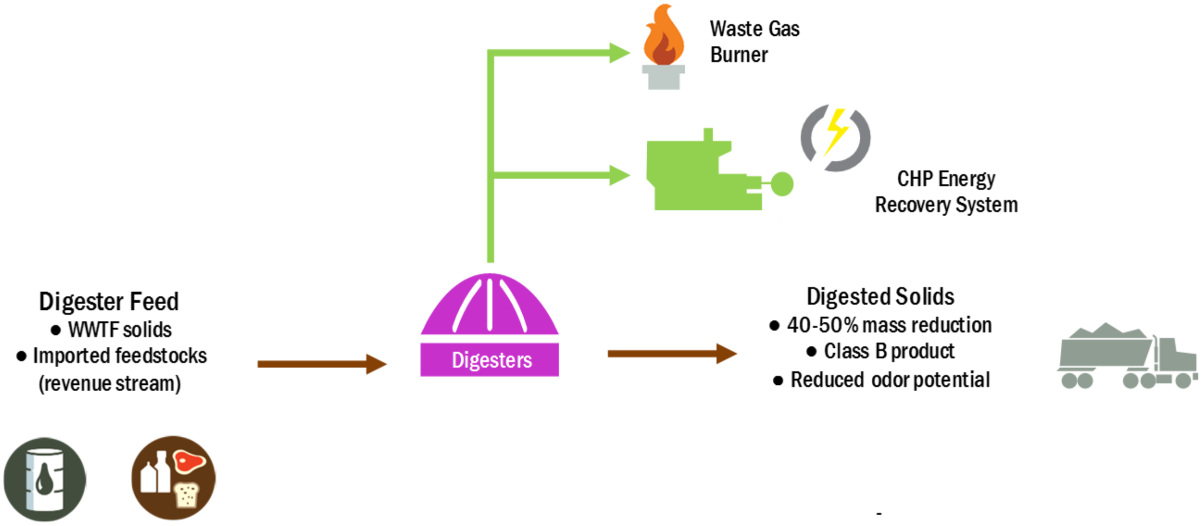


Figure 1-1. Anaerobic digestion bioenergy generation schematic

In addition to evaluating the financial impact from the conventional benefits listed above, this feasibility study includes an evaluation of two unique opportunities associated with undertaking a new solids processing strategy at the Springfield Regional WWTF with anaerobic digestion. First, anaerobic digestion systems provide the potential to serve as a merchant facility taking in solids from other publicly owned treatment works (POTWs), liquid organics from other sources such as fats, oils, and grease (FOG), liquid organics separated from the municipal waste stream (source-separated organics [SSO]), and liquid industrial waste. Second, as an additional solids management strategy, drying downstream of anaerobic digestion has the potential to provide further cost control of solids hauling and disposition. These two opportunities are described in greater detail below.

1.1 Regionalized Facility Operation

Anaerobic digestion facilities operating with excess processing capacity can receive imported feedstocks for co-digestion and charge an associated tipping fee. The imported digestion feedstocks also generate additional biogas, increasing energy production and allowing some plants to become energy self-sufficient. Digestion facilities within New England, notably those located at Greater Lawrence Sanitary District and Lewiston-Auburn Water Pollution Control Authority operate co-digestion facilities with CHP energy recovery systems. These facilities receive a mixture of SSO and other high-strength organic wastes (HSOW) such as FOG.

Additional digester capacity can also be used to process solids from other POTWs. In fact, recent challenges to find outlets for solids in New England has generated significant interest in increasing regional wastewater solids processing and disposal options. Given the current state of the market, co-digestion with imported wastewater solids may offer greater opportunity for revenue generation and longer term contracts compared to HSOW. However, certain technical and contractual considerations would need to be validated in this scenario. Factors to consider in evaluating the imported organics market are discussed in Section 2, while the technical elements associated with processing imported organics are discussed in Section 3.

1.2 Drying as an Additional Solids Management Strategy

As mentioned above, wastewater solids disposal and end-use options are growing increasingly constrained in the region, leading to rising disposal costs. There are three methods for managing WWTF solids – incineration, landfilling, and land application. The region also contains a limited number of compost facilities. Capacity in each option is limited and costs have risen, with reasons being:

- higher incinerator capital investments required to make infrastructure repairs and meet new air emission requirements,
- stringent regulatory requirements and negative public perception associated with composting and land application, and
- the closure of local landfills and increased difficulty of constructing and operating landfills, leaving a relatively small number of larger regional landfills in the area.

Anaerobic digesters reduce the overall volume of solids and can provide adequate stabilization to create a Class B biosolids product. Under Title 40 of the Code of Federal Regulations (CFR), Part 503, a Class B biosolids product can be applied/recycled to specifically permitted agricultural sites. In most areas of the country, production of a Class B biosolids product results in a significantly reduced hauling and end use cost, improving the economic viability of undertaking an anaerobic digestion project. This has been demonstrated to a lesser extent in New England. A recent 2016 survey by the North East Biosolids & Residuals Association (NEBRA) estimates that the average cost to haul and land apply Class B biosolids in New England is 20 to 50 percent lower than that of unclassified solids disposal, which is less than other areas of the country (Beecher 2016). This can be linked to both public sentiment and a general lack of farmland and land application programs in the region.

One option to control solids hauling and disposal costs is to further reduce the mass of the solids following digestion through thermal drying. Thermal dryers are often considered for production of a higher-quality biosolids product; however, given the regional market conditions, a more promising option may be production of a dried product for use as an alternative fuel source. For example, the Massachusetts Water Resources Authority provides about 20 percent of their heat-dried solids product to a Maryland cement kiln. There also exists a demonstrated pathway to incinerate dried solids in an incinerator outfitted with an energy recovery system without triggering the restrictive Section 129 Maximum Achievable Control Technology (MACT) emission standard by demonstrating the heating value of the dried product. Given the nearby location of a municipal solid waste incinerator equipped with energy recovery equipment, this is a promising solids management strategy to investigate.

1.3 Feasibility Study Approach

In this feasibility study, several solids and energy process alternatives are evaluated to determine the economic viability of bioenergy production with the different feedstocks and solids management strategies described above. Project viability is not simply a matter of technical viability but also overall reduction in long-term operating costs relative to the required capital investment. Based on this concept, a successful project will not only be technically viable, it will also reduce the overall lifecycle costs of ownership to the Commission. This feasibility study discusses the following steps used to conduct this analysis:

1. Evaluate current conditions and loadings to determine required digestion capacity at the Springfield Regional WWTF (Section 2)
2. Evaluate suitable solids processing and biogas energy recovery technologies and associated gas treatment (Section 3)
3. Develop a conceptual design of facilities (Section 4)
4. Conduct an economic analysis (Section 5)
5. Consider project progression and development (Section 6)
6. Conclude with final recommendations (Section 7)

Support for this feasibility study was provided through a grant from the Massachusetts Clean Energy Center (MassCEC) Organics-to-Energy Program. The goals of the program are to increase knowledge about and support the development of facilities that convert waste organic materials into heat and electricity, as well as create additional products of value in agriculture, horticulture or landscaping. This study follows the direction of the Organics-to-Energy Program in that its evaluation seeks to understand the scope of work required to implement a digestion and biogas energy recover system program at the Springfield Regional WWTF and evaluate the economic viability on a lifecycle cost basis.

Section 2

Process Baseline Definition

Currently, no solids stabilization technologies are used at the Springfield Regional WWTF and the solids are hauled off site and disposed of as raw dewatered cake. Existing infrastructure currently in use consists of primary sludge (PS) gravity thickening and holding tanks, waste activated sludge (WAS) gravity belt thickeners and thickened WAS (TWAS) holding tanks, blended sludge holding tanks, dewatering centrifuges, and dewatered cake truck loadout. The technologies and their general orientation are shown in the process flow diagram in Figure 2-1 below.

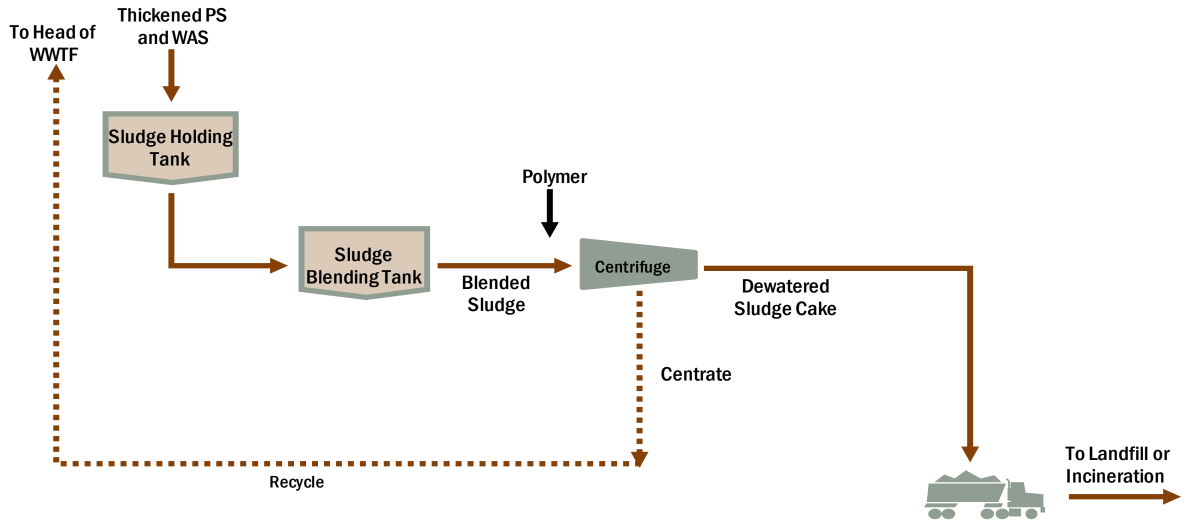


Figure 2-1. Existing solids stream process flow diagram

This section presents the current solids stream mass balance, peaking factors, and projected growth factors used to baseline WWTF process operation. Theoretical imported digester feedstocks are also discussed with regards to potential regionalized digester facility operation. Solids flows and loads from the baseline process and theoretical feedstocks receiving are used to develop the solids process capacity and economic analyses for digestion.

2.1 Process Loadings

The loading conditions developed include:

- **Average annual.** This represents the base operating condition of the processes during a typical year. Often, service events occur during these base loading conditions, avoiding reducing capacity at peak loading conditions. For this analysis, it is assumed that the Commission would service its digesters and other equipment at average annual flows and loads.
- **Peak 30-day average.** The peak rolling 30-day average is calculated to support the estimated impact of return stream loads on relevant plant processes.

- **Peak 14-day average.** The maximum 14-day average flow and load approximates the time frame of a primary process limitation of anaerobic digestion—a minimum hydraulic residence time (HRT) of 15 days.
- **Peak day.** The peak day flow and load is used to evaluate the pumping capacity of the system, gas conveyance, and dewatering process, assuming significant peak shaving is not available through storage.

2.1.1 Current System Mass Balance

In order to estimate current and future operating conditions at the Springfield Regional WWTF, a solids stream mass balance was developed and populated using 5 years of plant data (January 1, 2014 to August 5, 2018). This data was not independently verified and is assumed to be generally reliable for this analysis. To improve model accuracy, a statistical analysis was conducted to evaluate the data for outliers using the interquartile rage method. Outliers, high or low, were excluded from the original data set analysis to reduce the skewing of averages and maximum/minimum values.

The results of the solids stream mass balance are depicted in Figure 2-2. The data presented are based on annual average operations assuming a 24-hour, 7 days per week, 365 days per year operation of all units.

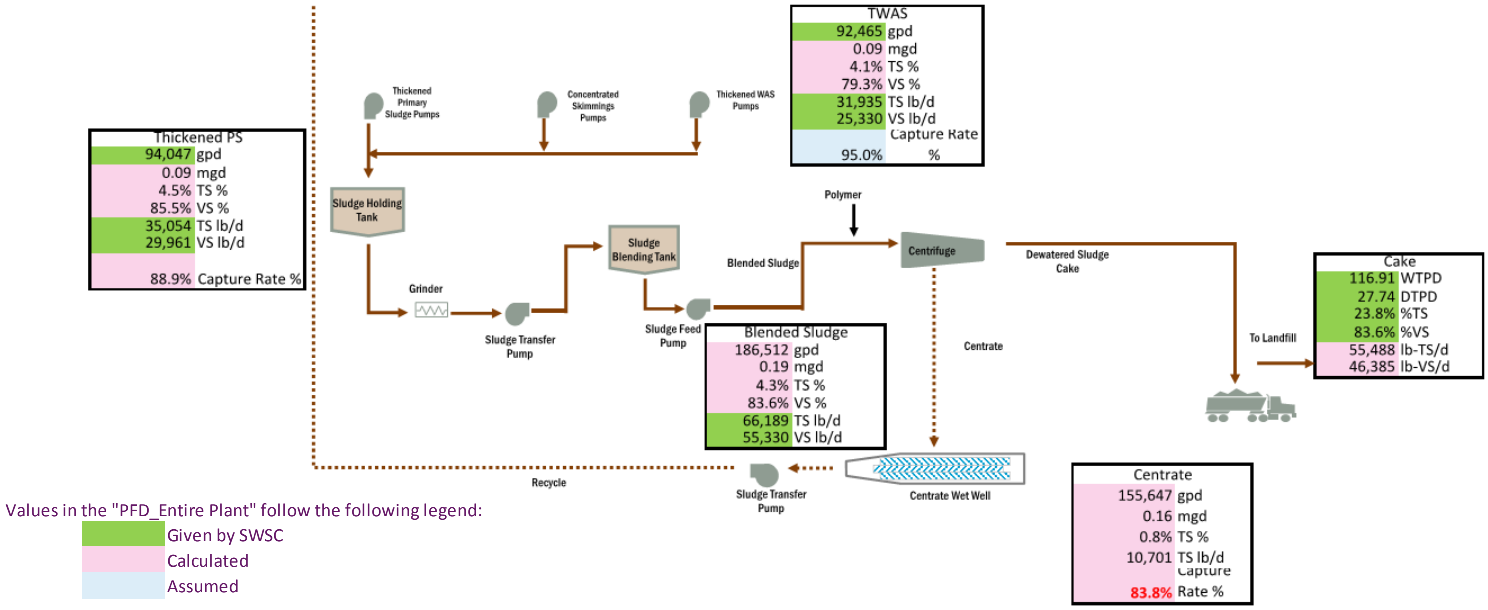


Figure 2-2. Existing solids stream mass balance data

2.1.2 Peaking Factors

To assess the capacity and sizing of specific processes and equipment either existing at the plant or to be added, a variety of peak loading conditions need to be developed, as outlined above. The peaking factors for the raw sludge (PS and WAS) production were developed by evaluating 5 calendar years of WWTF data. The large data set mitigates the risk of underrepresenting the peak flows and loads a given WWTF can receive. Table 2-1 summarizes the peaking factors used in this study.

Table 2-1. Springfield Regional WWTF Sludge Peaking Factors [a,b]

Parameter	Annual Average	Maximum Day	Maximum 7-day	Maximum 14-day	Maximum 30-day
Thickened PS	1.00	2.48	1.47	1.43	1.26
TWAS	1.00	3.14	1.49	1.41	1.35
Blended Sludge	1.00	2.11	1.38	1.29	1.24

a. *Peaking factors proposed are based on historical data from 2014-2018 and on daily sludge production values.*

b. *Blended sludge values are calculated by adding daily thickened PS and TWAS production values.*

It should be noted, in the cases where imported feedstocks are considered in the study, no peaking factor was considered on those data. Rather, it was assumed that average loading would sufficiently represent the actual operations. As part of any design or implementation plan, it is recommended the Commission evaluate imported feedstock load variability to verify facilities' sizing.

2.1.3 Projected Growth

This feasibility study evaluates near and long-term impacts of digestion and energy production at the Springfield Regional WWTF. As such, current solids production is expected to increase over the 20-year planning window of the study. To estimate the change in sludge production over time, it was assumed that the solids production would increase proportional to the expected increase in population in the service area. Using the most recent census data for the City of Springfield and the Commission's six-member communities, sourced from the University of Massachusetts Donohue Institute, a 0.4 percent annual population increase is estimated for the study planning horizon. It should be noted that using this approach does not account for any industries entering the service area or changes in the plant process that may increase or reduce sludge production.

2.1.4 Projected Solids Production for Design Year 2038

The current average and future sludge productions, presented in Table 2-2, serve as the basis of all system evaluations in this feasibility study.

Table 2-2. Summary of Projected Flow and Load Estimates and Operating Conditions

Parameter	Current Load	20-year Projected Loads [a]			
	Average annual	Average annual	Maximum 30-day average	Maximum 14-day average	Maximum day
Blended Sludge (Digester Feed)					
TS, lb-TS/d	66,190	71,200	89,650	93,400	152,000
VS, lb-VS/d	55,330	59,590	73,990	77,090	125,460
Volatile fraction, lb-VS/lb-TS	83.6%	82.5%	82.5%	82.5%	82.5%
TS concentration, lb-TS/lb-sludge	4.3%	4.3%	4.3%	4.3%	4.3%
Flow, gpd	186,510	201,010	249,590	260,030	423,190

a. *Assumes sludge production growth is to be proportional to population growth; there will be no significant shift in the commercial, residential, and industrial composition of the Commission service area for the planning period; and the main treatment processes current operation will continue in terms of efficiency and sludge yield.*

2.2 Imported Organics Characteristics and Design Assumptions

In an urban environment like Springfield, MA several different organic wastes are typically available, such as fats, oils and grease (FOG), food processing wastes and food waste. HSOW can also include outside sludges from other wastewater treatment facilities. Each waste source has unique physical and biochemical characteristics and market considerations (availability, tipping fee, load security). For this analysis the SWSC indicated that there was a greater interest in the wastewater sludge market, as such a generic place holder for HSOW was used and efforts focused on developing an understanding of the sludge market in the region. Flows and loads for the imported co-digestion feedstocks used in this study are described below.

2.2.1 Imported HSOW

To assess the impact of HSOW co-digestion, it was assumed a generic imported feedstock would be received rather than defining it around specific waste sources. An organics market assessment can be conducted in the future to define the program around specific waste sources. The HSOW loading rate was set at a reasonably conservative amount of 25 percent of the native WWTF blended sludge volatile solids (VS) content. The generic surrogate characteristics assumed are described below in Table 2-3.

Table 2-3. Projected HSOW Co-digestion Program Size

Parameter	
TS load, lb-TS/d [a]	17,640
VS load, lb-VS/d [b]	14,990
Hydraulic load, gpd [a]	42,300
Hydraulic load, gallons per week [a]	296,100
Delivery truck, number per week [c]	50

a. Assumes 5% TS concentration by weight.

b. Assumes 85% VS content by weight.

c. Assumes 6,000-gal tank trunk, rounded to the nearest whole truck load.

2.2.2 Imported Wastewater Solids

An inventory of the number of POTWs within a 50-mile radius of the Springfield Regional WWTF was taken to determine potential sources of wastewater solids for co-digestion. A total of 54 POTWs were identified (Figure 2-3).

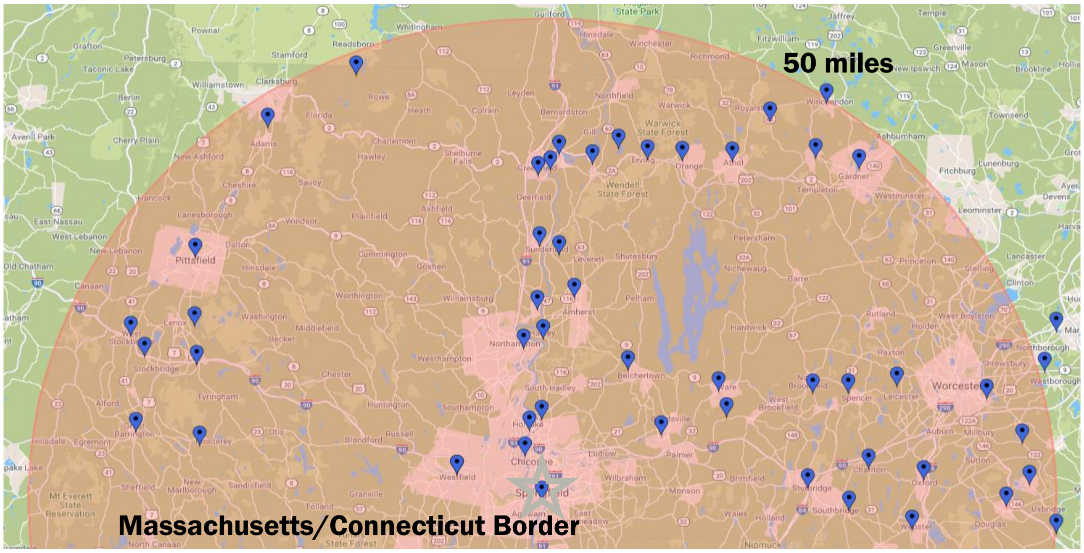


Figure 2-3. POTWs in a 50-mile radius of the Springfield Regional WWTF

Given the high-level nature of the study, POTWs were not contacted to gauge interest in delivering solids to the Springfield Regional WWTF for co-digestion. Like the HSOW program projections, a reasonably conservative estimate was used to select a representative cluster of POTWs that would be willing to supply their solids at market rate under a long-term contract. This representative POTW cluster consisted of 12 plants, or approximately 20 percent of POTWs in the area by sheer number. The selected plants are presented below in Table 2-4, with average solids production values from the 2013 to 2016 Environmental Protection Agency (EPA) Biosolids Reporting Database.

Table 2-4. Representative Wastewater Solids Co-digestion Program Sources

Distance from SWSC (miles)	Facility Name	Annual Avg. Production (dry tons)	Daily Avg. (dry tons)	Form
7	Chicopee WWTP	1,446	4.0	Cake
9	Holyoke WPCF	1,794	4.9	Cake
19	Northampton POTW	1,046	2.9	Cake
21	Belchertown WWTP	78	0.2	Slurry
22	Hadley Indian Hills WWTP	136	0.4	Slurry
27	Hatfield WWTP	28	0.1	Cake
32	South Deerfield WWTP	114	0.3	Slurry
32	Sunderland WWTP	34	0.1	Slurry
38	Greenfield DPW WPCP	335	0.9	Slurry
39	Sturbridge WWTP	401	1.1	Cake
42	South Hadley WWTP	506	1.4	Cake
52	Stockbridge WWTP	39	0.1	Slurry
Total	**12 Plants**	**5,957**	**16.4**	**-**

Data Source: MassCEC: EPA Biosolids Reports 2013-2016

The data in Table 2-5 shows that although the plants are split almost evenly between the number that haul cake and the number that haul a slurry (thickened liquid sludge), the plants that haul cake are significantly larger and contribute nearly 85 percent of the solids on a dry mass basis. Solids hauled as a slurry can be added directly to the anaerobic digestion process, while cake requires upstream processing. Although cake receiving and processing adds operational complexity and capital expense, without having a guarantee that all plants suppling solids would provide them as a slurry, the study assumed that the solids would be received in the form described in Table 2-5 at the daily loading rates provided below in Table 2-5. The conceptual cake receiving and processing facilities developed for the study are described in Section 3.

Table 2-5. Projected Imported Wastewater Solids Program Size

Parameter	Dewatered Cake [a]	Slurry [b]
TS load, lb-TS/d	28,800	4,000
VS load, lb-VS/d	23,040	3,200
Daily load, wtpd or gpd	72 wtpd	9,590 gpd
Weekly load, wet tons or gal	500 wet tons	67,150 gal
Delivery truck, number per week [c]	26	12

a. *Assumes 20% TS concentration by weight, 80% VS content by weight*

b. *Assumes 5%TS concentration by weight, 80% VS content by weight.*

c. *Assumes 20 ton or 6,000-gal tank trunk, rounded to the nearest whole truck load.*

2.3 Digester Sizing Evaluation

The study evaluates conventional anaerobic digestion at mesophilic conditions. Mesophilic design parameters are generally established to produce a Class B biosolids product by achieving a minimum temperature of 95 degrees Fahrenheit (°F) and minimum detention time of 15 days. The primary compliance point for this analysis is thus maintaining an HRT of 15 days and a maximum organic loading rate (OLR) of 0.18 pounds VS per cubic foot per day (lb-VS/ft^3-d is used to maintain stable digestion.

Given the process baseline flows and loads and imported feedstock projections described above, the required capacity of the digestion process was evaluated. The operating limits of the digestion system were based on the following flow and loading condition:

- **Annual average with the largest unit out of service.** This represents operation under a planned service outage for digester cleaning, equipment service, etc. Standard Brown and Caldwell (BC) design requires availability of a backup digester to process the solids load while the duty digester is out of service. This is considered especially critical with an imported organics co-digestion program to ensure the WWTP can receive the outside organics during digester shutdowns.

Note that using this loading criteria does not protect the digestion system against a catastrophic failure such as a toxic contaminant load leading to process upset. In such an event, the plant would need to haul excess solids to alternative disposal points until the process can be stabilized and/or recovered. It has been BC's experience that this level of process protection/redundancy is well accepted within the industry.

The resulting digester sizing requirements are provided below in Table 2-6.

Table 2-6. Digester Process Volume Requirements

	Without Imported Feedstocks	+ Imported Wastewater Solids	+ HSOW	+ Imported Wastewater Solids + HSOW
Number of Digesters	4	4	4	4
Size (Volume), MG	1.4	1.5	1.6	1.8
HRT (annual average), d	21.9	21.1	20.5	20.7
Diameter, ft	58	61	62	65

2.4 Liquid Stream Impacts

Table 2-7 presents a cursory order-of-magnitude analysis using a pseudo-calibrated process model to evaluate the potential impacts of each alternative on plant operations. The BioWin process model was calibrated to plant historical effluent and solids production data presented in the base case mass balance data. Preliminary modeling of the existing operations scenario shows the existing facility reduces total nitrogen (TN) discharges to roughly 5 mg N/L which matches historical data from the June 2008 to May 2009 sampling event. Modeling also suggests the plant is achieving enhanced biological phosphorus removal (EBPR) with total phosphorus (TP) discharges less than 1 mg P/L.

Addition of mesophilic anaerobic digestion increases the nitrogen recycle loading to the headworks through the release of ammonia in the digestion process, increasing the primary effluent nitrogen concentration by roughly 4 mg/L. The increased nitrogen recycle loading will increase the effluent nitrogen, except for ammonia discharges. Effluent TP discharges also increase with mesophilic anaerobic digestion. Note that this analysis is relative in nature and should not be used to define exact values. Whether operational changes will improve effluent will depend upon available carbon and other operational parameters. A detailed BioWin wastewater characterization, calibration and analysis is needed to predict this/effluent quality.

Review of the predicted aeration basin mixed liquor suspended solids (MLSS) and oxygen transfer rate show adding digestion has minimal impact on the aeration basin operating parameters. Adding mesophilic anaerobic digestion may also require adding alkalinity to the liquid stream process as preliminary modeling shows effluent alkalinity decreases below 70 mg $CaCO_3$/L, which if sustained, can be corrosive to tankage and equipment.

A key concern with adding mesophilic anaerobic digestion is struvite formation in the digesters and associated impacts on dewatered cake solids. Modeling and industry practice shows significant struvite formation occurs in anaerobic digesters with liquid stream EBPR facilities. Adding EBPR to mesophilic anaerobic digestion facilities has also been shown to further decrease centrifuge dewatered cake solids by 2 to 4 percentage points.

To mitigate struvite formation, two common methods are to add ferric chloride to the anaerobic digesters to reduce digester phosphate concentrations to roughly 75 mg P/L (estimated dose of 1,500 gpd of 40% $FeCl_3$ solution) or to prevent EBPR in the liquid stream process by increasing the internal mixed liquor recycle to maintain anoxic conditions in the unaerated zone.

Adding HSOW and/or imported wastewater solids from another facility at the loadings assumed in this study in concert with mesophilic anaerobic digestion has minimal additional impact on the liquid stream operations as shown in Table 2-7.

It is recommended a detailed evaluation be conducted using a BioWin process model calibrated to 3 to 6 months of plant operating data to confirm, refine the preliminary findings presented, and confirm the most economical method to mitigate struvite formation.

Table 2-7. Digestion Scenarios Liquid Stream Impacts

		Status Quo	Without Imported Feedstocks	+ Imported Wastewater Solids	+ HSOW	+ Imported Wastewater Solids + HSOW
Plant influent						
Flow	mgd	36				
cBOD5	mg/L	255				
TSS	mg/L	195				
TKN	mg N/L	23				
Ammonia	mg N/L	12				
Total phosphorus	mgP/L	5				
Primary effluent						
Flow	mgd	36.1	36.1	36.1	36.1	36.1
TKN	mg N/L	20	24	24	24	24
Ammonia	mg N/L	12	16	16	17	16
Total Phosphorus	mgP/L	4.1	7.2	7.2	7.5	7.4
Aeration Basins						
MLSS	mg/L	2,450	2,500	2,530	2,510	2,520
Oxygen transfer rate	lb/hr	3,010	3,115	3,110	3,140	3,130
Final Effluent						
Ammonia	mg N/L	0.2	0.1	0.2	0.1	0.1
Nitrate and Nitrite	mg N/L	3	5	5	6	6
TN	mg N/L	5	7	7	7	7
Alkalinity	mg CaCO3/L	80	69	70	68	69
Total phosphorus	mgP/L	0.3	2.0	1.9	2.2	2.2

2.5 Dewatering Sizing Evaluation

This feasibility study also evaluated the current dewatering process at Springfield Regional WWTF. The current dewatering process includes two Centrisys 21HC dewatering centrifuge units. Each unit has a maximum solids loading capacity of 2,250 pounds per hour (lb/hr), for a combined capacity of 4,500 lb/hr and a maximum hydraulic capacity of 225 gallons per minute (gpm) per unit, with a combined hydraulic capacity of 450 gpm. The Commission has had positive operational experience with this equipment. To evaluate the dewatering process, peak day flow and load conditions are used to define the operating limits of the system, including the solids and hydraulic capacities. Solids capture rate was assumed at 92 percent. Results of this evaluation indicate the current centrifuge units would meet the annual average solids and hydraulic demand with the addition of imported wastewater solids and HSOW. Use of on-site storage would be required to meet peak day solids and hydraulic demand.

Table 2-8. Dewatering Process Requirements

	Without Imported Feedstocks	+ Imported Wastewater Solids	+ HSOW	+ Imported Wastewater Solids + HSOW
Number of duty dewatering centrifuges	2	2	2	2
Peak day solids loading, lb/hr	3,585	5,313	4,015	5,743
Annual average solids loading, lb/hr	1,701	2,521	1,905	2,725
Peak hydraulic loading, gpm	288	325	348	385
Annual average hydraulic loading, gpm	137	155	165	183

2.6 Energy Recovery System Sizing Evaluation

Given the different flow and loading conditions to anaerobic digestion, digester process performance and biogas production is estimated using BC design criteria and past project experience. To estimate the CHP energy recovery system sizing, the estimated total available biogas energy is converted to an electrical power output for each scenario using an electrical efficiency of 36 to 39 percent, depending on the size of the prime mover (larger units typically have higher electrical efficiencies) based on vendor-provided published performance information. This feasibility study evaluates internal combustion (IC) engines as the prime mover of the CHP systems, as described in later sections. Given the estimated CHP output, engine sizes were selected with the following considerations in mind:

- Engines would be partially loaded at average conditions to provide capacity for high-production conditions.
- Engines would be co-fired with natural gas if additional heat output is required for anaerobic digester heating.
- Multiple suppliers are available to provide selected engine size to allow for competitive bidding.
- For larger systems, multiple installations of a single engine model will be selected for maintenance efficiency.

Table 2-9. Digester Process Volume Requirements

	Without Imported Feedstocks	+ Imported Wastewater Solids	+ HSOW	+ Imported Wastewater Solids + HSOW
Number of engines	1	2	2	3
Proposed engine size, kW [a]	1,548	1,100	1,100	1,100
Estimated engine fuel consumption at annual average load, scfm	330	470	470	600
Estimated load at annual average biogas production, %	83	82	82	79

Table 2-9. Digester Process Volume Requirements

	Without Imported Feedstocks	+ Imported Wastewater Solids	+ HSOW	+ Imported Wastewater Solids + HSOW
Estimated engine output at annual average production, kW	1,280	1,800	1,790	2,380

a. *Engine sizing represents first-cut estimate. Further refinements may be required given biogas management system design (e.g., biogas storage, waste gas burner orientation).*

Section 3

Review of Relevant Technologies and Industry Practices

This section provides an overview of the solids and biogas technologies considered for bioenergy generation at the Springfield Regional WWTF. The technologies and their general orientation with regard to existing equipment are depicted below in Figure 3-1.

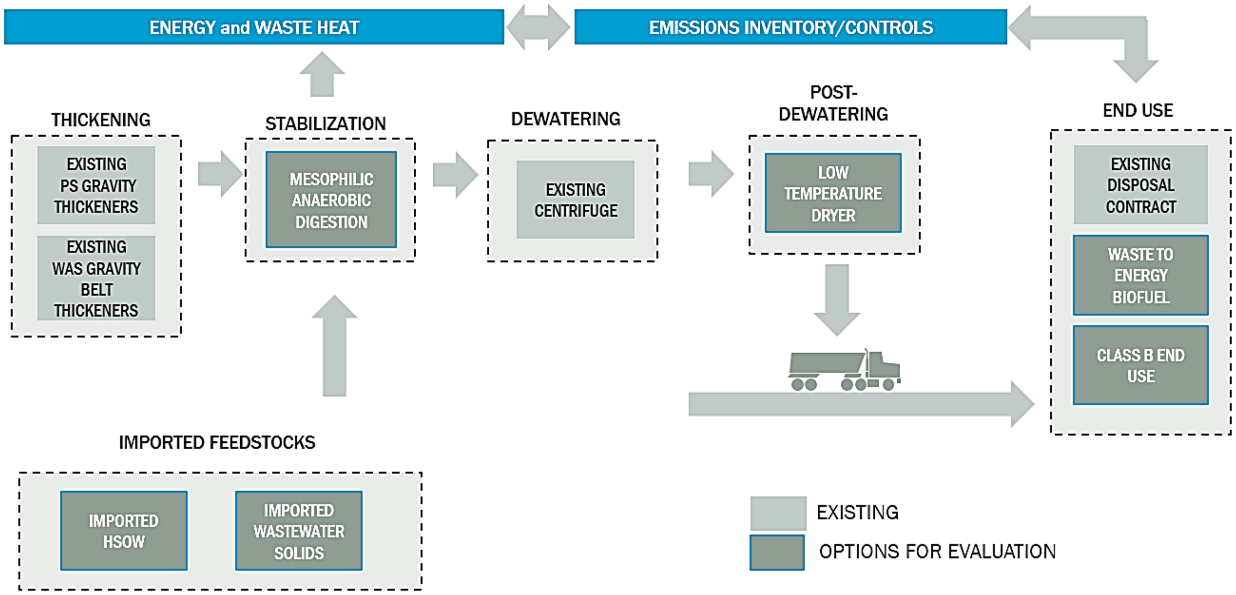


Figure 3-1. Springfield Regional WWTF bioenergy technology options

The technologies and associated data discussed in this section are presented as representative technologies providing adequate service for a given unit process based on prior BC experience. If the project is advanced, it is recommended that a detailed analysis of technology selection be performed with the next step. Operational and process efficiency improvements may be available with installation of different types of equipment.

3.1 Imported HSOW Receiving

Two of the main considerations for implementing a HSOW receiving program are managing grit and debris from the feedstock and on-site storage. HSOW often contains high levels of rags and debris that need to be removed to protect downstream processing. Storage is required to prevent slug-loading digesters with the high strength material, which can cause process upset. Figure 3-2 depicts examples of HSOW receiving station designs.

Trucked waste offloading at Iona Island WWTP

FOG Receiving Screen pilot at HRSD wastewater plant

Gresham, OR FOG receiving station

Figure 3-2. Example HSOW receiving station designs at municipal WWTFs

One strategy for grit and debris management is to use a packaged offloading and screening system. The Enviro-Care™ BEAST is an example of the technology that integrates the truck offloading connection, hauler control station, and automated screen into one packaged system. The hauler station contains an electrically actuated inlet valve, magnetic flow meter, hauler access panel, and software to operate and track the system's operation. Figure 3-3 depicts a representative BEAST receiving station installation.

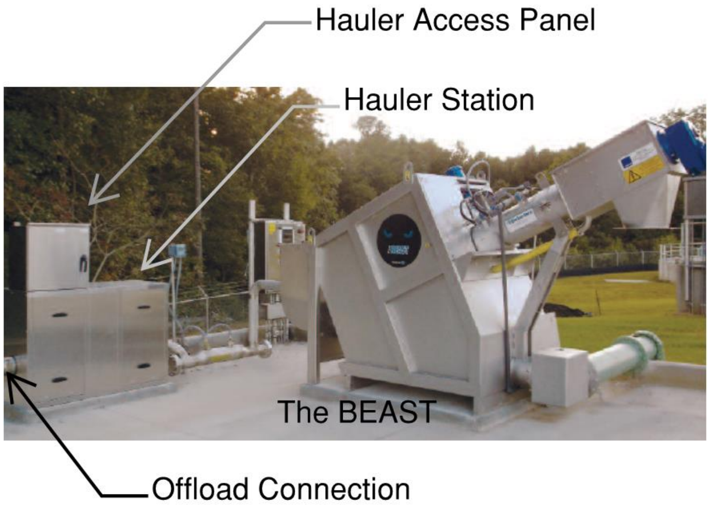


Figure 3-3. Enviro-Care™ BEAST Receiving Station

Courtesy of Enviro-Care™

BC assumed two comparable screening systems would be used to receive the HSOW and that storage would be provided by dedicating one of the four holding tanks to a HSOW storage tank.

3.2 Imported Wastewater Solids Receiving

As mentioned in Section 2, there are two programmatic options for implementing wastewater solids receiving and co-digestion systems. The first is to work with the regional plants and haulers to abandon their dewatering operation and establish liquid sludge only receiving agreements. This creates added complexity with additional stakeholder coordination, but results in a relatively simple receiving operation at the plant. Generally, all that is required are quick connects and offload pumps to transfer the sludge to the digester feed and blend tanks.

Conversely, receiving and processing cake on site allows the regional plants and haulers to continue with their status quo operation and simplifies the hauling agreement arrangement. Without having guarantees from regional plants to ensure the plants would cease dewatering and would haul liquid sludge, this study included a cake receiving system sized to adequately handle the wastewater cake flows and loads projected in Section 2. Examples of commercially available trucked cake receiving stations are shown below in Figure 3-4 for reference.

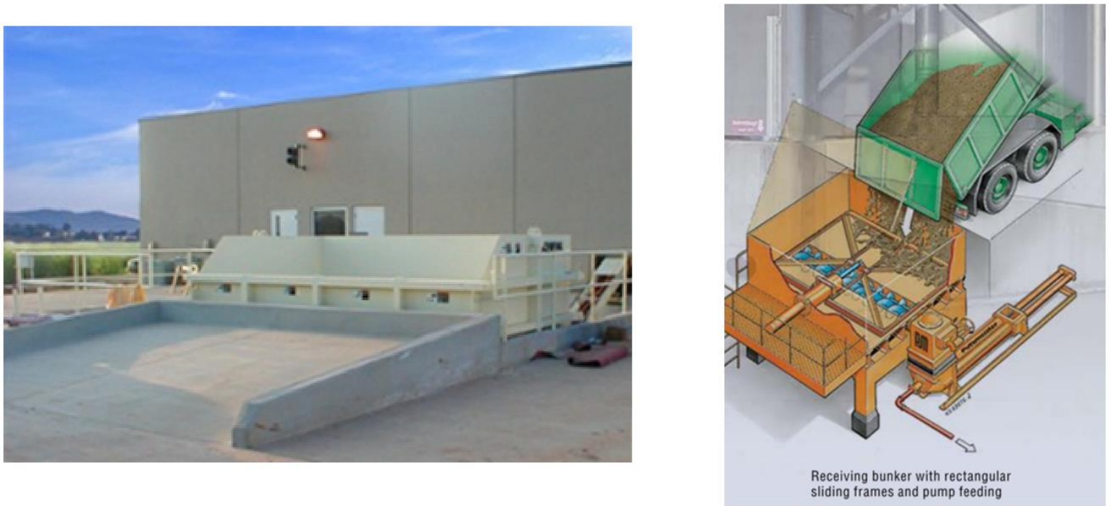


Figure 3-4. Trucked cake receiving stations

Courtesy of Schwing Bioset and Putzmeister

Regional facilities, such as The Metropolitan District Commission's plant in Hartford, Connecticut currently take imported wastewater cake and dilute it down for addition back to the solids thickening train to equalize loading to a regionalized incinerator. However, there are no facilities within the region that receive dewatered cake and slurry it for feed into an anaerobic digester. In the industry, thermal hydrolysis process (THP) and thermochemical hydrolysis process (TCHP) systems are growing in popularity as a means to break down dewatered cake, changing its consistency into a pourable liquid that can be fed directly to digestion. However, preliminary correspondence with Commission staff indicate that the steam requirements and additional operational complexity associated with THP and TCHP technologies are too great to warrant consideration at this level of evaluation. Thus, a conceptual mechanical cake blending/slurrying system design was developed by BC and a regional solids handling and blending technology vendor to serve as an alternate solution. The intent of the mechanical system is to dilute and blend the cake so that it forms a flowable mixture can be homogenized with the native sludge, rather than settling out portions of the imported solids. BC is not aware of current applications of this system for cake slurrying prior to digestion and recommends that if it is carried forward in the project, thorough testing plans be developed and carried out to validate its use.

3.3 Mesophilic Anaerobic Digestion

This feasibility study considered conventional mesophilic anaerobic digestion as the primary sludge stabilization and bioenergy generation technology. Mesophilic anaerobic digestion employs operating temperatures between 95 and 102°F and digests solids under anaerobic conditions. This stabilization process has the longest operational history of all the digestion technologies, with the most supporting operational data to date. It represents the standard digestion technology configuration and has the advantages of being non-proprietary and having a proven track record.

Figure 3-5. Conventional mesophilic digester at the City of San Diego, California

The performance of anaerobic digesters is improved by providing uniform and well-mixed conditions within the digester. The digester contents are mixed by gas recirculation, pumping, or draft-tube mixers. Continuous feeding to the digesters is preferred, or at a minimum on a 30-min to 2-hr time cycle to help maintain constant conditions in the digester. Digesters may have a fixed, floating, or gas membrane cover. Floating and membrane covers can provide excess gas storage, while for a fixed cover, the biogas may be collected and stored in a separate gasholder. Digesters may also be configured in an egg-shape to reduce dead zones in the reactor as well as liquid surface area and corresponding scum buildup. The egg-shaped digesters at the Massachusetts Water Resources Authority's Deer Island Treatment Plant are shown below in Figure 3-6.

Figure 3-6. Egg-shaped digesters at the Deer Island Treatment Plant, Boston, MA

Typically, as described in Section 2, mesophilic anaerobic digestion systems are operated at a minimum HRT of 15 days which, when requirements for vector attraction reduction (VAR) are met, guarantees Class B pathogen status, allowing for beneficial reuse in land application. Pathogen classes (A and B) and VAR designations are defined in 40 CFR Part 503 and determine the type of land onto which different types of biosolids may be applied. Class B biosolids have less stringent pathogen destruction demonstration requirements than Class A, but greater restrictions for land applications.

3.4 Thermal Belt Drying

As discussed in Section 1, this study considered addition of a drying process following dewatering of the digested solids. A low temperature belt dryer was selected as the representative drying technology, primarily due to the ability to operate at low enough temperatures (approximately 200 degrees Fahrenheit) to make use of the available heat from a CHP system. The other main wastewater solids drying technologies, paddle and rotary drum dryers, operate at approximately 500 and 1,000 degrees Fahrenheit, respectively. Typically, waste heat from a CHP system is used to provide process heating to the anaerobic digesters, but during summer months the CHP systems can generate significantly more usable heat than is required to heat the digesters. In this scenario, the excess heat could be supplied to supplement the heat generated for drying, offsetting the natural gas costs incurred from generating the dryer heat.

Belt dryer installations are common in both the United States and Europe. They can be either direct or indirect. Heat is typically supplied by a fuel-burning furnace or boiler that serves to heat a thermal fluid, water, or flue gas. Dewatered solids are distributed via conveyor or nozzles or perforated extruder plates onto a slow-moving, typically porous, belt, providing a large surface area exposed to the hot gases. The slow-moving belt provides contact time and minimizes dust and fines in the dryer cabinet. It is often preferred to blend incoming biosolids with previously dried biosolids to reduce the moisture content and to create a more uniform product.

Overall, belt dryers typically achieve 1,400 to 1,700 British thermal units (BTUs) per pound of water evaporated. The footprint required for belt dryers is relatively large and operating complexity is moderate. Additionally, the end product is dependent upon the belt dryer manufacturer. Spaghettilike strings or pellet product may be created, and additional processing may be necessary to create smaller, harder particles if compatibility with other fertilizer products is desired. A cutaway of a typical belt dryer with an exhaust treatment system is shown in below Figure 3-7.

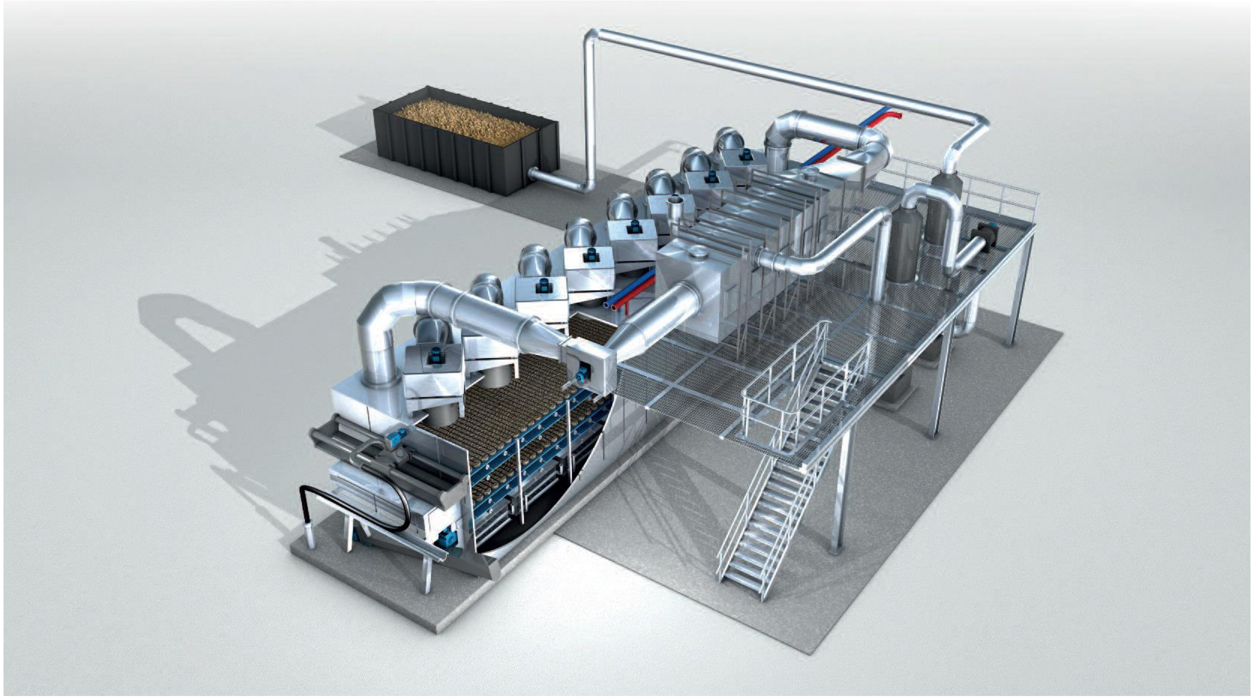


Figure 3-7. HUBER two-belt dryer and exhaust condensation, scrubber, and biofilter unit

Courtesy of HUBER

3.5 CHP Energy Recovery System

The anaerobic digestion process produces biogas, a renewable source of energy. Biogas contains an appreciable heating value (400 to 600 Btu per standard cubic foot [Btu/scf]) compared to natural gas (1,000 Btu/scf) and, with appropriate treatment and/or conditioning, can be used in several energy applications in the place of natural gas.

One demonstrated method for energy recovery from biogas is the use of CHP systems to generate on-site electrical power and useful thermal energy, such as steam or hot water, as depicted in Figure 3-8. This allows for overall system efficiencies of over 80 percent; improving upon the 50 percent system fuel efficiency commonly observed in conventional technologies such as grid-supplied electricity and on-site boilers operated separately.

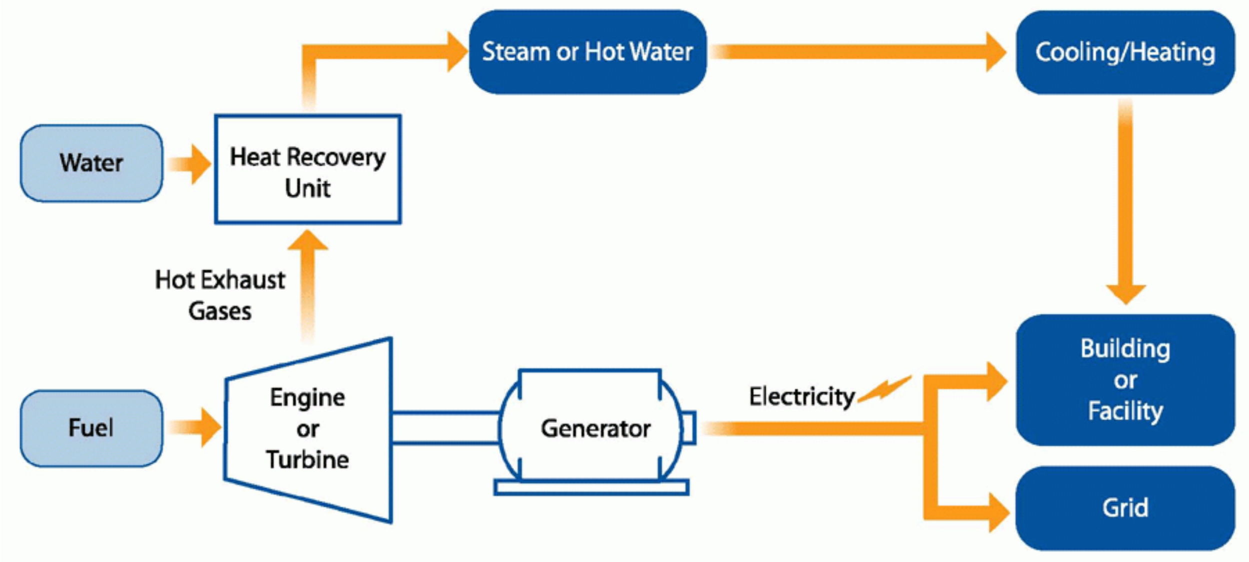


Figure 3-8. Combustion turbine or reciprocating engine CHP system

Source: epa.gov

The thermal energy from a biogas-fueled CHP system is often used to provide digester process heating in addition to building or facility heating. However, dual fuel (biogas/natural gas) boilers are typically included in the digester system design as a back-up to these heat sources.

Beneficial biogas use applications and their corresponding efficiency are determined based on the quality of biogas used. One of the main constituents of biogas requiring evaluation and potential removal is hydrogen sulfide (H_2S) due to its potential for odors, corrosives, and sulfur emissions from combustion. H_2S production is directly correlated to organic and inorganic sulfate content in the digester feed. H_2S removal technologies are well established and include wet processes (e.g., iron sponge). Liquid ferric chemical injection into the digester feed can also be used to precipitate, dissolve or keep the H_2S in solution form. Other biogas components that may require evaluation and removal include carbon dioxide, water vapor, mercaptans, siloxanes, and other trace organics and particulates to increase its energy value. Other equipment that requires incorporation into a biogas management system design include safety, storage, compression, and transmission components.

IC engines are the most widely used prime movers for CHP systems at facilities of a comparable size to the Springfield Regional WWTF. The IC engine prime mover technology is discussed in the following subsection.

3.5.1 IC Engines

Biogas-fired IC engines for electric generation can be supplied at a range of output horsepower/ speeds and are widely used at WWTFs for their competitive fuel economy, durability, reliability, compact foot print, and lower capital investment. Three of the main manufacturers of biogas-driven IC engines include GE Power (Jenbacher), Caterpillar, and Cummins. An example facility with Cummins IC engines is shown in Figure 3-9.

Figure 3-9. CHP facility with (4) 1.1-megawatt IC engines and post-combustion treatment

H_2S and siloxane content within the biogas fuel source must be considered with regards to engine emissions and useful life span. Siloxane removal technologies may be required to prevent fouling of the fuel systems, combustion chambers, and post-combustion controls.

Biogas-fired IC engine emissions are regulated by state and federal air emission standards for criteria pollutants (nitrogen oxides, carbon monoxides, volatile organic carbon, and sulfur oxides) and air toxics or hazardous air pollutants (e.g., formaldehyde, acetaldehyde, acrolein, and methanol). Should an IC engine option emerge from an alternatives analysis, further regulatory analysis would be performed accordingly.

Heat, typically in the form of 190-degree Fahrenheit hot water, is recovered from the engine jacket and an exhaust heat recovery unit. This heat can be used to for digester or building heating systems. When the quantity of recovered heat exceeds the heat demand, radiators are used to reject the excess heat.

Section 4

Conceptual Design of Alternatives

This section provides an overview of conceptual design elements used to develop the feasibility study alternatives. The technologies considered, and their general orientation with regard to existing infrastructure, are depicted below in Figure 4-1.

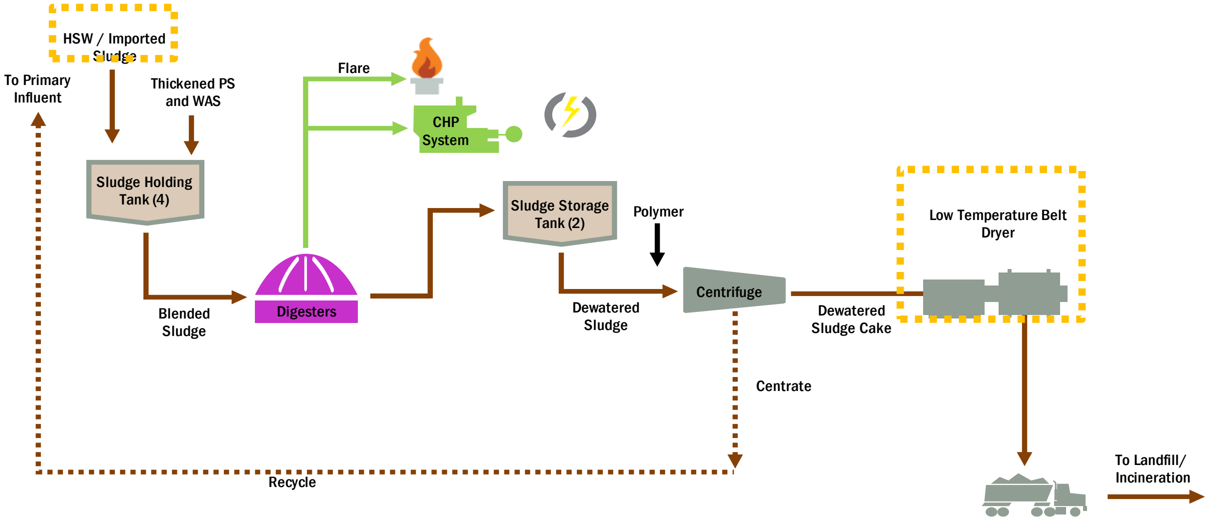


Figure 4-1. Springfield Regional WWTF bioenergy process flow diagram

As shown in the figure, the existing holding and storage tanks are re-purposed as the digester feed and blend tanks and digested sludge storage tanks, respectively. The new technologies included in the alternatives include HSOW and imported wastewater solids receiving, anaerobic digestion, CHP biogas energy recovery, and cake solids drying.

4.1 Site Layout

Concurrent with evaluating the technical viability of bioenergy generation at the Springfield Regional WWTF, a conceptual design was developed to determine if the WWTF site could accommodate the infrastructure and identify potential logistics surrounding facility construction. Using a combination of Commission input, BC experience, and process analysis results, a conceptual facility layout was developed and is illustrated below in Figure 4-2. Facilities shown in red represent new facilities or infrastructure.

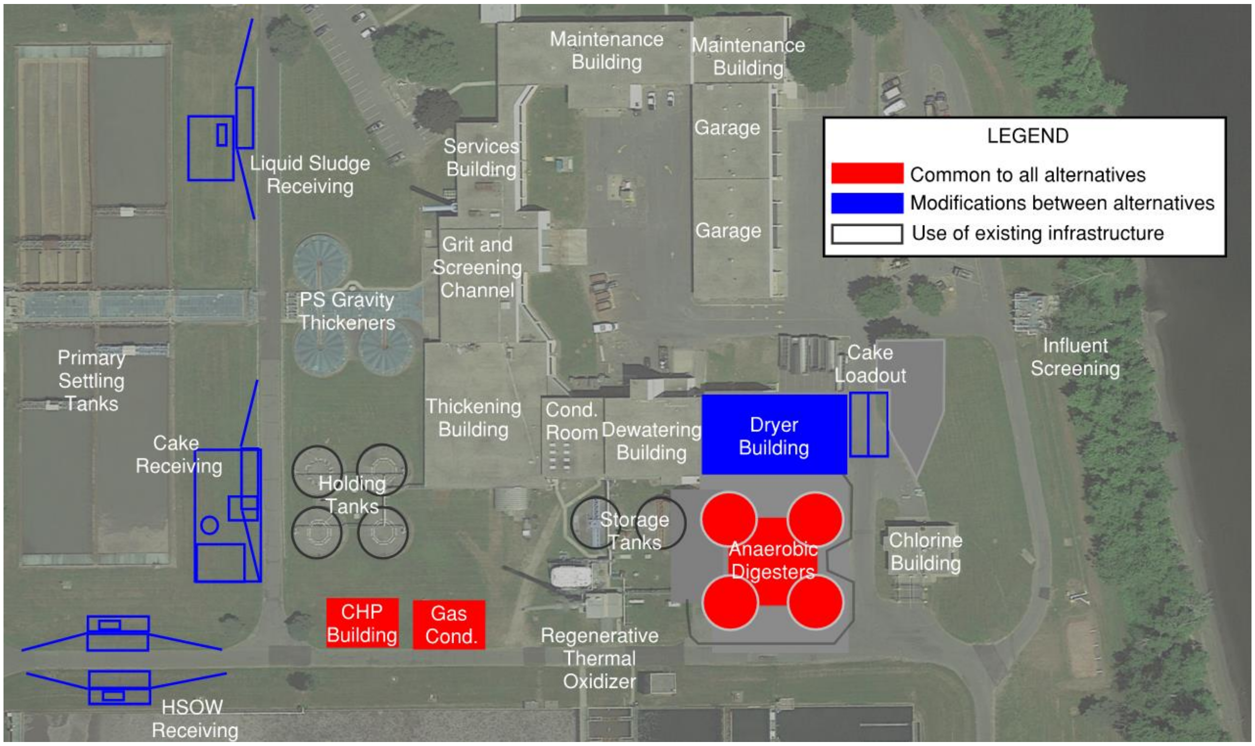


Figure 4-2. Conceptual site layout of new facilities for bioenergy generation

4.1.1 Imported Feedstock Receiving

The imported feedstock receiving stations are shown along a single corridor on the western side of the plant. There appears to be enough space to locate new truck receiving stations alongside the existing road such that the offloading trucks can position themselves for offloading by pulling straight through without having to back up or perform complex maneuvering.

The imported feedstock receiving equipment is located at grade adjacent to the truck offloading pads. As discussed in Section 3, the imported liquid sludge receiving facility is the least complex and is composed of truck offloading pumps, day tanks, and transfer pumps. The imported cake and HSOW receiving facilities each include additional process equipment to slurry and screen the imported materials, respectively. All receiving facilities transfer the received material to the digester feed and blend (holding) tanks upstream of anaerobic digestion. The imported feedstock receiving stations are shown as separate facilities but depending on project phasing or the scope of the imported feedstocks programs, single stations could be configured to receive multiple feedstocks.

4.1.2 Anaerobic Digestion

The anaerobic digesters and digester control building are shown in the footprint of the abandoned composting facility. Locating the digesters in this area requires that all the infrastructure associated with the composting facility be demolished. The available footprint is set by establishing 10 feet of clearance from existing buildings and roadways given biogas area classification requirements. This clearance is established to maintain the current National Fire Protection Association (NFPA) area classification ratings for existing equipment nearby.

The area available for anaerobic digestion does impact some of the process design elements and facility configuration. Given the footprint limitations, the digesters shown are configured as silo-shaped tanks to provide the adequate capacity for processing solids under the flows and loads from the various scenarios of the study. The silo-shaped tank is designed with an aspect ratio of 1 to 1, compared to a conventional short-cylinder or “pancake” shaped tank that generally has an aspect ratio of 2 to 1 or greater. The silo-shaped digester has a smaller footprint per unit volume, allowing for installation of higher capacity digestion facilities in a limited footprint, but requires a more robust structural design and has a higher cost compared to the pancake-shaped digester. The increased hydrostatic pressure requires thicker walls compared to other tank options, Also, the small footprint requires a more substantial foundation. Example silo-style and pancake-style digestion facilities are pictured below in Figures 4-3 and 4-4, respectively.

Figure 4-3. Silo-style digesters (taller) and sludge storage tank (shorter) under construction at the Brightwater WWTP, Woodinville, Washington

Figure 4-4. Short-cylinder (a.k.a. pancake) style digester at the Chambers Creek WWTP, University Place, Washington

To site the larger capacity digester facilities required for processing HSOW **and** imported wastewater solids, the digester control building footprint would likely need to be further reduced, requiring installation of some of the digester process heating equipment in the existing building space. If the project is advanced, further evaluation should be conducted to determine if space in the existing thickening, dewatering, or drying buildings is adequate to locate anaerobic digestion ancillary equipment and reduce the size of a new digester control building.

4.1.3 Thermal Belt Dryer

The dryer building shown on Figure 4-2 is set over the footprint of the existing abandoned paddle dryer building. A new cake or dried product loadout is located on the east side of the building with a drive-through configuration. As shown on the figure, belt drying technology requires a significantly larger footprint than that of a paddle dryer given the operating principle of the slow-moving belt. A preliminary dryer model selection from HUBER shows that at the operating temperature of 200 degrees Fahrenheit, two model BT18 units (each 17.3 feet wide by 73.7 feet long) are required. Additional equipment included with the dryer system includes cake storage and pumping, a process heating boiler, process air fans, exhaust fans and exhaust treatment equipment (chemical scrubber, condensation units, and often a biofilter), and dried product conveyance and storage. An example drawing of a BT18 unit configured with typical ancillary facilities and equipment is shown below in Figure 4-5.

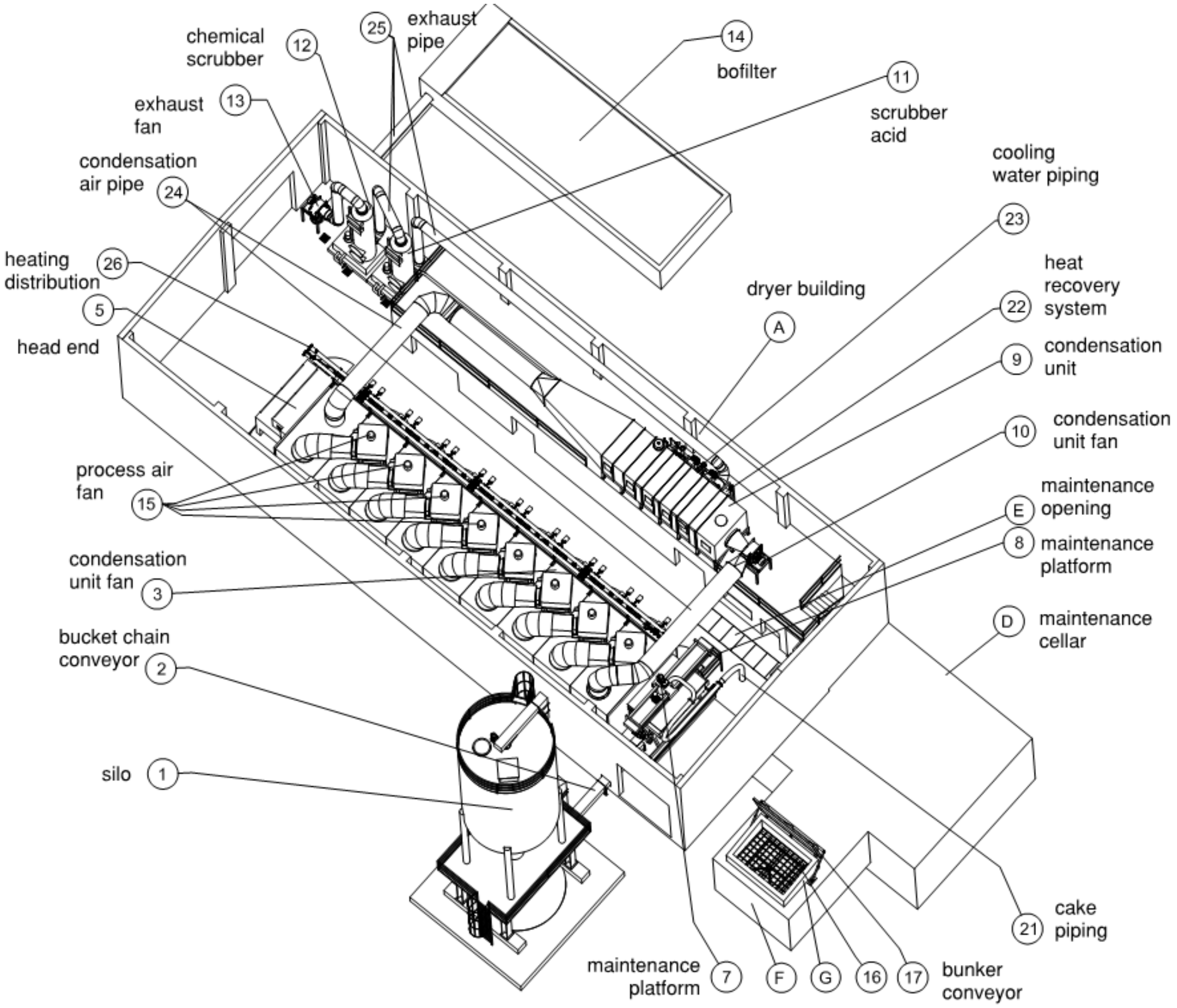


Figure 4-5. Example HUBER BT18 dryer facility

Though operation of the dryer at 200°F provides opportunities for annual cost recovery with seasonal CHP heat use, the dryer can also be operated at 285°F. Operation at the higher temperature of 285°F is more efficient, and allows for installation of a single, larger dryer unit. This results in lower capital outlay given the reduction in equipment cost and building construction, but does not allow the use of CHP heat and necessitates boiler certification to operate a pressurized hot water boiler. If the dryer is advanced forward in the project, BC recommends performing a detailed business case evaluation to evaluate the optimal value from operating the digester at the two temperature setpoints, as well as dried product target percent solids and potential to fuel the dryer boiler with biogas. In addition, BC recommends the available capacity of the regenerative thermal oxidizer (RTO) be evaluated to determine if dryer exhaust can be managed in the RTO.

4.2 Biogas Conditioning and CHP Building

Two separate footprints are established for the biogas conditioning skid and CHP building in the site layout on Figure 4-2. A conventional biogas conditioning treatment train is assumed for this study. The gas conditioning system components included in this study are presented in the process flow schematic in Figure 4-6 and briefly discussed below.

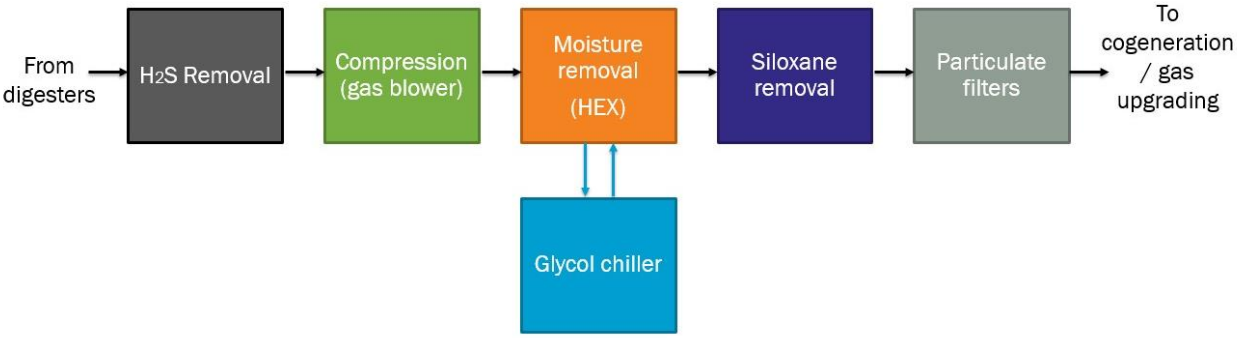


Figure 4-6. Process flow schematic for biogas conditioning system

Figure 4-7 shows an example gas conditioning system at the Columbia Boulevard WWTP in Portland, Oregon, where two 850 kilowatt (kW) IC engine-generators are installed.

Figure 4-7. Digester gas treatment system, Columbia Boulevard WWTP

Source: Jim Brown, Cliff Meier, "Anaerobic DG CHPeration Technology," PNCWA 2009.

4.2.1 Biogas Conditioning Unit Processes

The specific biogas conditioning unit process areas are described in greater detail below. Gas conditioning equipment is located next to the new CHP building with a portion of the gas conditioning system located outdoors and a portion located in a new, separate gas conditioning building.

4.2.1.1 H_2S Removal

H_2S and other sulfides are typically removed from warm, moist biogas using packed-bed vessels to prevent corrosion and reduce sulfur oxide emissions from combustion sources. The packing can be iron sponges, which consist of iron-oxide-impregnated wood chips or a specialized granular iron-impregnated media such as SulfaTreat. Iron sponges typically have the lowest life-cycle costs but are more difficult to remove from the vessels than a specialized media as the media tends to “cement” together over time. At least two vessels are typically installed to allow operation during media replacement or regeneration. A service ladder and platform assist in filling and removing the media.

Other H_2S removal technologies exist for installations with high H_2S in the biogas and higher biogas flows, including aerobic biotrickling filters and ferric chloride dosing at the digesters.

4.2.1.2 Compression and Moisture Removal

The biogas must be boosted in pressure to overcome the pressure losses of the gas treatment system and generally supply enough pressure for the gas’ end use. The biogas pressure is boosted by a blower or compressor, which also adds heat to the biogas.

Moisture is removed from the biogas to help prevent engine damage from condensing water droplets. Following compression, water is removed by cooling the biogas to around 35°F in a heat exchanger, forcing moisture to condense. Once the gas dew point is lowered, the cold gas is reheated to around 80°F using the incoming hot blower discharge flow. This reheating improves the effectiveness of the downstream siloxane removal media and reduces the relative humidity of the biogas.

4.2.1.3 Siloxane Removal

Siloxanes are a class of volatile compounds that cause increased operations and maintenance (O&M) costs on most downstream gas usage technologies. For example, when biogas and siloxanes are combusted in an IC engine, the siloxanes oxidize to form silica particles that are deposited on engine components and can damage the engines. After compression and moisture removal, the warm dry gas passes through an activated carbon filter to remove siloxanes before being sent to the CHP system. Typically, two or more vessels are included in a lead-lag configuration to allow operation during media replacement.

4.2.2 CHP Building

The CHP facility is shown constructed in a new designated building next to the gas conditioning system. The CHP building contains heat recovery systems to beneficially use the heat that is created by the engines’ jacket water and hot engine exhaust. The CHP hot water heat loops are constant flow heated water systems regulated by various three-way control valves and controls systems and the radiator systems are designed to handle each engine’s full load jacket water and exhaust heat cooling requirements.

Cogeneration redundancy is not required for the plant to continue its process-related activities for treating wastewater. However, installing multiple smaller engines in lieu of one larger engine allows for some cogeneration redundancy in that major rebuilds and other scheduled maintenance activities can be performed on one engine at a time. This allows for the other engine to continue producing power for the plant and heat for the digesters, helping to reduce the plant’s power and natural gas (heating) costs compared to having only one engine. While one or both engines are down, a boiler provides backup heating as necessary to maintain crucial digester process temperatures. The plant electrical feed maintains the power to all the plant motor control centers and switchgear, allowing motors and other electrical devices to continue operating uninterrupted.

Section 5

Basis of Evaluation

BC created a custom model to combine mass and energy balances to evaluate both technical performance and operational costs for the new systems under consideration. When combined with the capital investment required for each alternative, the model produces a net present value (NPV) lifecycle cost of each alternative that, when compared to the baseline process condition, determines its financial viability. For this study, it was assumed that the planning horizon for the project would be 20 years.

5.1 Model Cost Inputs

To extrapolate potential changes in operating costs under the bioenergy alternatives, historical cost factors were used to project estimates for future conditions. Operational costs are based on actual costs incurred by the Commission for fiscal year 2017; parameters evaluated included commodity prices as well as estimated labor rates. Information was requested and received from operations staff for both commodity unit costs and the quantities used, which were not independently verified. Table 5-1 summarizes the various operational cost metrics used in this analysis.

Table 5-1. Assumptions for Lifecycle Cost Analysis

Cost Element	Value in Model	Basis
Biosolids Hauling and Disposition		
Unclassified solids hauling and disposal (to landfill or incinerator), $/wt	$105	Assumes $5/dt annual increase from existing Casella contract (averaged; increase from recent contract bids)
Class B Biosolids hauling and disposition, $/wt	$80	Assumes $5/dt annual increase from 2016 NEBRA market study (averaged)
Dried product hauling and disposition, $/wt	$45	Assumes half of dried product disposed of as non-waste fuel source at $10/wt
Commodity Prices		
Cost of electricity, average usage and demand (per kW-hour)	$0.1395	Historic data from Contract Year 2018 (July 17 - June 18)
Natural gas unit cost, average (per million Btu)	$10.67	Historic data from Contract Year 2018 (July 17 - June 18)
Dewatering polymer use, current centrifuge (lb per ton of dry solids)	16	Based on historical average use reported by Commission staff
Polymer cost, average (per lb of polymer)	$1.95	Based on historical average reported by Commission staff
Operations and Maintenance		
General equipment maintenance (percent of equipment cost)	2%	Assumed
O&M Labor Rate, average ($/hr)	$54	Assumed (incl. benefits/admin)
Tipping Fees and Revenue		
HSOW tipping fees, $/gal	$0.06	
Imported liquid sludge tipping fee, $/gal	$0.06	
Imported wastewater cake tipping fee, $/wt	$65	

While commodity and labor rates can be extrapolated using historical cost data, soft costs assumptions such as biosolids hauling and disposal costs, tipping fees, and revenue values are developed from recent market studies and regional trends. The soft cost values represent "middle-of-the-road" assumptions and may vary in the future given changes in the market. Sensitivity analyses on the impact of these soft cost parameters are discussed in the following sections.

With respect to the impact of flows and loads on lifecycle costs, the model was structured as follows:

- O&M costs were based on plant loadings.
- Where alternatives require new equipment, they are sized (and estimated) for design growth projections.
- Rough estimates of project cost are included where new equipment and/or facilities are required. These are purely budgetary numbers that should be vetted as part of a more in-depth condition assessment and review of repair or improvement needs of current facilities.
- NPV is calculated over 20 years with a 2 percent escalation rate and a 2.5 percent discount rate (net 0.5 percent). These numbers were taken from the 2017 Office of Management and Budget (Circular No. A-94).

The general NPV assumptions are shown below in Table 5-2.

Table 5-2. NPV Assumptions

Component	NPV Assumption
NPV term, years	20
Nominal discount rate, annual percentage	2.5%
Inflation rate, annual percentage	2.0%
Real discount rate, annual percentage	0.5%

5.2 Methodology

The process baseline model was used to calibrate the base inputs and model performance. After the baseline was developed, alternatives were created to model the key operational parameters such as digester process efficiency, biogas production, digested biosolids flow to dewatering, energy recovery from CHP, and process heating demands. These outputs were used with Commission-specific operational costs to generate the lifecycle operational costs. Project capital costs were developed and added to the lifecycle operational costs to determine the NPV of each alternative in 2018 dollars. Development of specific operational parameters is described in more detail below:

- Gas benefit was calculated assuming the CHP facility is sized to accommodate all biogas production. The biogas production rate for each alternative was converted into one million Btu using an assumed 560 Btu/scf. Heat recovery from the future CHP system was assumed to preferentially supply process heat to digestion, with excess heat provided to the dryer where appropriate.
- Labor was adjusted for each alternative to represent the complexity of the process and the amount of equipment needed.
- The maintenance cost for each alternative was based on a ratio of equipment capital cost to account for the increased maintenance activities from new equipment.

- Disposition costs were calculated using the biosolids output from each alternative and the unit disposition costs and distribution assumptions shown in Table 5-1. The analysis assumes that the current solids disposition contract will be the primary disposal option for solids in the future for the Commission.
- The scheduled maintenance of the CHP system itself was accounted for separately on a dollar per kW hour (kWh) basis given BC's experience with CHP provider service contracts, the details of which are provided in Appendix A.

Parameters used to develop the project costs for installation of new equipment are described below:

- The capital costs develop reflect a total project cost and include a 20 percent markup for general conditions and overhead and profit, a 20 percent markup for engineering and implementation, and a 25 percent undefined details design allowance.
- A replacement and residual (R&R) cost was allocated for equipment installed in the alternatives to account for component replacement after 15 years as a ratio of equipment capital cost.

5.3 Alternatives Description

The bioenergy study alternatives were developed from different digester feedstock and solids management strategies described above. As a result, the following five alternatives were considered for analysis with the planning baseline.

- **Planning Baseline:** Status quo operation
- **Alternative 1:** Conventional mesophilic digestion with IC engine CHP system
- **Alternative 2:** Conventional mesophilic digestion with IC engine CHP system and imported wastewater solids co-digestion
- **Alternative 3:** Conventional mesophilic digestion with IC engine CHP system and imported wastewater solids co-digestion and solids drying
- **Alternative 4:** Conventional mesophilic digestion with IC engine CHP system and imported wastewater solids and HSOW co-digestion
- **Alternative 5:** Conventional mesophilic digestion with IC engine CHP system and imported HSOW co-digestion

The alternatives' major construction elements and project considerations are summarized below in Table 5-3. A breakdown of unit process additions and operational costs associated with each alternative is provided in Appendix B.

Table 5-3. Summary of Alternative Features

Planning Baseline (Status Quo)	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System				
	Alt 1: No Imported Feedstocks	Alt 2: + Imported Wastewater Solids	Alt 3: + Imported Wastewater Solids + Dryer	Alt 4: + Imported Wastewater Solids + HSOW	Alt 5: + HSOW
Major Construction Elements No new equipment installation or process enhancements	**Major Construction Elements** • (4) 1.4 MG anaerobic digesters and control building • Reconfiguration of holding and blending tanks • Gas conditioning and 1.5 MW CHP facility	**Major Construction Elements** • Imported liquid sludge receiving • Imported cake receiving and slurrying facility • (4) 1.5 MG anaerobic digesters and control building • Reconfiguration of holding and blending tanks • Gas conditioning and 2.2 MW CHP facility	**Major Construction Elements** • Imported liquid sludge receiving • Imported cake receiving and slurrying facility • (4) 1.5 MG anaerobic digesters and control building • Reconfiguration of holding and blending tanks • Gas conditioning and 2.2 MW CHP facility • (2) belt dryers and dryer building	**Major Construction Elements** • Imported liquid sludge receiving • Imported cake receiving and slurrying facility • Imported HSOW receiving and screening facility • (4) 1.8 MG anaerobic digesters and control building • Reconfiguration of holding and blending tanks • Gas conditioning and 3.3 MW CHP facility	**Major Construction Elements** • Imported HSOW receiving and screening facility • (4) 1.6 MG anaerobic digesters and control building • Reconfiguration of holding and blending tanks • Gas conditioning and 2.2 MW CHP facility
Operational Considerations • Largest volume of solids required to be hauled and disposed of (6-7 trucks/d) • Concern for increasing solids hauling and disposal costs	**Operational Considerations** • Reduced volume of solids for hauling and disposition (3-4 trucks/d) • Limited end use opportunities with Class B cake	**Operational Considerations** • Imported wastewater solids receiving (7-9 trucks/d) • Limited end use opportunities with Class B cake • Slight volume reduction of solids for hauling and disposition (5-6 trucks/d) • Limited end use opportunities with Class B cake • Nearing energy neutrality	**Operational Considerations** • Imported wastewater solids receiving (7-9 trucks/d) • Greater end use flexibility with dried product (potential fuel categorization) • Highest volume reduction of solids for hauling and disposition (1-2 trucks/d) • Nearing energy neutrality	**Operational Considerations** • Imported wastewater solids receiving (7-9 trucks/d) • Imported HSOW receiving (10-20 trucks/d) • Slight volume reduction of solids for hauling and disposition (5-6 trucks/d) • Electricity production more than plant consumption	**Operational Considerations** • Imported wastewater solids receiving (7-9 trucks/d) • Imported HSOW receiving (10-20 trucks/d) • Slight volume reduction of solids for hauling and disposition (4-5 trucks/d) • Nearing energy neutrality

Section 6

Economic Evaluation of Alternatives

This section presents capital cost estimates, O&M costs, and the resulting NPV of the project alternatives. Financial evaluation for all alternatives is provided alongside the planning baseline scenario, which represents the status quo operation over the 20-year planning period. The NPV evaluation considers the required capital investment of the alternatives with the projected revenue streams to provide the Commission with a holistic metric to assess the financial viability of the alternatives and their unique considerations.

6.1 Capital Cost Estimate

Conceptual capital cost estimates developed for the alternatives are presented in Table 6-1. The capital costs are based on Class 5 conceptual cost estimates per the Association for the Advancement of Cost Engineering International (AACEI), which carry a level of accuracy of -50 to +100 percent. Major equipment costs were performed based on vendor budgetary estimates and comparable recent project costs. Where a vendor budgetary quote was obtained, the equipment cost was multiplied by a sequence of standard cost estimate planning factors to develop an overall estimated project cost. The capital costs in Tables 6-1 reflect equipment sized for future growth conditions over the 20-year planning period. Capital costs in the table reflect the immediate capital outlay for reference and do not include projected R&R costs assumed to hit at 15 years. Projected R&R costs are included in the total capital number added to the NPV presented later in in Table 6-3. It is assumed that the capital projects are financed through long-term lending programs over the project at standard interest rates.

Table 6-1. Estimated Capital Costs for Feasibility Study Alternatives in Millions of Dollars [a]

Capital Cost Component	Planning Baseline	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System				
		Alt 1: No Imported Feedstocks	Alt 2: + Imported WW Solids	Alt 3: + Imported WW Solids + Dryer	Alt 4: + Imported WW Solids + HSOW	Alt 5: + HSOW
Imported Liquid Sludge Receiving	-	-	$0.4M	$0.4M	$0.4M	-
Imported Dewatered Cake Receiving	-	-	$3.7M	$3.7M	$3.7M	-
HSOW Receiving	-	-	-	-	$2.4M	$2.4M
Anaerobic Digestion	-	$46.2M	$48.5M	$48.5M	$55.1M	$50.7M
Drying	-	-	-	$22.5M	-	-
CHP System	-	$14.7M	$22.0M	$22.0M	$30.0M	$22.0M
Total Capital	-	$60.9M	$74.6M	$97.2M	$91.6M	$75.2M

a. *Where an equipment vendor quote was obtained the equipment, cost was multiplied by the following factors to develop a project cost: 100% for installation cost, 20% for general conditions and overhead and profit, 20% for engineering and capital program administration, and 25% for an undefined details design allowance.*

6.2 Annual Operating Costs and Revenue

This section presents estimated annual O&M costs and annual revenue projections for the alternatives.

6.2.1 O&M Costs

O&M costs were developed by applying historic unit costs to alternative solids process models. The O&M costs incurred by the planning baseline alongside the project alternatives are presented in Table 6-2 below. Revenue from imported feedstock tipping fees or electricity production are discussed in the subsection below and **excluded** from Table 6-2.

Table 6-2. Estimated Annual O&M Costs for Feasibility Study Alternatives [a]

O&M Cost Component	Planning Baseline	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System				
		Alt 1: No Imported Feedstocks	Alt 2: + Imported WW Solids	Alt 3: + Imported WW Solids + Dryer	Alt 4: + Imported WW Solids + HSOW	Alt 5: + HSOW
Solids Disposition Costs	$4,870,000	$2,100,000	$3,110,000	$460,000	$3,330,000	$4,870,000
Electricity Costs	$360,000	$520,000	$660,000	$910,000	$730,000	$360,000
Natural Gas Cost	-	-	-	$990,000	-	-
Polymer Costs	$410,000	$360,000	$540,000	$540,000	$580,000	$410,000
Labor	$110,000	$280,000	$280,000	$340,000	$280,000	$110,000
Contract/Annual Maintenance	$110,000	$300,000	$750,000	$790,000	$960,000	$110,000
Total O&M	**$5,860,000**	**$3,560,000**	**$5,340,000**	**$4,030,000**	**$5,880,000**	**$5,860,000**

a. *These are rough estimates based on experience. The ultimate values may vary a little or moderately depending on regulatory impacts, inflation or local impacts.*

Table 6-2 shows largest difference between alternatives is observed in the solids disposition costs. Anaerobic digestion of the native plant solids results in annual savings of $2.8 million, while operation of a dryer, even with the imported feedstocks, can reduce solids hauling and disposition costs by $4.4 million. The alternatives all demonstrate increased O&M cost in all other categories to account for operation of the next equipment with the most noticeable increase being the $1.0 million in natural gas costs for the dryer operation.

6.2.2 Operating Cost Offsets and Revenue Generation

Table 6-3 presents the project revenue projections based on the information available at the time of this feasibility study. The tipping fees represent a middle of the road approach to pricing given recent regional market studies and published solids hauling and end use bid prices.

The electricity offset and revenue rates were developed from a review of reference materials as well as contact with the Massachusetts Department of Energy Resources (Mass DOER). The electricity offset value represents the dollars saved from the plant's electricity bill achieved by replacing utility provided electricity with renewable electricity generated onsite from the CHP system. Electricity offset was calculated by assuming all electricity production from the CHP system was used to offset historic usage charges at a 90 percent IC engine availability. The demand offset was calculated by assuming that one IC engine would always be operating; therefore, credit was applied for the one IC engine monthly. Where more electricity is produced than used at the plant (Alternative 4), it is assumed the

Commission is able to sell the excess electricity back to the grid and offset supply charges at pump stations in their collection system.

The Mass DOER Renewable Portfolio Standards (RPS) incentives are included under electricity offset. A 2017 review of the RPS conducted for the Northeast Clean Energy Council (NECEC) showed that the renewable energy certificates supply is expected to surpass demand in the next 5 to 10 years; therefore, a conservative value of $0.005 per kWh was used. Based upon the information available at the time of this study, the RPS alternative energy certificates (AECs) are not expected to see a drop in demand, so a moderate value from the Mass DOER CHP AECs online estimator tool was used. Additional CHP incentives may be available from the electric utilities supplying power to the plant; however, no programs of this kind were identified at the time of this study. Therefore, no additional incentives were included.

Table 6-3. Revenue Values for Lifecycle Cost Analysis

Cost Element	Value in Model	Basis
Imported liquid feedstocks tipping fees (per gal)	$0.06	Recent regional market assessment
Imported dewatered cake tipping fees (per wt)	$65	Recent regional market assessment
Electricity offset rate, average supply and delivery (per kWh)	$0.127	Historic WWTP rate (Apr 2017 to Mar 2018)
Class I Renewable Energy Certificates (per kWh)	$0.005	NECEC Analysis of the Massachusetts RPS
Alternative Energy Certificates (per kWh)	$0.026	Mass DOER APS CHP `s Estimator

Projected revenue streams from the CHP electricity production and imported feedstocks are presented in Table 6-4.

Table 6-4. Estimated Annual Revenue for Feasibility Study Alternatives

Revenue Component	Planning Baseline	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System				
		Alt 1: No Imported Feedstocks	Alt 2: + Imported WW Solids	Alt 3: + Imported WW Solids + Dryer	Alt 4: + Imported WW Solids + HSOW	Alt 5: + HSOW
HSOW Tipping Fees	-	-	-	-	$930,000	$930,000
Imported Cake Tipping Fees	-	-	$1,710,000	$1,710,000	$1,710,000	-
Imported Liquid Sludge Tipping Fees	-	-	$210,000	$210,000	$210,000	-
Electricity Offset	-	$1,250,000	$1,780,000	$1,780,000	$2,340,000	$1,760,000
Electricity Incentives	-	$310,000	$430,000	$430,000	$570,000	$430,000

6.3 NPV Analysis

As a conservative measure, no funding or grants are included in the NPV analysis. An overview of potential grants and incentives relevant to implementation of a bioenergy project at the Springfield Regional WWTF is provided in Appendix C. Electricity production RPS credits are, however, included in the NPV analysis because they are not competitive to obtain. For the baseline NPV analysis, the electrical and natural gas utility costs are assumed to increase at the escalation rate identified in Table 5-2.

Following the baseline NPV analysis, three sensitivity analyses are presented:

- Increase or decrease in biosolids disposition rate
- Increases or decreases in tipping fees
- Increase in grant funding

The NPV results are based upon several assumptions and variables outlined in this study and are based upon the data available at the time of the analysis. Actual NPV increases over the baseline alternative may vary if any of the assumptions or variables differ from what was assumed in the analysis.

6.3.1 NPV with Baseline Assumptions

Figure 6-1 shows the baseline NPV results and Table 6-5 summarizes the NPV parameters with a breakdown of capital, O&M costs, and revenue. The NPV figures are presented as bar graphs where the dark bottom portion represents capital investment, the lighter top color represents the annual costs, the green bar represents the revenue, and the gold line represents the NPV.

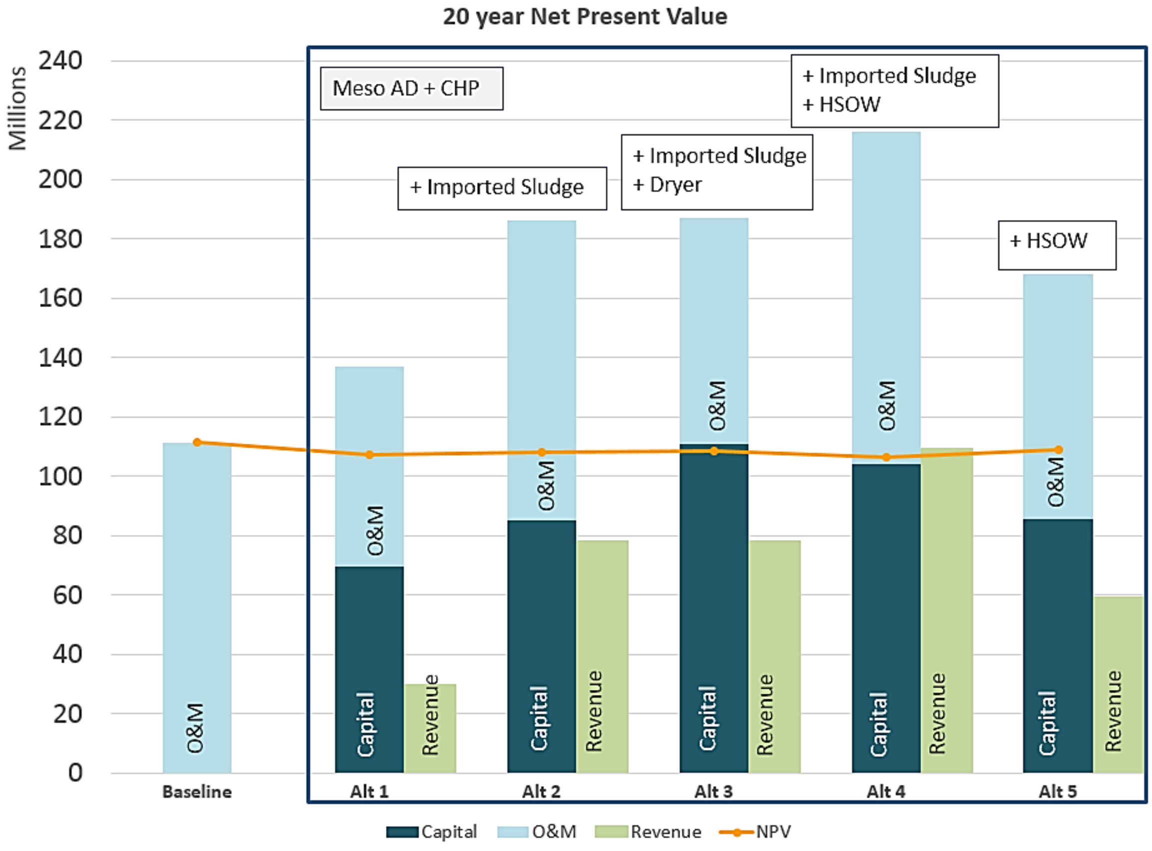


Figure 6-1. Baseline 20-year NPV results

Table 6-5. Estimated NPV for Feasibility Study Alternatives [a]

Cost Component	Planning Baseline	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System				
		Alt 1: No Imported Feedstocks	Alt 2: + Imported WW Solids	Alt 3: + Imported WW Solids + Dryer	Alt 4: + Imported WW Solids + HSOW	Alt 5: + HSOW
Total Capital Costs	-	$69,400,000	$85,000,000	$110,700,000	$104,300,000	$85,700,000
Revenue	-	-$29,600,000	-$78,400,000	-$78,400,000	-$109,400,000	-$59,200,000
Total O&M Costs	$111,300,000	$67,600,000	$101,400,000	$76,400,000	$111,700,000	$82,600,000
20-year NPV Cost	**$111,300,000**	**$107,400,000**	**$108,000,000**	**$108,700,000**	**$106,600,000**	**$109,100,000**

a. *These numbers are based upon the various assumptions and variables indicated in the report, including a Class 5 cost estimate. Changes to key variables or assumptions may impact these results in a favorable or unfavorable manner. A more detailed project vetting should be undertaken as a next step to further refine this analysis.*

The NPV results show overall lifecycle costs all within 5 percent of each other. Given the high level at which the cost estimates were developed, it is not clear whether one alternative clearly has an advantage, but all are shown as financially viable. The results show a general trend where increased capital expenditure results in greater opportunities for reductions in solids hauling and disposition cost and realization of reoccurring revenue.

6.3.2 NPV Sensitivity to Biosolids Disposition Costs

As noted in Section 6.2.1, biosolids hauling and disposition represents the largest cost component of the annual solids handling and processing costs. Given existing market trends, further constraints could create additional stress within the limited existing biosolids end use and disposal options, further driving up costs. Additionally, there exists a degree of uncertainty associated with disposition costs as the Commission's current operations contract is set to expire shortly. Table 6-6 below shows the impact from both $10 and $20 increases to hauling and disposal/disposition costs.

Table 6-6. 20-year NPV results based on $10 and $20 per wet ton hauling and tip fee increases

Cost Component	Planning Baseline	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System				
		Alt 1: No Imported Feedstocks	Alt 2: + Imported WW Solids	Alt 3: + Imported WW Solids + Dryer	Alt 4: + Imported WW Solids + ,.. HSOW	Alt 5: + HSOW
Baseline Assumptions	$111,300,000	$107,400,000	$108,000,000	$108,700,000	$106,600,000	$109,100,000
+$10/wt Sludge Management[a,b]	$120,100,000	$112,400,000	$110,400,000	$104,700,000	$106,600,000	$111,800,000
+$20 /wt Sludge Management[a,b]	$128,900,000	$117,400,000	$112,800,000	$100,700,000	$106,600,000	$114,300,000

a. *Sludge Management includes increases in tipping and hauling costs for sum total increase indicated.*

b. *Assumes sludge receiving fees increase commensurate with sludge disposal rate changes*

c. *These numbers are based upon the various assumptions and variables indicated in the report, including a Class 5 cost estimate*

A substantial increase in NPV cost is observed in the planning baseline scenario, while the digestion alternatives demonstrate an ability to weather the cost increase. Alternatives that receive imported wastewater solids are shown benefitting from the ability to charge the additional $10 and $20/wt tip fee, creating a net economic benefit when paired with the dryer (Alternative 4).

6.3.3 NPV Sensitivity to Tipping Fees

Additional opportunities could be uncovered if a market assessment is conducted and shows the current imported feedstocks market (both wastewater solids and HSOW) would support higher tipping fees the Commission could charge to receive the imported materials. Given the proximity of industrial food processing waste generators to the WWTF and current wastewater solids market constraints, tipping fees greater than the project assumptions of $0.06 per gallon for HSOW and liquid wastewater sludge and $65 per wet ton for dewatered wastewater solids may be possible.

Table 6-7. 20-year NPV results based on $15% and 30% increase in tipping fees charged by the Commission

Cost Component	Planning Baseline	Conventional Mesophilic Anaerobic Digestion with IC Engine CHP System				
		Alt 1: No Imported Feedstocks	Alt 2: + Imported WW Solids	Alt 3: + Imported WW Solids + Dryer	Alt 4: + Imported WW Solids + HSOW	Alt 5: + HSOW
Baseline Assumptions	$111,300,000	$107,400,000	$108,000,000	$108,700,000	$106,600,000	$109,100,000
+15% tip fee charged	$111,300,000	$107,400,000	$102,500,000	$103,200,000	$98,500,000	$106,500,000
+30% tip fee charged	$111,300,000	$107,400,000	$97,100,000	$97,800,000	$90,400,000	$103,800,000

The increased tip fees show substantial economic opportunities are possible if the market can support a higher tip fee. These tip fees may be reasonable for wastewater solids if hauling costs are lower than the baseline assumption, but a market study would be required to confirm. Likewise, a market study would provide insight into likely tip fees that could be charged for HSOW and the corresponding quality of the HSOW feedstocks.

Section 7

Summary and Recommendations

This feasibility study provides an evaluation of the technical systems and costs, benefits, and risks of undertaking an anaerobic digestion bioenergy project at the Springfield Regional WWTF. The study develops conceptual design of facilities, mass, and energy process models to identify project conditions, system inputs/outputs, and costs and revenue generation. The study is structured broadly to compare different opportunities including co-digestion with imported HSOW and imported wastewater solids, as well as thermal drying of the digested solids. Based on these underlying fundamentals, this feasibility study sought specifically to address the following questions:

- Is it more financially attractive to generate renewable energy from anaerobic digestion and CHP over the 20-year planning period or does the status quo represent the better model for cost and rate control?
- Can sufficient revenues be generated via electricity production and imported feedstock tip fees to justify the investment for the import of regional sludge and HSOW; such as fats, oils and grease (FOG)?
- Does drying the digested solids reduce solids hauling and disposition costs enough to justify installation and operation of a drying facility?

Based in the underlying assumptions, data available, and processes selected for this analysis the 20 year NPV of all alternatives ranged from a low of $106 million to a high of $111 million. At the current level of analysis (design, cost estimating, market assessment, energy use profile, incentives, grants, etc.) the data show that there is no significant financial benefit from implementing anaerobic digestion, but there is not a significant detriment either. The preliminary analysis demonstrates that the Commission can invest in the infrastructure needed to convert its sludge and the sludges of other regional POTWs to generate renewable electrical energy at the same cost it would incur if it were to simply continue current solids management practices, which does not recover any energy or manage long-term risk.

Environmental Benefits

Moving forward with a solids-to-energy project at the Commission, depending on scope, can provide the following range of energy and positive environmental attributes:

- Onsite-Renewable Power Generation: 1.2 MW to 2.1 MW, or approximately 57 to 100 percent of average electrical demand of the plant including new facilities.
- Equivalent Carbon Emissions (power and natural gas only): 1,600 to 8,900 tons of CO2e per year relative to a status quo rate of 6,700 tons CO_2e per year.

Risk Management

Further, risk mitigation factors should be considered in the decision to proceed or not with different process configurations. A key advantage of implementing anaerobic digestion is that it has the potential to reduce solids hauling and disposition costs by approx. 57% on an annual basis (~$2.7M/yr) under the cost factors assumed for the study. Figure 7-1 depicts the avoided solids disposition costs between the planning baseline and the WWTP solids only anaerobic digestion alternative (Alternative 1).

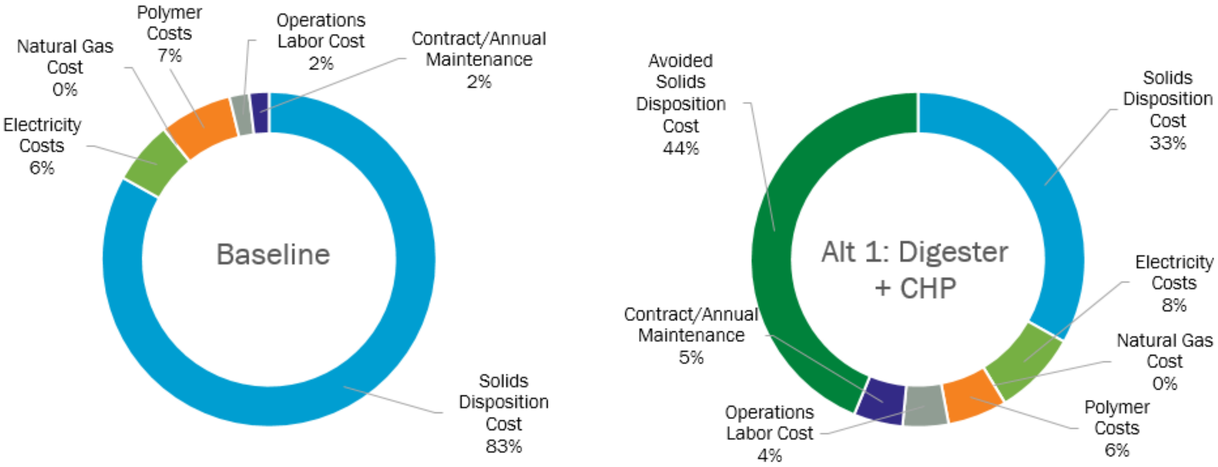


Figure 7-1. Annual solids handling cost breakdown

Given that wastewater solids disposal and end-use options are growing increasingly constrained in the region, this represents a significant ability to manage the Commission's risk of increasing solids management costs. A tightening biosolids management market, primarily through a reduction in local disposal locations, is increasing haul distance and/or tipping fees at the increasingly limited disposal points. These impacts on one of the Commission's largest operating cost centers are lessened by the mass reduction from digestion and the further reduction in mass achieved through drying, as was shown in Table 6-6 in the previous section. An increase in the combined solids hauling and disposal fee by $10 and $20 per wet ton is better absorbed by process configurations with anaerobic digestion. Under current sludge management practices the life-cycle cost for the planning period increases by $8.8 to $17.6 million, with a $10 and $20 per wet ton sludge management cost increase, respectively. For the same increases in management costs, digestion of Commission sludge only, sees cost increase of $5 to $10 million, a savings of $3.8 to $7.6 million over continuing current practices. Importing sludges and the addition of a sludge dryer demonstrates the greatest overall risk management saving the Commission $12.8 to $25.6 million over the same period, benefiting from revenues from sludge acceptance and increased mass reduction.

Imported Organics

The import of additional feedstock, HSOW and/or outside wastewater sludges, has the potential to generate additional revenue, provide needed regional service, and increase the total energy production from a Commission digestion process. At the current level of analysis, the addition of imported feedstocks demonstrated little additional benefit from an economic standpoint, based on the current understanding of the market and associated assumptions. While from a purely economic standpoint of significantly reduced operating costs, each alternative showed little relative difference in overall cost of ownership (capital and operating costs) making risk reduction and additional environmental benefit the primary drivers for decision making, based on the current information.

Core Assumptions Evaluation

Based on an evaluation of the data, underlying assumptions and the specific sensitivities of this analysis several areas were noted that have the potential to improve the overall financial benefit to the Commission. These include:

- Energy Production: for this analysis combined heat and power (CHP) was selected as the model energy system. Exploration of high value renewables such as renewable compressed vehicle fuel could generate significantly more revenue given to the value of Renewable Identification Numbers.

- Wastewater Sludge Disposal Fees: given a detailed market assessment of current sludge disposal costs from regional generators and a market-based assessment of potential tipping fees, the market demand for a regional digestion facility may demonstrate better cost factors than assumed in this study.
- High Strength Organic Wastes: given a more detailed market assessment surrounding the quantity and characteristics of available HSOW in the market, local tip fee limits and their potential for capital and operating cost recovery could be determined.
- Non-Waste Fuel Source: the potential to supply a dried product to nearby incinerators or biomass boilers with energy recovery systems and corresponding tipping fees could be demonstrated through additional outreach efforts. If viable combustion end uses are identified, regulators would be engaged to identify the steps required to classify the dried product as a non-waste, combustion fuel source.
- Grants and Incentives: exploration of low cost or no-cost capital grants should be explored along with any additional energy incentives that may prove relevant for electricity or other renewable energy production.

In summary, anaerobic digestion with CHP will likely be no more costly than continued operation under the current process model, raw sludge incineration and landfilling. There appears to be some marginal benefit associated with the digestion of imported wastewater solids and HSOW, though not beyond the tolerances of this analysis. However, in-terms of risk management, specifically long-term cost controls, and the associated environmental benefits of the renewable power production and carbon emissions reductions, in most cases, the digestion options are superior to the current practice of raw sludge management. The Commission would be best served by further developing these alternatives and refining value-added elements to further optimize the balance of financial and operations risks specific to their market. These tasks are a part of the due diligence necessary in the progression from initial feasibility study (this study) to the design, construction and operation of Commission located facility

Section 8

Limitations

This document was prepared solely for the Commission in accordance with professional standards at the time the services were performed and in accordance with the contract between the Commission and BC dated July 19, 2018. This document is governed by the specific scope of work authorized by the Commission; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by the Commission and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Further, BC makes no warranties, express or implied, with respect to this document, except for those, if any, contained in the agreement pursuant to which the document was prepared. All data, drawings, documents, or information contained this feasibility study have been prepared exclusively for the person or entity to whom it was addressed and may not be relied upon by any other person or entity without the prior written consent of BC unless otherwise provided by the Agreement pursuant to which these services were provided.

Section 9

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Appendix A: CHP Energy Recovery System Technical Information

Electrical Interconnection Requirements

With the installation of on-site power generation equipment that will operate on a continuous basis under normal operating conditions (as opposed to back-up generators that only run intermittently), the project will need to upgrade the electrical infrastructure for parallel operation with the grid. These upgrades will include additional infrastructure for both the customer-owned systems and the systems owned and operated by the serving electrical utility. Upgrades to the utility-owned systems will normally include additional controls, upgraded metering capability, additional disconnecting means, new system protection relays, additional communication devices, etc., that collectively become known as the electrical interconnection system.

The Commission is in the service territory of Eversource Energy and Great Eastern Energy. In order for the facility to generate electricity and operate in parallel with the grid supplied power, the facility will need to apply for electrical interconnection authorization with Eversource Energy and Great Eastern Energy. The cost of simply applying for interconnection will be in the range of $300 to $7,500. The actual cost will vary based upon the size of planned generation capacity (in kW) and other various contributing factors affecting the complexity of the planned interconnection. Factors such as the type of electrical infrastructure currently in place at the WWTP facility (radial feed versus network feed), the load of the WWTF facility in relation to the substation that provides electric service to the facility, and the consumption of all site generated power by the facility behind the meter versus the need to export power to the grid (potential net metering capabilities) all contribute to the overall project complexity.

Upon submittal of an application for interconnection and payment of the associated fee, the utility will review the application information and determine a cost to perform an Impact Study (to be paid by the interconnection customer). The Impact Study determines how the new power generating equipment and system will impact the local grid. The Impact Study includes a determination of whether enough information is known, in which case the study will provide an estimated cost to implement and construct the physical interconnection or determine if additional review is required.

If the complexity of the project requires additional review, the Impact Study will provide an estimated cost to perform a Detailed Study, which is paid for by the utility. The objective of the Detailed Study is to provide an estimated cost to implement and construct the physical interconnection.

Upon completion of any required studies and the proposed estimated cost of interconnection, the interconnecting customer will be required to execute an Interconnection Agreement with the utility agency that will authorize the utility agency to begin the design and construction of the necessary utility system upgrades to allow for the parallel operation of the new power generation equipment and systems. While interconnection agreements can generate revenue with sale of power to the grid, each study and agreement required to achieve the Interconnection Agreement incur a fee and can impact schedule. While the application and studies can range from a total cost of $5,300 to $57,500, the costs of design, construction and implementation of the interconnection itself are estimated to be in the range of $100,000 to $250,000.

Air Emissions/Permitting Evaluation

The combustion devices will either be IC engines ranging in size (in aggregate) from approximately 1.5 to 3.3 MW. The fuel source will be biogas (conditioned to remove moisture, siloxanes, and H_2S) generated on site via anaerobic digestion. Generally a Comprehensive Plan Approval (CPA) is required in accordance with the Massachusetts Department of Environmental Protection (MassDEP) 310 CMR 7.26 (43) and (45). Approvals are valid for the life of the emission unit.

Based on the nature of the proposed equipment, the potential emissions are predicted to be less than the Major Source Thresholds. As such, the units would not be subject to the requirements of Prevention of

Significant Deterioration regulations promulgated in 40 CFR Part 52.21 or the Massachusetts Environmental Policy Act Review requirements of 301 CMR 11.00.

MassDEP requests that the permitting process begin with a meeting including personnel from the appropriate MassDEP regional office. During the initial meeting, MassDEP will discuss any measures that may be required in addition to the standard CPA application requirements in accordance with MassDEP 310 CMR 7.02 (5) as summarized below. Additional measures MassDEP may require include air dispersion modeling to evaluate compliance with the National Ambient Air Quality Standards, sound survey, sound study, and sound suppression/mitigation measures. Based on a discussion with Roseanna Stanley, MassDEP Central Regional Permit Chief, Best Available Control Technology (BACT) requirements (discussed below in number 6) for biogas combustion devices will likely include an oxidation catalyst for carbon monoxide and volatile organic compounds, and possibly selective catalytic reduction to control the formation of nitrogen oxide. MassDEP also recommends sampling and analyzing the digester gas prior to design and permitting for use during the design phase and to facilitate evaluation of pre- and post-treatment emissions.

Following the submittal of a complete application package to MassDEP (via Massachusetts' online ePlace Portal), a review period will begin in accordance with 310 CMR 4. Under the rule, MassDEP will complete the administrative completeness review within 24 days and complete the technical review within 72 days of completing the completeness review. A 30-day public comment period will follow the completion of the technical review. Brown and Caldwell notes these timelines may be extended based on the quality of the application and any associated data gaps identified by MassDEP.

Under 310 CMR 7.02 (5), the following are required to be included in all CPA applications:

1. Site information.
2. A description of the proposed activity.
3. Plans, specifications, and drawings illustrating the design of the facility.
4. Procedures describing the manner in which the facility will operate and be maintained.
5. Calculations detailing the nature and amount of all emissions (i.e., potential to emit).
6. Demonstration of compliance with the requirements of 310 CMR 7.02(8)(a) relating to emission limitations (i.e., in accordance with the requirements of 310 CMR 7.02 (8), BACT is required of all CPA approvals). Applicants shall identify BACT for their specific application using a top-down BACT analysis. BACT may include a design feature, equipment specification, work practice, operating standard or combination thereof (see definition of BACT in 310 CMR 7.00).
7. A discussion of compliance with applicable State and federal air pollution control regulations.
8. An affirmative demonstration that any facility(ies) in Massachusetts, owned or operated by such persons (or by an entity controlling, controlled by or under common control with such person) that is subject to 310 CMR 7.00, is in compliance with or on a Department-approved compliance schedule to meet all provisions of 310 CMR 7.00, and any plan approval, notice of noncompliance order or plan approval issued thereunder.
9. The application shall bear the seal and signature of a professional engineer registered in the Commonwealth of Massachusetts under the provisions of Massachusetts General Law, Chapter 112.

Additional information may be requested by MassDEP including, but not limited to, air dispersion modeling, additional plans or specifications, and documentation or evidence to support the application.

IC Engines: Maintenance Costs

The maintenance costs for the IC engine alternatives are based on industry experience and vendor supplied pricing for a service contract. The engine-generator costs cover routine maintenance such as oil changes and filter replacements and major events such as top- and bottom-end overhauls. The gas treatment O&M includes costs for H_2S and siloxane removal media replacement, gas compression, and moisture removal. The O&M costs for the IC engine alternatives are shown in Table A-1. Note that the engine and gas treatment operating costs are expressed on a per kWh basis to reflect the run time and wear on the system.

Table A-1. IC Engine and Gas Treatment Operating Cost Assumptions

Criterion	Value
Engine-generator O&M, $/kWh [a]	0.025
Blower and chiller power, percent of produced power [b]	6%
Gas treatment maintenance, $/kWh [c]	0.015
Labor: gas treatment (FTE)	0.1
Labor: engine-generator (FTE)	0.25
Engine availability (uptime), %	90%

a. Based on gross output of engine-generator. Value based on industry experience and service plans for similarly sized engines.

b. Assumes compression to 5 psig.

c. Includes media replacement purchase, shipping, labor, and disposal.

d. These are rough estimates based on experience. The ultimate values may vary a little or moderately depending on regulatory impacts, inflation or local impacts.

Appendix B: Financial Model Summary Sheets

Scope Summary			**Baseline**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**	**Alt 5**
			Baseline	**Meso + CHP**	**Meso + Outside Sludge + CHP**	**Meso + Outside Sludge + CHP + Dryer**	**Meso + Outside Sludge + HSW + CHP**	**Meso + HSW + CHP**
Element			Baseline	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
	Imported Liquid Sludge Receiving							
		Number of Offload Pumps	-	-	2	2	2	-
	Imported Dewatered Cake Receiving							
		Number of Dewatered Cake Hoppers	-	-	1	1	1	-
		Volume of Dewatered Cake Hopper, cu. yd.	-	-	50	50	50	-
		Dewatered Cake Slurrying Process	-	-	Mechanical	Mechanical	Mechanical	-
	High Strength Waste (HSW) Receiving							
		Debris Removal	-	-	-	-	Screening	Screening
		Number of Screening Units	-	-	-	-	2	2
		Capacity of Screening Units, gpm	-	-	-	-	1,400 gpm	1,400 gpm
	Digester Feed and Blending							
		System Configuration	Existing Holding Tanks	Existing Holding Tanks	Existing Holding Tanks	Existing Holding Tanks	Existing Holding Tanks	Existing Holding Tanks
		Number of Digester Feed and Blend Tanks	4	4	4	4	3	3
		Volume of Digester Feed and Blend Tanks, gal	175,000	175,000	175,000	175,000	175,000	175,000
		Hold Time Capacity at Avg Flow, days	*3.5*	*3.5*	*3.1*	*3.1*	*1.9*	*2.2*
	Digestion							
		System Configuration	-	Meso	Meso	Meso	Meso	Meso
		Number of Digesters	-	4	4	4	4	4
		Active Volume of Digesters	-	1.4	1.5	1.5	1.8	1.6
		Building Addition/Modification	-	Digester Control Bldg	Digester Control Bldg	Digester Control Bldg	Digester Control Bldg	Digester Control Bldg
	Dewatering Feed/Digested Sludge Storage (DSS)							
		System Configuration	Existing Storage Tanks	Existing Storage Tanks	Existing Storage Tanks	Existing Storage Tanks	Existing Storage Tanks	Existing Storage Tanks
		Number of DSS Tanks	2	2	2	2	2	2
		Volume of DSS Tanks, gal	210,000	210,000	210,000	210,000	210,000	210,000
		Hold Time Capacity at Avg Flow, days	*2.1*	*2.1*	*1.9*	*1.9*	*1.6*	*1.8*
	Dewatering							
		Process Technology	Centrifuge	Centrifuge	Centrifuge	Centrifuge	Centrifuge	Centrifuge
		Total Number of Units	2	2	2	2	2	2
		Solids Loading Capacity of Each Unit, dry-lb/hr	2,250	2,250	2,250	2,250	2,250	2,250
	Drying							
		Process Technology	-	-	-	Belt Dryer	-	-
		Total Number of Units	-	-	-	2	-	-
		Capacity of Each Unit, WTPD	-	-	-	53	-	-
		Number of Cake Feed Hoppers	-	-	-	2	-	-
		Volume of Cake Feed Hoppers, cu. yd.	-	-	-	30	-	-
		Building Addition/Modification	-	-	-	New Building and Loadout	-	-
	Solids Disposition							
		Solids Classification	Unclassified	Class B	Class B	Class B	Class B	Class B
		Solids Conveyance	Truck Loadout	Truck Loadout	Truck Loadout	Truck Loadout	Truck Loadout	Truck Loadout
		Trucks per Day	6.4	3.6	5.3	1.4	5.7	4.0
	Digester Gas Use							
		Gas Use Technology	-	ICE CHP	ICE CHP	ICE CHP	ICE CHP	ICE CHP
		Capacity of Each Unit, kW	-	1,548	1,100	1,100	1,100	1,100
		Useful Heat from Each Unit, MMBtu/hr	-	4.5	6.3	6.3	8.1	6.3
		Number of Units	-	1	2	2	3	2
		Peak Digester Gas Use Capacity, scfm	-	432	471	471	604	467

Performance Summary			Notes	Baseline	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
Solids Flows and Loads				**Baseline**	**Meso + CHP**	**Meso + Outside Sludge + CHP**	**Meso + Outside Sludge + CHP + Dryer**	**Meso + Outside Sludge + HSW + CHP**	**Meso + HSW + CHP**
Element				**Baseline**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**	**Alt 5**
Process Feeds									
	TPS	Average Digester Feed Load, dry lbs TS/hr		1,575	1,575	1,575	1,575	1,575	1,575
	TPS	Average Digester Feed Load, %TS		4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
	TPS	Average Digester Feed Load, %VS		85.5%	85.5%	85.5%	85.5%	85.5%	85.5%
	TPS	Average Digester Feed Rate, gpm		70.4	70.4	70.4	70.4	70.4	70.4
	TWAS	Average Digester Feed Load, dry lbs TS/hr		1,433	1,433	1,433	1,433	1,433	1,433
	TWAS	Average Digester Feed Load, %TS		4.1%	4.1%	4.1%	4.1%	4.1%	4.1%
	TWAS	Average Digester Feed Load, %VS		79.3%	79.3%	79.3%	79.3%	79.3%	79.3%
	TWAS	Average Digester Feed Rate, gpm		69.2	69.2	69.2	69.2	69.2	69.2
	Sludge	Average Digester Feed Load, dry lbs TS/hr		-	-	167	167	167	-
	Sludge	Average Digester Feed Load, %TS		-	-	5.0%	5.0%	5.0%	-
	Sludge	Average Digester Feed Load, %VS		-	-	80.0%	80.0%	80.0%	-
	Sludge	Average Digester Feed Rate, gpm		-	-	6.7	6.7	6.7	-
	Cake	Average Digester Feed Load, dry lbs TS/hr		-	-	1,200	1,200	1,200	-
	Cake	Average Digester Feed Load, %TS		-	-	20.0%	20.0%	20.0%	-
	Cake	Average Digester Feed Load, %VS		-	-	80.0%	80.0%	80.0%	-
	Cake	Average Digester Feed Rate, gpm		-	-	12.0	12.0	12.0	-
	HSW	Average Digester Feed Load, dry lbs TS/hr		-	-	-	-	735	735
	HSW	Average Digester Feed Load, %TS		-	-	-	-	5.0%	5.0%
	HSW	Average Digester Feed Load, %VS		-	-	-	-	85.0%	85.0%
	HSW	Average Digester Feed Rate, gpm		-	-	-	-	29.4	29.4
		Average Digester Gas Production, scfm		-	327	463	463	596	459
		Average Dewatering Feed Load, dry lbs TS/hr		3,008	1,701	2,521	2,521	2,725	1,905
		Average Dewatering Feed Load, %TS		4.3%	2.5%	3.3%	3.3%	3.0%	2.3%
		Average Dewatering Feed Load, %VS		82.5%	69.1%	68.3%	68.3%	66.6%	66.6%
		Average Dewatering Feed Rate, gpm		139.6	137.0	154.5	154.5	182.9	165.3
Hauled Solids									
		Solids Disposition							
		Average Hauled, wet tons/d		127.1	71.9	106.5	28.2	114.2	80.5
		Average Hauled, wet lbs/hr		10,592	5,990	8,878	2,348	9,516	6,709
		Average Hauled, dry lbs TS/hr		2,521	1,426	2,113	2,113	2,284	1,597
		Average Hauled, %TS		23.8%	23.8%	23.8%	90.0%	24.0%	23.8%
		Average Hauled Volatile Solids, %VS		82.5%	69.1%	68.3%	68.3%	66.6%	66.6%
		Trucks per Day	a	6.4	3.6	5.3	1.4	5.7	4.0
Staffing									
		FTEs Required to Operate the Solids		1.0	1.0	1.0	1.0	1.0	1.0
		Additional FTEs Required		-	1.5	1.5	2.0	1.5	1.5
Annual Average Electricity									
	Total Solids Handling Electricity Use, kWh per year			2,635,300	3,835,824	4,875,362	6,726,251	5,395,893	4,328,592
		Digestion Electricity Load, kW		-	200	208	208	217	208
		Dewatering Electricity Load, kW		301	170	252	252	273	191
		Dryer Electricity Load, kW		-	-	-	211	-	-
		Gas Conditioning, kW		-	68	96	96	127	95
		Total Solids Handling Electricity Load, kW		301	438	557	768	616	494
Annual Average Natural Gas									
	Usable Heat Recovery from CHP, MMBtu per hr			-	4.4	6.2	6.2	8.0	6.2
	Digester Process Heating, MMBtu/hr			-	3.5	3.9	3.9	4.6	4.2
	Net Heat, MMBtu per hr			-	0.9	2.3	0.1	3.4	2.0
	Natural Gas required, MMBtu/h		b	-	-	-	9.62	-	-
Chemicals									
	Dewatering Polymer Use, lb-poly/hr			24.1	21.3	31.5	31.5	34.1	23.8
Energy Production									
	Electricity Production, MW			-	1.25	1.78	1.78	2.35	1.76

Notes:

a Assumes 20 wet tons per truck

b assumes lower heating value

Cost Summary	Notes	**Baseline**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**	**Alt 5**
		Baseline	**Meso + CHP**	**Meso + Outside Sludge + CHP**	**Meso + Outside Sludge + CHP + Dryer**	**Meso + Outside Sludge + HSW + CHP**	**Meso + HSW + CHP**
Element		**Baseline**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**	**Alt 5**
Capital Costs							
Immediate							
Total Capital Outlay		$0	$60,900,000	$74,600,000	$97,200,000	$91,600,000	$75,200,000
Present Worth of Future Capital		**$0**	**$60,900,000**	**$74,600,000**	**$97,200,000**	**$91,600,000**	**$75,200,000**
15 year							
Rehabilitation and Repair Capital		$0	$9,135,000	$11,190,000	$14,580,000	$13,740,000	$11,280,000
Present Worth of Future Capital		**$0**	**$8,500,000**	**$10,400,000**	**$13,500,000**	**$12,700,000**	**$10,500,000**
Total Present Worth of Capital		**$0**	**$69,400,000**	**$85,000,000**	**$110,700,000**	**$104,300,000**	**$85,700,000**
Annual Operations & Maintenace							
Solids Disposition Cost							
Dewatered Cake Costs		$4,871,430	$2,099,055	$3,110,739	$462,722	$3,334,346	$2,350,681
Annual Solids Handling Costs, $/y:		**$4,871,430**	**$2,099,055**	**$3,110,739**	**$462,722**	**$3,334,346**	**$2,350,681**
Electricity Costs							
Energy Costs		$355,766	$517,836	$658,174	$908,044	$728,446	$584,360
Total Annual Electricity Costs, $/y:		**$355,766**	**$517,836**	**$658,174**	**$908,044**	**$728,446**	**$584,360**
Natural Gas Cost							
Natural gas Costs	a	$0	$0	$0	$989,037	$0	$0
Total Annual Nat Gas Cost, $/y:		**$0**	**$0**	**$0**	**$989,037**	**$0**	**$0**
Polymer Costs							
Dewatering Cost		$411,107	$363,280	$538,370	$538,370	$581,919	$406,828
Total Annual Polymer Cost, $/y:		**$411,107**	**$363,280**	**$538,370**	**$538,370**	**$581,919**	**$406,828**
Operations Labor Cost							
FTEs Required to Operate Dewatering		$111,885	$111,885	$111,885	$111,885	$111,885	$111,885
Additional FTEs required for solids processing		$0	$167,827	$167,827	$223,770	$167,827	$167,827
Annual Solids Operations Cost, $/y:		**$111,885**	**$279,712**	**$279,712**	**$335,654**	**$279,712**	**$279,712**
Contract/Annual Maintenance							
Digester cleaning		$0	$12,500	$12,500	$12,500	$12,500	$12,500
Dewatering maintenance Cost		$111,210	$62,894	$93,207	$93,207	$100,747	$70,433
Other Major Equipment Maintenance Cost		$0	$76,990	$87,667	$125,333	$102,667	$88,667
Engine Maintenance		$0	$0	$350,693	$350,693	$462,722	$347,730
Gas Conditioning System Maintenance		$0	$148,361	$210,416	$210,416	$277,633	$208,638
Annual Solids Contracted Maintenance Cost, $/y:		**$111,210**	**$300,745**	**$754,482**	**$792,149**	**$956,269**	**$727,969**
Annual Operations & Maintenace Total Annual Cost, $/y		**$5,861,396**	**$3,560,628**	**$5,341,477**	**$4,025,977**	**$5,880,691**	**$4,349,550**
Revenue							
HSW Tipping fee		$0	$0	$0	$0	-$926,365	-$926,365
Outside Cake Tip Fee		$0	$0	-$1,708,200	-$1,708,200	-$1,708,200	$0
Outside Slurry Tip Fee		$0	$0	-$210,072	-$210,072	-$210,072	$0
Electricity Offset		$0	-$1,252,170	-$1,775,908	-$1,775,908	-$2,343,225	-$1,760,906
Electricity Incentives (RECs, AECs)		$0	-$306,614	-$434,859	-$434,859	-$573,775	-$431,185
Annual Revenue, $/y		**$0**	**-$1,558,784**	**-$4,129,039**	**-$4,129,039**	**-$5,761,637**	**-$3,118,456**
Total Annual Revenue Cost, $/y		**$0**	**-$1,558,784**	**-$4,129,039**	**-$4,129,039**	**-$5,761,637**	**-$3,118,456**
Net Present Worth							
Total Capital Costs		$0	$69,400,000	$85,000,000	$110,700,000	$104,300,000	$85,700,000
Revenue		$0	-$29,600,000	-$78,400,000	-$78,400,000	-$109,400,000	-$59,200,000
Total O&M Costs		$111,300,000	$67,600,000	$101,400,000	$76,400,000	$111,700,000	$82,600,000
20-year Lifecycle Cost		$111,300,000	$107,400,000	$108,000,000	$108,700,000	$106,600,000	$109,100,000

a cost based on higher heating value

Operations and Maintenance Assumptions for Springfield BioEnergy Feasibility Study

Cost Element	Units	Value in Model	Notes for Baseline Values
Biosolids Hauling and Disposition			
Unclassified solids hauling and disposal (to landfill or incinerator)	$/wt	$105	Assumes 5$/dt annual increase from current Casella contract (averaged)
Class B Biosolids hauling and disposition	$/wt	$80	Assumes 5$/dt annual increase from 2016 NEBRA market study (averaged)
Dried product hauling and disposition	$/wt	$45	Assumes half of dried product disposed of as non-waste fuel source at $10/wt
Digester Assumptions			
Primary Sludge VSR	%	65%	BC project experience
WAS VSR	%	38%	BC project experience
Outside thickened sludge, %VSr	%	50%	BC project experience
Outside cake sludge, %VSr	%	50%	BC project experience
HSW, %VSr	%	85%	BC project experience
Tipping Fees and Revenue			
HSW Tip fees	$/gallon	$0.06	Assumed given recent organic market studies
Imported Cake tip fee	$/wt	$65.00	Assume 65% of local contracts of $100/wt (35% is hauling)
Imported Liquid Sludge tip fee	$/gallon	$0.06	Assumed given recent regional sludge hauling and disposal bids
Electricity Costs			
Electricity Costs (Usage and Demand Charge included)	$/kWh	0.135	Contract Year 2018 (July 17 - Jun 18)
Electricity Usage Offset	$/kWh	0.127	Contract Year 2018 (July 17 - Jun 18)
Electricity Demand Offset	$/kW	3.28	Contract Year 2018 (July 17 - Jun 18)
Electricty for Dewatering	kWh per lb/hr	0.1	calculated given typical centrifuge operation
Electricity for Drying	kWh per lb/hr	0.1	calculated given typical drying operation
Electricity for Biogas Blower and Chiller	% of prod pwr	6%	BC project experience
CHP Unit Availability	%	90%	BC project experience
Class I Renewable Energy Certificates (applied globally)	$/kWh	$0.005	NECEC Analysis of the Massachusetts RPS
Alternative Energy Certificates (applied globally)	$/kWh	$0.026	MassDOER APS CHP AECs Estimator
Electric Utility Cogen Incentives (ICE offset only)	$/kWh	$0.000	Ongoing evaluation
Nat Gas Costs			
Bondi's WWTF Cost	$/MMBtu/hr	$10.67	Provided by Springfield Staff
Chemical Costs			
Digested Centrifuge Usage	lb-Active Poly/dt	25	BC project experience
Existing Centrifuge Usage	lb-Active Poly/dt	16	Provided by Springfield Staff
Centrifuge Polymer Cost	$/lb-Active Poly	1.95	Provided by Springfield Staff
Maintenance Contracts			
Digester cleaning	$/yr	$12,500	$100k every 8 yrs
Dewater maintenance	$/dt	$8	BC project experience
Other Major Equipment - Percent of equipment cost	%	2%	BC project experience
Other Major Equipment - Percent of capital cost	%	15%	Assumes 15% of capital cost attributed to mechnical equipment cost
Enginer-generator O&M, $/kWh	$ per kWh	$0.025	Assumes general maintenance service contract
Gast treatment maintenance, $/kWh	$ per kWh	$0.02	Assumes general maintenance service contract
Labor			
Average Supervisor Labor Cost	$/hr	$54	Provided by Springfield Staff (35% added for benefits to hourly rate)
Economics			
Escalation Rate	%	2.0%	From OMB circular A92 2017
Discount Rate	%	2.5%	From OMB circular A92 2017
Net Rate	%	0.5%	From OMB circular A92 2017
Present Worth Comparion	years	20	
P:A for 20 years		19	P:A formula
Present Worth Comparion	years	15	
P:F for 15 years		0.93	P:F formula

Appendix C: Potential Grants and Incentives

Organization	Program (key words)	Purpose or Use of Funds	How to Apply	Website	Contact
GRANT PROGRAMS					
Economic Development Administration, Department of Commerce	Public Works Program (water, sewer)	This program empowers distressed communities to revitalize, expand, and upgrade their physical infrastructure, and generate or retain long-term, private sector jobs and investment.	Application packages are available at www.grants.gov. Applications will be accepted on an ongoing basis until the publication of a new EDAP FFO.	https://www.grants.gov/web/grants/view-opportunity.html?oppId=306735	Debra Beavin dbeavin@eda.gov 215-597-8719 900 Market Street, Room 602 Philadelphia, Pennsylvania 19107
	Economic Adjustment Assistance Program (water, sewer)	This program assists state and local interests in designing and implementing strategies to adjust or bring about change to an economy. The program focuses on areas that have experienced or are under threat of serious structural damage to the underlying economic base.		https://www.grants.gov/web/grants/view-opportunity.html?oppId=301936	
Department of Housing and Community Development, The Executive Office of Housing and Economic Development	Community Development Block Grant Program (CDBG) (water, sewer)	This program is designed to help small cities and towns meet a broad range of community development needs. Assistance is provided to qualifying cities and towns for housing, community, and economic development projects that assist low and moderate-income residents, or by revitalizing areas of slum or blight.	The CDBG online application and grant management system can be accessed in the Online Business section. First-time users need to contact the CDBG staff at DHCD (617-573-1100) prior to using the online system. Application guidance packages are also available.	https://www.mass.gov/service-details/community-development-block-grant-cdbg	Department of Housing and Community Development 617-573-1100 100 Cambridge Street, Suite 300 Boston, Massachusetts 02114
U.S. Environmental Protection Agency (EPA)	Healthy Communities Grant Program (water, wastewater, stormwater)	The Healthy Communities Grant Program is EPA New England's main competitive grant program to work directly with communities to reduce environmental risks to protect and improve human health and the quality of life. The Water Programs works with regulated entities including municipalities, wastewater systems, and drinking water systems to protect the environment and public health.	Grant solicitations can be found on www.grants.com. To receive the annual application guidance, please contact Sandra Brownell.	https://www3.epa.gov/region1/eco/uep/hcgp.html	Sandra Brownell brownell.sandra@epa.gov 617-918-1797 5 Post Office Square, Suite 100 Boston, Massachusetts 02109
Massachusetts Department of Agricultural Resources	Leading by Example (LBE): Climate Change & Pilot Projects (energy management)	The LBE Program sets aggressive targets for facilities owned and operated by the Commonwealth of Massachusetts regarding greenhouse gas emission reductions, energy conservation and efficiency, renewable energy, green buildings, and water conservation.	For more information on this program, please contact Eric Friedman	https://www.mass.gov/leading-by-example-program	Eric Friedman Eric.Friedman@state.ma.us 617-626-1034 251 Causeway Street, Suite 500 Boston, Massachusetts 02114

Massachusetts Clean Energy Center	Organics-to-Energy Program	Funding is available to both public and private entities for Implementation and Pilot Projects and for Feasibility Studies, and to public entities for Technical Studies/Services. Created in September 2011, Commonwealth Organics-to-Energy supports the development of facilities that convert source-separated organic materials and sewage sludge into heat, electricity and/or compressed natural gas.	◦Feasibility Studies - This solicitation is currently closed. A new solicitation is expected Summer 2018. Please sign up for program updates for Organics to Energy to be notified when it is available. ◦Technical Services/Technical Studies	http://www.masscec.com/innovate-clean-energy/funding-opportunities	Rachel Ackerman Commonwealth Organics-to-Energy organics@masscec.com 617-315-9326
Massachusetts Department of Environmental Protection	Sustainable Materials Recovery Program (SMRP) Municipal Grants	Supports local recycling, composting/organics, reuse, source reduction, program development, and enforcement activities that increase diversion and reduce disposal	MassDEP accepts applications between early April and mid June annually.	https://www.mass.gov/how-to/sustainable-materials-recovery-program-smrp-municipal-grants	Janine Bishop, 617-348-4004 janine.bishop@state.ma.us
	Gap Funding Program	The Baker-Polito Administration today awarded $4 million in grants to 36 drinking water and wastewater facilities across the Commonwealth to help these facilities reduce energy use, increase energy efficiency and generate renewable energy. Awarded through the Gap Funding Grant Program, these grants will expedite implementation of previously assessed energy efficiency and clean energy generation projects at municipal treatment facilities. The program is designed to fill the last "gap" in project financing, enabling facilities to use utility incentives and funds from other sources to build or install selected energy efficiency and clean energy projects. Maxiumum award is $200,000	MassDEP accepts applications		Michael DiBara michael.dibara@state.ma.us 508-767-2885 8 New Bond Street Worcester, Massachusetts 01606
	Clean Energy Results Program (CERP) (energy management)	The Massachusetts Clean Energy Results Program (CERP) is a government-led, statewide partnership of the MassDEP, the DOER, and Mass CEC.This program connects and leverages technical and financial assistance resources from these agencies and other partners (e.g., Mass save – an initiative sponsored by Massachusetts energy efficiency providers) to implement energy efficiency and clean energy development projects at drinking water and wastewater facilities, and other sites.	For more information on this program, please contact Michael DiBara.	http://www.mass.gov/eea/agencies/massdep/climateenergy/energy/	James Doucett james.doucett@state.ma.us 617-292-5868
Ford Foundation	All areas	The Ford Foundation is always open to new ideas, and we welcome your input. Please keep in mind that in relation to the large number of worthwhile submissions we receive, our funds are limited: In a typical year, less than one percent of unsolicited grant ideas result in funding.	Submit your idea through https://www.fordfoundation.org/work/our-grants/idea-submission/	https://www.fordfoundation.org/work/our-grants/ https://www.fordfoundation.org/work/our-grants/idea-submission/	
Organization	**Program (key words)**	**Purpose or Use of Funds**	**How to Apply**	**Website**	**Contact**
LOAN PROGRAMS					

National Rural Water Association	NRWA Revolving Loan Fund (water, wastewater)	The Rural Water Loan Fund (RWLF) is a funding program specifically designed to meet the unique needs of small water and wastewater utilities. The RWLF provides low-cost loans for short-term repair costs, small capital projects, or predevelopment costs associated with larger projects. The RWLF was established through a grant from the USDA/RUS, and repaid funds used to replenish the fund and make new loans.	Applications can be accessed on website. Applications and supporting documents can be sent by mail or email.	http://nrwa.org/initiatives/revolving-loan-fund/	David Kaczenski dkaczenski@massrwa.org 413-498-5779 168 Main Street, Suite 2 Northfield, Massachusetts 01060
Rural Community Assistance Partnership (RCAP)	Communities Unlimited Water/Wastewater Loans (water, wastewater)	Communities Unlimited offers loans with terms up to 15 years for small, rural community water/wastewater projects. Loans enable rural communities to make the necessary repairs and improvements needed to maintain an uninterrupted supply of safe drinking water and wastewater disposal for their customers.	For more information, contact the main office. Applications can be accessed on website. Applications can be sent by email.	https://www.communitiesu.org/index.php/How-We-Help/water-waste-water-loans.html	Communities Unlimited, Inc. info@CommunitiesU.org 479-443-2700 3 East Colt Square Drive Fayetteville, Arkansas 72703
CoBank	Rural Water and Wastewater Lending (water, wastewater)	CoBank works with rural water and wastewater not-for-profit systems, municipalities, and investor-owned utility companies to provide interim and bridge financing, refinance of existing debt, term loans for system upgrades, and lines of credit.	Applications are accepted continuously. To apply, complete an online Loan Request Form at: www.cobank.com/h2oloan	https://www.cobank.com/corporate/industry	Mark Shillingford Water@cobank.com 844-846-3135 6340 South Fiddlers Green Circle Greenwood Village, Colorado 80111
Massachusetts Department of Environmental Protection	Clean Water State Revolving Loan Fund (CWSRF) (sewer)	The SRF Program provides a low-cost funding mechanism to assist municipalities in complying with federal and state water quality requirements. $100,000,000 loan. Some rebate programs with utilities if it's a municipality. 20-yr, 2% loan, solicitation for 2020 will be next June, July into August.	The applicant must be able to file a complete loan application no later than October 15 of the calendar year. Application and financial assistance forms can be accessed on the website.	http://www.mass.gov/eea/agencies/massdep/water/grants/cleanwater-state-revolving-fund.html	Steve McCurdy steven.mccurdy@state.ma.us 617-292-5779 One Winter Street Boston, Massachusetts 02108
USDA Rural Development	Community Facility Loan Program	Mainly a loan program, but for communities of populations of <20,000, interest rate is 3.125%	Application package can be sent out.	https://www.rd.usda.gov/programs-services/community-facilities-direct-loan-grant-program	Anne Correia, USDA Rural Development 15 Cranberry Highway West Wareham, MA 02576 Tel: (508) 295-5151 Ext. 4 anne.correia@ma.usda.gov http://www.rd.usda.gov/ma

Massachusetts Department of Environmental Protection	SRF Clean Water Program	Funding is available for the planning and construction of projects including: CSO mitigation, New wastewater treatment facilities, and upgrades of existing facilities, Infiltration/inflow correction, Wastewater collection systems Nonpoint source pollution abatement projects, such as: Landfill capping, Community programs for upgrading septic systems (Title 5), Brownfield remediation, Pollution prevention, Stormwater remediation In addition, non-structural projects are eligible for SRF funding, such as: Green infrastructure planning projects for nonpoint source, problems which are consistent with the MassDEP's Nonpoint Source Management Plan and that identify pollution sources and suggest potential remediation strategies. An enhanced loan subsidy is also available for certain wastewater nutrient management projects. See details in the documents below.	Apply online at: https://www.mass.gov/lists/state-revolving-fund-applications-forms	https://www.mass.gov/service-details/srf-clean-water-program	Michael DiBara michael.dibara@state.ma.us 508-767-2885 8 New Bond Street Worcester, Massachusetts 01605