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# Technical Memorandum

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Prepared for: City of Bellingham Public Works Department

Project Title: Post Point Biosolids Planning

Project No.: 150048.220.223

**Technical Memorandum No. 2**

Subject: Final Alternative Selection

Date: May 9, 2019

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*Limitations:*

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# List of Abbreviations

| | |
|---|---|
| °F | degrees Fahrenheit |
| % | percent |
| ATAD | autothermal thermophilic aerobic digestion |
| BFP | belt filter press |
| BOD | biochemical oxygen demand |
| CHP | combined heat and power |
| City | City of Bellingham |
| cy | cubic yard(s) |
| d | day(s) |
| DAFT | dissolved air flotation thickeners |
| ERU | equivalent residential unit |
| $ft^3$ | cubic feet |
| gal | gallon(s) |
| gpm | gallons per minute |
| GBT | gravity belt thickener |
| GHG | greenhouse gas |
| gpm | gallons per minute |
| hr | hour(s) |
| kW | kilowatt(s) |
| kWh | kilowatt-hour(s) |
| lb | pound(s) |
| LCFS | Low Carbon Fuel Standard |
| mgd | million gallon(s) per day |
| mm | millimeter(s) |
| MMBtu | one million British thermal units |
| NPW | net present worth |
| O&M | operations and maintenance |
| ppd | pound(s) per day |
| ppm | parts per million |
| Post Point | Post Point Wastewater Treatment Plant |
| Project | Post Point Biosolids Planning Study |
| PSE | Puget Sound Energy |
| RDT | rotary drums thickener |
| RIN | renewable identification number |
| RNG | renewable natural gas |
| rpm | revolutions per minute |
| scfd | standard cubic feet per day |
| SRT | solids retention time |
| SWEET | Solids-Water-Energy-Evaluation Tool |
| TBL+ | triple-bottom-line plus |
| TM | technical memorandum |
| TPAD | temperature-phased anaerobic digestion |
| TS | total solids |
| TSS | total suspended solids |
| USEPA | United States Environmental Protection Agency |
| VS | volatile solids |
| W3 | plant water |
| WAC | Washington Administrative Code |
| WAS | waste activated sludge |
| WT | wet ton |
| WWTP | wastewater treatment plant |



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# Section 1: Introduction

This section provides background on the City of Bellingham's (City's) biosolids planning efforts, summarizes the findings completed to date, and outlines the structure for this Technical Memorandum (TM) No. 2 (TM 2).

## 1.1 Background

The City currently utilizes multiple-hearth furnaces to incinerate wastewater residual solids recovered from the Post Point Wastewater Treatment Plant (Post Point). Because of the age of the existing multiple-hearth furnaces and the desire to employ a more sustainable solids management solution, the City has initiated investigations into alternative means of managing its solids. CDM Smith completed initial preliminary studies in 2010 and 2012, investigating and evaluating a limited number of biosolids management alternatives, and concluded that anaerobic digestion coupled with thermal drying is potentially the best alternative to meet the City's objectives. In 2016, the City retained the Brown and Caldwell/Carollo team for the Post Point Biosolids Planning Study (Project) to further develop and evaluate a comprehensive list of biosolids management alternatives and select a preferred alternative for implementation.

## 1.2 Previous Findings

TM 2 is the second of two documents that describe the alternatives considered for the Project and identifies the preferred alternative for solids management. TM 1 summarized Phase 1 of the Project including the initial screening, the first round of evaluations of all possible alternatives, and selection of a preferred conceptual alternative. TM 1 concluded that anaerobic digestion was the solids stabilization process that best aligned with the City's values and commitments. In addition, it concluded that a process that produces a Class A biosolids material that could be beneficially used locally, with digestion performed at Post Point and final biosolids product manufactured at an off-site location, scored the highest when evaluated using triple bottom line plus (TBL+) criteria.

In Phase 2 of the Project, summarized herein, the preferred conceptual alternative was further developed, specific processes were evaluated (including pre-digestion, digestion, and post-digestion processes), and the preferred final alternative was identified.

## 1.3 Document Outline

To develop and select the preferred final alternative, the sequential evaluation steps were completed in Phase 2 and are documented in the following sections:

1. **Introduction:** Provides background and document outline
2. **Basis of Analysis:** Establishes the basis for the analysis, including a description of TBL+ evaluation criteria developed in Phase 1 of the study and solids projections for sizing new facilities
3. **Conceptual Alternatives:** Identifies the world of possible alternatives for the City to consider and screen to the recommended alternatives for anaerobic digestion, solids handling, biogas end use, and final biosolids product processing components
4. **Development of Alternatives:** Develops packaged alternatives based on the screened components
5. **Solids, Energy, and Greenhouse (GHG) Evaluations:** Evaluates the solids, energy, and GHG gas balances of the packaged alternatives
6. **Cost and Schedule Evaluation:** Provides estimated costs and an implementation schedule for the packaged alternatives as well as the potential local market for a Class A biosolids product



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7. **Phase 2 TBL+ Evaluation Results:** Evaluates the packaged alternatives based on the TBL+ criteria
8. **Findings and Recommendations:** Identifies the preferred final alternative for implementation

Figure 1-1 summarizes the work flow for Phase 2 of the Project.

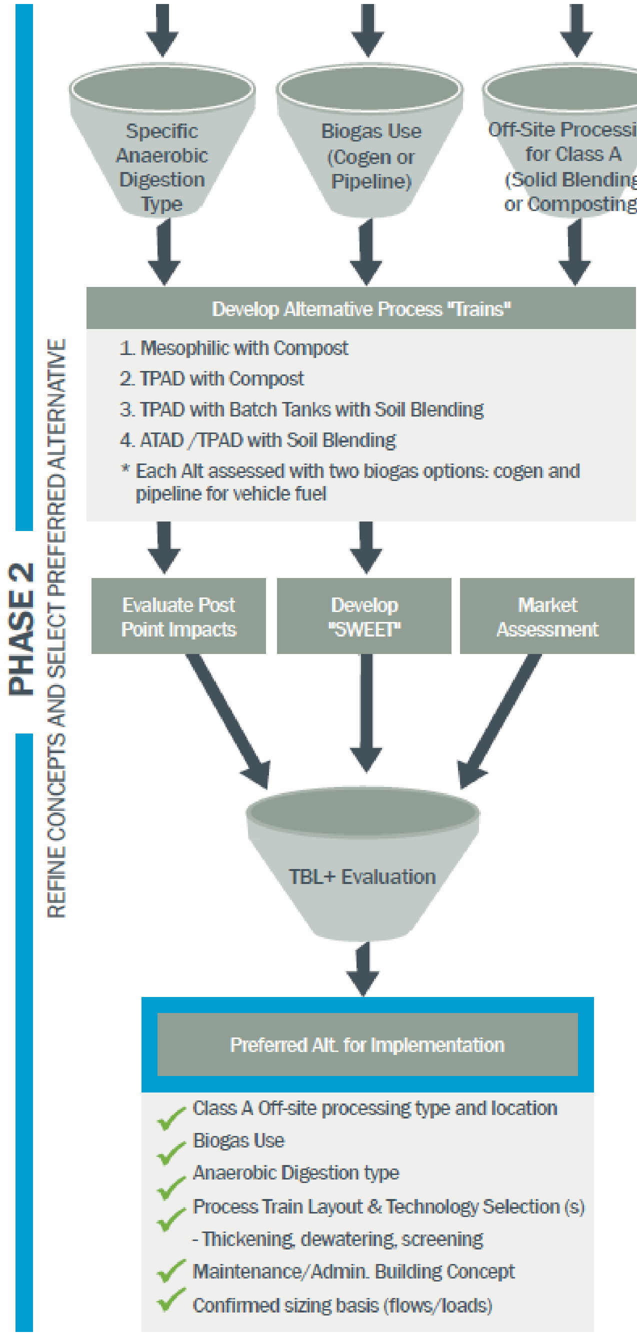


**Figure 1-1. Phase 2 work flow**

# Section 2: Basis of Analysis

This section describes the basis upon which alternatives were analyzed, including the evaluation methodology and projected solids loadings to a new biosolids processing facility at Post Point.

## 2.1 Evaluation Methodology

A TBL+ approach has been used to successfully facilitate community input and communicate decisions in a clear and defensible manner for the City's largest public works projects in recent years. This approach compares and evaluates alternatives based on four considerations that impact projects or programs delivered by a municipal utility: (1) environmental, (2) financial, (3) social, and (4) technical impacts. Input from a variety of stakeholders is included when considering the impacts and values of these four categories.

TBL+ evaluation criteria, based on stakeholder values and the City's published Legacies and Strategic Commitments, were developed for each of the four considerations in Phase 1. These criteria were likewise applied to the refined alternatives evaluated in Phase 2. Consistent with Phase 1, although the number of criteria vary between the categories, the total number of points allowable for each category remains equal (i.e., 25 percent per category). This approach results in no single category having more weight or influence than another.

### 2.1.1 Environmental Criteria

Five environmental criteria were identified to support the City's goal of maintaining a healthy environment and are summarized in Table 2-1.

Table 2-1. Environmental Criteria

| Criterion | Parameter | Supports these Legacy Goals |
|---|---|---|
| E1. Minimizes carbon footprint | Pursues alternatives that emit the lowest levels of GHG | Healthy environment (reduce contribution to climate change) |
| E2. Protects air quality | Reduces air pollutant discharge to minimize human exposure | Healthy environment (protect and restore ecological functions and habitat) |
| E3. Maximizes opportunities for resource recovery | Maximizes beneficial reuse of resources | Healthy environment (conserve natural and consumable resources) |
| E4. Minimizes net energy usage | Minimizes the City's energy use | Healthy environment (conserve natural and consumable resources) |
| E5. Protects and improves local habitat | Maximizes protection of local environmental assets | Healthy environment (protect and restore ecological functions and habitat) |

These criteria reflect the City's strong environmental ethics and priority to improving the local environment. As an example of the preference for local beneficial impacts, a biosolids end use that could be utilized and benefit the local area would be considered more compatible with the City's goals than end uses that benefit distant communities (e.g., eastern Washington agriculture).

### 2.1.2 Social Criteria

Five social criteria were identified to support the City's goal of maintaining a sense of place and preserving access to quality-of-life amenities and are summarized in Table 2-2.



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| Table 2-2. Social Criteria | | |
|---|---|---|
| **Criterion** | **Parameter** | **Supports these Legacy Goals** |
| S1. Minimizes public exposure to noise | Minimize public exposure to noise | Sense of place (support sense of place in neighborhoods) |
| S2. Minimizes public exposure to odor | Minimize public exposure to odors | Sense of place (support sense of place in neighborhoods) |
| S3. Minimizes public exposure to truck traffic | Minimize neighborhood exposure to truck traffic | Sense of place (support sense of place in neighborhoods) |
| S4. Minimizes local visual impacts | Minimizes impact on view corridors and line of sight | Access to quality-of-life amenities (maintain and enhance publicly owned assets)<br>Sense of place (support sense of place in neighborhoods) |
| S5. Minimizes exposure to toxins | Minimizes neighborhood exposure to toxins | Sense of place (support sense of place in neighborhoods) |

The social criteria focus on minimizing impacts to the neighborhoods surrounding Post Point, an area that currently supports social amenities available within the City. For this evaluation, any facilities located off the current Post Point site are assumed to be in a less sensitive area that's appropriately zoned for the use (e.g., a site without immediate neighbors or in a heavy industrial area).

### 2.1.3 Technical Criteria

Four technical criteria were identified to support the City's goals of providing quality responsive services and are described in Table 2-3.

| Table 2-3. Technical Criteria | | |
|---|---|---|
| **Criterion** | **Parameter** | **Supports these Legacy Goals** |
| T1. Incorporates reliability and proven performance | Utilizes a proven process technology<br>Meets technology reliability<br>Maximizes use of stable long-term market or disposal options | Quality responsive City services (deliver efficient, effective, and accountable municipal services)<br>Safe and prepared community (increase community readiness and resilience) |
| T2. Minimizes existing process impacts | Minimizes the solids and nutrient return impact to the liquid stream | Quality responsive City services (deliver efficient, effective, and accountable municipal services) |
| T3. Provides flexibility for future | Minimizes current space requirements<br>Technology allows the City flexibility to adapt to future requirements | Quality responsive City services (deliver efficient, effective, and accountable municipal services)<br>Sense of place (protect natural green settings and access to open space) |
| T4. Minimizes implementation complexity | Implementation complexity related to permitting, public acceptance, and land acquisition, etc. | Quality responsive City services (deliver efficient, effective, and accountable municipal services) |

The technical criteria reflect the City's preference for a reliable treatment process and end use, while also maintaining flexibility, operability, and innovation for resource recovery.

### 2.1.4 Financial Criteria

Three financial criteria were identified to support the City's goal of providing quality, responsive services, and supporting a vibrant and sustainable economy, identified in Table 2-4.



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| Table 2-4. Financial Criteria | | |
|---|---|---|
| Criterion | Parameter | Supports these Legacy Goals |
| F1. Optimizes system value | Provides balanced ROI using TBL+ criteria over 50-year life | Quality, responsive City services (deliver efficient, effective, and accountable municipal services) |
| F2. Affordability | Consistent with long-term financial, environmental, and social goals of utility | Vibrant sustainable economy (support a thriving local economy across all sectors and promote inter-dependence of environmental, economic, and social interests) |
| F3. Minimizes risk of end-use market sensitivity | Limits risk or maximizes benefits from commodity market changes of end-use products | Quality, responsive City services (deliver efficient, effective, and accountable municipal services) |

These criteria represent the City's commitment to implementing a solution that effectively meets its financial capabilities while minimizing commodity market risks.

## 2.2 Solids Projections and Sizing Criteria

To properly evaluate alternatives, a basis for sizing the new equipment and processes is needed. The solids projections developed and documented in Phase 1 were also used in Phase 2 and serve as a conservative basis for preliminary project sizing. The projections are based on a dynamic BioWin V.5.0 wastewater treatment process model calibrated to a year of historical plant influent, primary effluent, and waste activated sludge (WAS) load data from April 25, 2016 through April 24, 2017. Refer to TM 1 for a more detailed description of how solids projections were developed.

Table 2-5 lists the influent total suspended solids (TSS) and biochemical oxygen demand (BOD) plant load in pounds per day (ppd) observed in 2016 and projected for 2025 (the planned beginning of operation for a new solids facility) and 2045 (the Project design year). Observed influent flows and loads have been relatively consistent over the last five years and 2016 was considered representative of current conditions.

| Table 2-5. Observed and Projected Solids Loads | | | | |
|---|---|---|---|---|
| Year | Annual Average BOD, ppd | Maximum Month BOD, ppd | Annual Average TSS, ppd | Maximum Month TSS, ppd |
| 2016 | 20,600 | 23,300 | 25,500 | 30,700 |
| 2025 | 24,800 | 30,700 | 30,100 | 36,900 |
| 2045 | 34,400 | 42,500 | 37,700 | 51,100 |

Historical records establish the starting basis for planning projections and model calibration. A review of the solids mass balance around the primary clarifier is typically the first and most straightforward step to confirm whether there are data anomalies that must be resolved. Review of historical records between April 2016 to April 2017 found the sum of the measured primary solids and primary effluent TSS loads to be significantly lower than the influent TSS loading measured and recorded at the raw sewage composite sampler between the influent screens and the grit basins.

The combined sludge projections developed in Phase 1 of the planning project (and shown in Table 2-6) were based on the more conservative influent solids loading, as the accuracy of the primary solids loading records may have been limited due to the nature of the sampling processes. Over the past year, City staff have been verifying historical records as well as field verifying measurements. The results will be documented in the next phase of work, including an adjustment of facilities sizing, if warranted. For Phase 2,



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influent solids loading continued to be used as the basis of the sludge production projections which provides up to a 20 percent conservative estimation of sludge production.

| Table 2-6. Combined Sludge Projections | | | | | | |
|---|---|---|---|---|---|---|
| Year | Average Annual | Max Month | Max Two Week | Max Week | Max 3 Day | Max Day |
| TSS Load, ppd | | | | | | |
| 2025 | 40,800 | 46,900 | 48,500 | 53,700 | 61,000 | 84,800 |
| 2045 | 56,300 | 64,500 | 66,800 | 73,800 | 83,100 | 117,600 |
| Volatile Suspended Solids Load, ppd | | | | | | |
| 2025 | 35,700 | 40,200 | 40,200 | 40,900 | 50,900 | 68,800 |
| 2045 | 49,100 | 55,400 | 56,700 | 55,200 | 68,000 | 93,400 |

# Section 3: Conceptual Alternatives

At the conclusion of Phase 1, the preferred conceptual alternative was identified. Phase 2 involves further refining the preferred conceptual alternative to identify the preferred specific components of the final alternative. This section describes the alternative anaerobic digestion, solids handling, biogas end use, and final product processing components, and recommends an alternative component(s) for further detailed evaluation.

## 3.1 Anaerobic Digestion Alternatives

Anaerobic digestion was selected during Phase 1 as the preferred means of stabilizing the residual solids from the Post Point treatment process. There are several approaches to anaerobically digesting solids. To facilitate the selection of a final anaerobic digestion process, each digestion approach is described below, and a shortlist of alternatives is identified for detailed analysis.

### 3.1.1 Mesophilic Anaerobic Digestion

Mesophilic digestion is the most commonly used anaerobic digestion process in the United States. Mesophilic digesters are operated within the mesophilic temperature range, 95 to 102 degrees Fahrenheit (°F), at SRTs exceeding 15 days. Typically, loading criteria range from 100 to 160 pounds of volatile solids (lb-VS) per 1,000 cubic feet ($ft^3$) per day (d) with limiting loadings rates of 200 lb-VS/1,000-$ft^3$/d. Figure 3-1 is a photograph of a mesophilic anaerobic digester operated by the King County Wastewater Treatment Division at the Brightwater Treatment Plant (near Woodinville, Washington).



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**Figure 3-1. Mesophilic anaerobic digester at Brightwater Treatment Plant**

Mesophilic digestion produces a Class B biosolids as defined by the United States Environmental Protection Agency's (USEPA) Part 503 regulations, suitable for most large-scale agricultural, forest, and mine reclamation applications. However, for small-scale public use, biosolids require further processing to produce a final Class A product.

### 3.1.2 Thermophilic Anaerobic Digestion

Thermophilic digestion occurs at temperatures between 120 and 135°F, at conditions suitable for thermophilic microorganisms. Biochemical reactions increase with temperature; therefore, microbial reactions in thermophilic digestion are much faster than mesophilic digestion. The advantages of thermophilic digestion include increased solids destruction capability, improved dewatering, increased gas production, and increased pathogen destruction. Because of the increased biochemical reaction rate, loadings to a thermophilic digestion have been reported as high as 450 lb-VS/1,000-ft$^3$/d, significantly higher than those of mesophilic digesters.

Disadvantages of thermophilic digesters include higher energy requirements for heating, poorer supernatant quality, and higher initial odors. Higher solids destruction rates in a thermophilic digester release greater concentrations of ammonia which contributes to the poorer supernatant quality, potentially impacting the plant's liquids steam processes. Thermophilic digestion also requires additional heat exchangers and heat resources relative to mesophilic digestion to heat the digester to higher temperatures; however, heat recovery heat exchangers can greatly reduce heating costs. Figure 3-2 is of the thermophilic digesters operated by Metro Vancouver at the Annacis Island Wastewater Treatment Plant (WWTP) in Delta, British Columbia.



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**Figure 3-2. Thermophilic anaerobic digesters at Annacis Island WWTP**

If properly configured, thermophilic digestion is capable of producing Class A biosolids. To prevent the potential for short-circuiting and increased pathogen levels above the Class A criterion in the digested sludge, batch tanks are used. The sludge is held in a batch tank for a set period of time (24 hours hold time required for Class A at 131°F) to prevent the opportunity for any sludge to pass through the entire digestion process in a shorter time period than required (i.e., short-circuiting the process). To meet USEPA requirements for Class A biosolids, separate batch tanks (or batch operation of the digesters) would need to be included with a thermophilic digestion process. Without batch tanks, the biosolids from a thermophilic digestion process operated at higher temperatures can potentially produce low pathogen sludge, meeting Class A requirements, but would require testing of each biosolids batch to prove the pathogen levels are in line with Class A requirements.

### 3.1.3 Temperature-Phased Anaerobic Digestion

Temperature-phased anaerobic digestion (TPAD) incorporates the advantages of thermophilic digestion and mitigates some of the disadvantages through the incorporation of mesophilic digestion to improve performance. TPAD utilizes digesters in series, where the first stage is thermophilic followed by a mesophilic stage. The high biochemical reaction rate in the thermophilic phase improves solids destruction capability, improves dewaterability of the sludge, increases gas production, and increases pathogen destruction rates. The following mesophilic stage(s) improves the performance of the digestion efficiency and mitigates the disadvantages of thermophilic digestion (specifically, poorer supernatant quality and odors). The higher temperature of the thermophilic stage and configuration's ability to minimize short circuiting contributes to greater pathogen destruction. Similar to thermophilic digestion, a greater number of heat exchangers and heat resources are required to heat the sludge to thermophilic temperatures and then cool the sludge to mesophilic temperatures. Figure 3-3 is a photograph of the TPAD system at Western Lake Superior Sanitary District's WWTP in Duluth, Minnesota.



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Figure 3-3. TPAD at Western Lake Superior Sanitary District WWTP

Similar to the thermophilic-only process, TPAD is capable of producing a Class A biosolid through the use of batch tanks.

### 3.1.4 Acid/Gas Phased Digestion

The acid/gas digestion process utilizes two reactors in series to separate the anaerobic digestion phases, the formation of acids (acidogenesis), and the generation of gas (methanogenesis) to improve process performance. In the first stage, solubilization of organic matter occurs and volatile acids are formed. The first stage is operated at a short SRT to promote the formation of acids (typically 1.5 to 2.5 days). The second stage is operated as either a mesophilic or thermophilic digester, in which volatile acids from the first stage are converted to gas. The separation of the anaerobic digestion phases results in improved solids reduction, increased gas production, reduced potential for foaming, and improved pathogen destruction. One disadvantage of acid/gas digestion is the generation of significant volatile acid odors in the first stage; therefore, the acid phase requires complete containment and odor control for any vent gases. The headspace of the acid phase is often connected to the digester gas system, limiting odors to emergency venting from vessel pressure/vacuum release valves and during cleaning.

Acid/gas digestion, if configured with thermophilic gas phase digesters and batch tanks, can achieve Class A biosolids. However, the thermophilic stage produces the majority or all of volatile solids reduction from acid digestion and obviates the need for the acid phase digesters. For this reason, acid/gas phase digestion systems are normally configured with mesophilic digesters and do not produce Class A biosolids.

### 3.1.5 Autothermal Thermophilic Aerobic Digestion Plus Temperature-Phased Anaerobic Digestion

Aerobic digestion was eliminated from consideration as the primary means of solids stabilization in Phase 1 of the Project; however, coupling aerobic digestion as an additional phase in the main anaerobic digestion process has some benefits. Autothermal thermophilic aerobic digestion (ATAD) achieves thermophilic temperatures by maintaining sufficient levels of oxygen and mixing to allow aerobic microorganisms to degrade volatile solids and release heat. When operating in batch mode, the ATAD process can meet USEPA's time-temperature requirement to produce Class A biosolids. Figure 3-4 is a photograph of the ATAD and TPAD system at the Central Treatment Plant in Tacoma, Washington.



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**Figure 3-4. ATAD and TPAD facilities at the City of Tacoma's Central Treatment Plant**

When coupled with anaerobic digestion, the SRT of the ATAD process can be as low as 1 to 2 days when utilizing pure oxygen to aerate the sludge. When air is used instead (which is only 21 percent oxygen), the SRT required to achieve autothermal conditions is on the order of 4 days. Most volatile solids degradation then takes place in the anaerobic phase; the longer SRT when using air instead of pure oxygen results in higher volatile solids destruction in the aerobic phase (and therefore reduced methane generation in the anaerobic phase).

The main benefits of coupling ATAD with TPAD are reduced heating requirements for the anaerobic phase, increased overall volatile solid reduction, and less odorous biosolids. The disadvantages of coupling ATAD with TPAD include higher capital costs (more tanks) and higher operating costs associated with the aeration required for the ATAD process. The ATAD process can achieve Class A standards via high-temperature, batch aeration process.

### 3.1.6 Post-Aerobic Digestion

With the post-aerobic digestion process, an aerobic digestion phase is added after the anaerobic digestion phase. Aerobically digesting solids that have already been anaerobically digested increases volatile solids reduction, reduces the strength of return streams to the liquid stream process, and results in less odorous biosolids. Disadvantages of post-aerobic digestion is the increased energy requirements for aerating the digested sludge and increased capital costs and site footprint for the additional process. For utilities with high biosolids end-use costs, the increased volatile solids reduction can decrease the costs to the utility. Because the increased volatile solids reduction happens aerobically, there is no associated increase in methane generation.



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The class of biosolid produced by this process is dependent on what type of anaerobic digestion process proceeds the post-aerobic stage. If thermophilic digestion or TPAD is utilized with batch tanks, a Class A biosolid can be produced. However, as with acid/gas digestion, the thermophilic stage would capture most of the increase in volatile solids reduction, reducing the benefit of the post-aerobic phase.

### 3.1.7 Recommended Alternatives for Further Evaluation

For the evaluation of final alternatives, three anaerobic digestion alternatives were selected for further detailed analysis. Based on the relative benefits and disadvantages, acid/gas phased digestion and post-aerobic digestion were not recommended for more detailed analysis. The significant increased potential for odors from an acid phase digester and the inability to produce Class A biosolids without a thermophilic stage are considered drawbacks of this process. The limited benefit to the City of the modest increased volatile solids reduction provided by the post-aerobic digestion process, while consuming valuable site space and energy, are the main disadvantages of post-aerobic digestion. These drawbacks led to the recommendation of eliminating these alternatives from more detailed evaluation. Considering both processes involve an add-on process stage to conventional mesophilic digestion, either could be added later if their benefits warranted additional processing.

Mesophilic digestion is the most common workhorse of the wastewater digestion industry and produces a well stabilized Class B biosolids suitable for most large land application programs. For these reasons it was retained for more detailed evaluation. Thermophilic anaerobic digestion is a viable alternative with the ability to produce Class A biosolids; however, for evaluation purposes, TPAD was considered a preferable process. TPAD has all the benefits of a thermophilic-only process and eliminates some of the disadvantages at only a minor increase in cost and complexity. ATAD/TPAD has the ability to produce Class A biosolids and the potential for reduced heating requirements for the anaerobic stage make it a promising alternative for further evaluation. As a result, mesophilic anaerobic digestion, TPAD, and ATAD/TPAD were recommended for further detailed analysis.

## 3.2 Solids Handling Components

In addition to the core stabilization process, a new digestion facility at Post Point will require additional solids handling components including screening, thickening, dewatering, and struvite management. The following sections describe the alternatives considered for these solids handling components and the recommended approach for the detailed evaluation.

### 3.2.1 Screening

Washington Administrative Code (WAC) Chapter 173-308-205 (known as the inerts rule) requires the removal of manufactured inert material larger than 3/8-inch from biosolids prior to beneficial use. Additionally, the biosolids must contain less than 1 percent by volume recognizable manufactured inerts to be land applied. Screens are the most commonly applied physical barrier to achieve compliance with this requirement. Screening may occur at any point in the treatment process; the two most common screening locations are wastewater influent screening and sludge screening.

Options for meeting this requirement at Post Point are described below along with a recommended approach.



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### 3.2.1.1 Influent Screening

Post Point's current preliminary treatment process includes three bar screens that screen raw sewage through 5/8-inch openings. Screened material is collected by an automatic cleaning mechanism for disposal. The City could replace the existing bar screens with smaller aperture bar spacing to comply with the inerts rule. Several types of screens could be considered to accommodate the existing channel dimensions, overhead clearance, and hydraulic requirements. Figure 3-5 below illustrates a multi-rake screen.

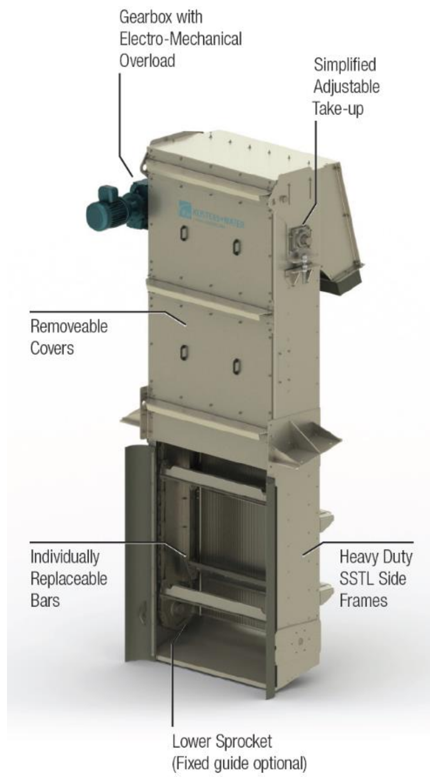


**Figure 3-5. Typical influent screen**

Preliminary hydraulic calculations indicate the existing bar screens can be replaced with new screens to meet WAC requirements without significantly modifying the channel dimensions. Based on preliminary investigation, curved or multi-rake screen configurations appear to be most suitable. Additional headloss through screens with a smaller opening may result in surcharges within the screenings channel during peak flows. This may be addressed by adjusting the existing weir elevations to avoid structural modifications to the screenings building. Additional analysis of hydraulic and space requirements would be necessary prior to implementing this approach.

### 3.2.1.2 Sludge Screening

Sludge screens can be installed in either a pressurized or open channel configuration. Pressurized sludge screens consist of a cylindrical screen with an integral screw conveyor and screenings press. A single drive is used for screening, conveying, dewatering, and compressing the screening material. These screens are mounted in a horizontal configuration, facilitating screenings collection and disposal.

The sludge screens could be installed in the existing solids handling building with modifications to accommodate piping, hoppers, and screenings removal. The co-thickened primary and secondary sludge would be pumped to the sludge screens prior to being sent to the digesters. Figure 3-6 shows pressurized screens installed at the Lulu Island Treatment Plant in Richmond, British Columbia.


**Figure 3-6. Lulu Island Treatment Plant sludge screens**

### 3.2.1.3 Recommendation

Based on preliminary analysis, both screening alternatives have similar constructions costs. Sludge screening was selected as the basis for the Phase 2 planning because of improved screenings performance and associated biosolids quality. This alternative also has less risk relative to the alternative that requires retrofitting the existing influent screens while the preliminary treatment process remains in service.

Table 3-1 summarizes the benefits and drawbacks of the two screening options.

**Table 3-1. Comparison of Screening Options**

| Parameter | Replace Influent Screens[1] | Add Sludge Screening[1] |
|---|---|---|
| Number | 3 duty | 1 duty, 1 standby |
| Material Handled | Raw sewage | Co-thickened sludge (3 to 5-percent solids) |
| Capacity | 24 mgd, each (approximately 17,000 gpm) | 350 gpm, each (approximately 0.6 mgd) |
| Benefits | • Inerts screened at head of plant, protecting inerts from clogging or damaging downstream processes<br>• Requires modest increase in O&M attention as compared to current screens<br>• Minor modifications to the existing screenings facility | • Minimal likelihood of inerts being introduced back into solids prior to digestion<br>• Enclosed process, minimizing odor issues<br>• Typically specified with 10 mm screen opening, enhancing inserts removal.<br>• Sized for sludge flow only |



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| Table 3-1. Comparison of Screening Options | | |
|---|---|---|
| Parameter | Replace Influent Screens[1] | Add Sludge Screening[1] |
| Drawbacks | • Inerts, such as rags, tend to accumulate during high influent flows<br>• Refined hydraulics analysis will be needed to define extent of impact on existing up and downstream water surface elevations<br>• Debris that is dropped or blows into exposed liquid stream tanks can contaminate sludge stream; i.e. rags, plastic bags, leaves, shells, etc.<br>• Sized for entire liquid stream flow | • Inlet feed susceptible to clog with rags and other large debris<br>• Requires addition O&M attention for equipment and screenings disposal<br>• Adds to footprint required for processes in the solids handling building[2] |

1. *Modifications are limited to equipment replacement. Structural modifications that would trigger building code upgrades or permits are not anticipated at this time.*
2. *Disadvantages as compared to the other alternative. Influent screens would replace existing screens.*

### 3.2.2 Solids Thickening

Primary and secondary sludge captured as part of the wastewater treatment process typically have solids concentrations that are between 0.5 and 2 percent but vary depending on the treatment processes used, type of sludge, process flow rate, and method of operation. Prior to solids stabilization, it is common to use a sludge thickening process to reduce the water content and sludge volume to be fed to digestion. Sludge thickening provides several benefits including increased capacity of tanks and equipment and reduced quantity of heat required to heat sludge for digestion.

The performance of a thickening process is typically measured by the total percent solids it can achieve in the thickened sludge and the percentage of solids that are captured in the process. The amount of polymer and power required to achieve that performance, as well as process footprint, operability, and cost, are also used to compare alternatives. Solids not captured in the thickening process are returned with the removed liquid to the liquid stream treatment process; thus, improved solids capture reduces the quantity of solids that are treated repeatedly.

Primary technologies used for sludge thickening are centrifuges, dissolved air flotation thickeners (DAFTs), gravity thickeners, gravity belt thickeners (GBTs), membrane thickeners, and rotary drums thickeners (RDTs). Each is described in more detail below. The relative advantages and disadvantages of co-thickening primary and secondary sludges together versus separately are described as well.

#### 3.2.2.1 Centrifuge Thickeners

Centrifuges can be used to thicken or dewater sludge. Centrifugal thickening uses high-speed rotation inside a cylindrical bowl to separate solids from liquid based on the differential density of the two materials. Figure 3-7 shows a typical cross section of a centrifuge, consisting of an outer bowl and an inner scroll. The bowl spins at several thousand revolutions per minute (rpm), creating the centrifugal forces needed for separation, while the scroll located inside the bowl spins at a slightly slower speed, conveying solids from one end to the other. Typically, the centrifuge includes a “beach” which helps further dry the solid material. The removed water (referred to as centrate) discharges from the opposite end of the unit. Polymer addition is common with centrifuges to improve the performance of the unit.

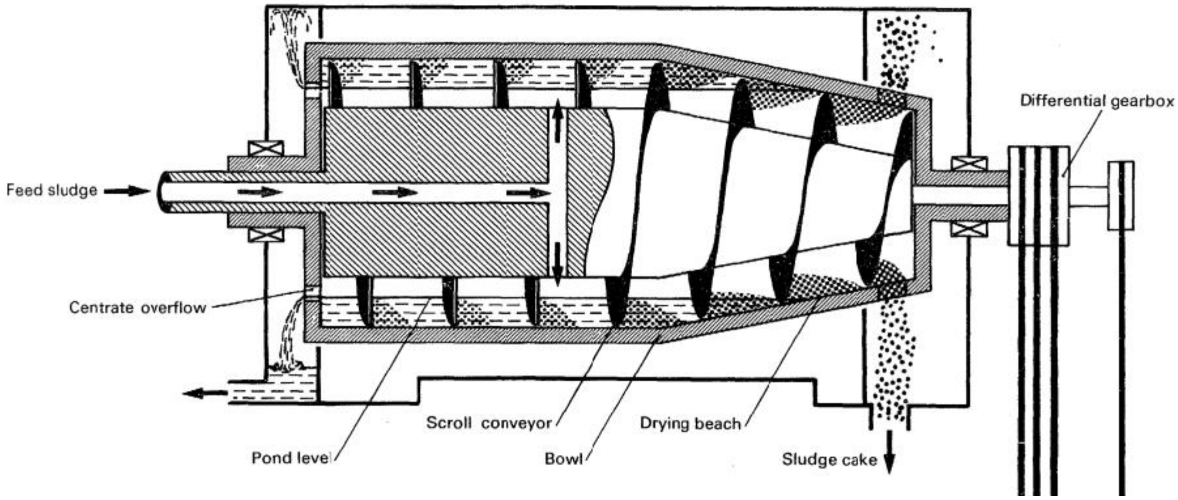


Figure 3-7. Typical centrifuge cross section

For thickening centrifuges, a thickened sludge solids content of 4 to 9 percent is typical. Solids capture are typically between 85 and 95 percent. The main advantages of centrifuge thickening are the high solids content, small footprint, and low odor potential. The main disadvantages are the high noise and power consumption.

#### 3.2.2.2 Dissolved Air Flotation Thickeners

A DAFT thickening process involves adding pressurized air to the feed sludge ahead of a DAFT tank. When the pressure is released in the tank, small air bubbles form and solid material in the sludge attaches to the bubbles and floats to the surface where solids are captured as thickened sludge by a skimmer. A DAFT tank at the Lulu Island WWTP in Richmond, British Columbia, is shown below in Figure 3-8.

Figure 3-8. Lulu Island WWTP DAFT tank



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DAFTs can typically capture 85 to 95 percent of the solids and achieve a solids content of 4 to 6 percent. The main advantages of a DAFT is their relative insensitivity to changes in hydraulic loading and ability to readily accept and remove scum streams from within the treatment plant. The main disadvantages are the high-power consumption required for the DAFT compressors, large footprint, the increased potential for odors, and the relatively low solids concentration in the thickened sludge. DAFTs are also not well suited for thickening primary sludge alone and are typically reserved for only thickening waste secondary sludge or co-thickening both sludge streams.

#### 3.2.2.3 Gravity Thickeners

Gravity thickeners separate solids from water through the tendency for higher-density solids material to settle to the bottom of a tank, similar to liquid stream clarifiers. Solids are allowed to settle and concentrate in a large circular tank with a sludge collection mechanism for solids removal on the bottom of the tank. Figure 10 shows a gravity thickener at the Lulu Island WWTP in Richmond, British Columbia

**Figure 3-9. Lulu Island WWTP gravity thickener**

Gravity thickeners typically achieve a solids concentration of 2 to 4 percent with a solids capture of approximately 90 percent. The main advantages of a gravity thickening process are minimal system complexity, low power consumption, and cost. The main disadvantages are the large footprint required, increased potential for odors, and relatively low solids concentration and solids capture. Because primary sludge and waste secondary sludges settle at different rates (with primary sludge settling quicker than secondary sludge), gravity thickeners are not typically used for co-thickening sludge and are rarely used for secondary sludge. Most gravity thickening installations are for primary sludge only.

#### 3.2.2.4 Gravity Belt Thickeners

The City currently uses GBTs to co-thicken the plant's primary sludge and WAS. A GBT spreads sludge, often flocculated by polymer, along a porous belt where water drains by gravity through the belt, thickening the sludge. The belt moves over rollers driven by a variable-speed drive and is cleaned by wash water. Figure 3-10 is a photograph of the existing GBT installation at Post Point.

Figure 3-10. Post Point GBT

GBTs can achieve typical solids concentrations of 4 to 7 percent, with a solids capture of approximately 95 percent. The main advantages of using GBTs are the low power consumption and the relatively simple operation. The main disadvantages are the large volume of wash water required during operation, high polymer consumption, and the need for odor control over the open belt. GBTs can be used for separate thickening of primary and secondary sludges and for co-thickening of combined sludges.

#### 3.2.2.5 Membrane Thickeners

Membranes have typically been used as a means of liquid-stream treatment, but recent applications have used similar equipment to thicken sludge. In this process, sludge is pumped into a membrane tank and water (permeate) is extracted through the membranes. Once the maximum liquid level in the tank is reached, the thickened sludge will overflow and be pumped to the digesters. Similar to the use of membranes in liquid-stream treatment, membrane thickening is sensitive to grease and gritty materials; therefore, it is not suited for thickening primary sludges.

Membrane thickeners can produce sludge up to 4 percent solids concentration without the use of polymer and have very high capture rates as the solid material is not able to permeate through the membranes. The main advantage of using membrane thickening is the high solids capture rate and the ability to perform without the use of polymer. The main disadvantages are the low solids concentration output and the limited application to high SRT secondary sludges only.

#### 3.2.2.6 Rotary Drum Thickeners

RDTs thicken sludge using gravity drainage similar to gravity belt thickeners. Sludge is pre-treated with polymer in a flocculation tank before entering the rotary drum. The rotary drum is a rotating cylindrical screen the water in the sludge drains through while the sludge is retained. The thickened solids are transported out of the drum by a spiraling flight built into the drum. Figure 3-11 is a photograph of an RDT at Kitsap County’s Suquamish WWTP.



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Figure 3-11. Suquamish WWTP RDT

An RDT can achieve similar performance as a GBT with solids concentrations ranging from 4 to 7 percent and solids capture typically at or above 95 percent. The main advantages of an RDT system is the small footprint, low power consumption, low maintenance, and ability to contain odors from the process. The main disadvantages are the need for polymer and wash water consumption to maintain good performance. RDTs can be used for separate thickening of primary and secondary sludges and for co-thickening of combined sludges.

#### 3.2.2.7 Co-thickening

There are two approaches to thickening sludges from a secondary treatment process prior to digestion: separate thickening for primary and secondary sludges and co-thickening both sludges together. The City currently co-thickens primary and secondary sludges in the existing GBTs. The most significant benefits of co-thickening are less thickening equipment is needed (compared to separate thickening) and often greater solids concentrations can be achieved.

As described in the previous sections, some thickening technologies are not well suited for thickening either primary or secondary sludges. When co-thickening the two sludge types, the technology must be well suited for both which can limit the suitable technologies from which to choose.

#### 3.2.2.8 Recommendations

As described in earlier sections, the City's current incineration process already includes a thickening step prior to incineration, utilizing GBTs to co-thicken primary sludge and WAS. Table 3-2 lists the characteristics of the existing thickening equipment.



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| Table 3-2. Characteristics of Existing Thickening Equipment at Post Point | |
|---|---|
| **Parameter** | **Thickening** |
| Technology | Gravity Belt |
| Number of Units | 2 |
| Installed | 1992 |
| Capacity | |
| Hydraulic Loading (gpm) | 600 |
| Solids Loading (lb/hr) | 4,850 |
| Solids Concentration (%-TS) | 5 |

Table 3-3 provides the thickening design criteria proposed for the solids facility at Post Plant.

| Table 3-3. Proposed Design Criteria for Thickening Equipment | | |
|---|---|---|
| **Parameter** | **Criteria** | **Comments** |
| Number of Units | n+1 | One redundant unit |
| Firm Capacity, total | | |
| Hydraulic Loading (gpm) | 680 | Represents peak day flow |
| Solids Loading (lb/hr) | 5,000 | Represents peak day load |
| Solids Concentration (%-TS) | 5 | Assumed |

The existing GBTs cannot meet the proposed design criteria while maintaining a fully redundant unit. Combined with the age of the existing units, this indicates that the GBTs would need to be replaced before the design year (2045) is reached. The decision on whether to reuse the existing equipment is also influenced by construction sequencing and the final facility layouts. During construction of the new solids facilities, it will be necessary to maintain operation of the existing incineration process until the new digestion process has been started and reaches a stable process state. As such, relocation of the existing thickening equipment is not recommended.

Of the technologies described in Section 3.2.2, GBTs and RDTs are best suited for the City's needs. These technologies provide superior performance within a limited footprint and have low maintenance requirements and power demand. In addition, both are well suited for thickening primary and secondary sludges, providing the City with the option to co-thicken. Manufacturers for the two thickening technologies were contacted to compare more detailed size and cost information. The RDT option would provide identical performance to the GBT option at a lower cost, smaller footprint, and would be contained, simplifying odor control. As a result, new RDTs are recommended for inclusion in the Post Point comprehensive biosolids alternatives with the provisions for co-thickening primary and secondary solids.

Reuse of the existing thickening equipment is an option but would require a phased replacement before the end of the design period once the existing units either reach the end of their useful life or cannot meet the redundancy needs of the observed solids loads. Stress tests of the existing GBTs will be conducted this spring to determine their capacity. For this evaluation, replacement of the existing units with a new thickening process is assumed.

The recommendation to replace existing thickeners with RDTs for co-thickening will be further evaluated in conjunction with Operations staff input during development of the Facility Plan in Phase 3 of the Project.

### 3.2.3 Solids Dewatering

After a digestion process, biosolids are generally dewatered to reduce the water content in the solids; therefore, reducing transportation and beneficial use costs. The dewatered biosolids product is commonly referred to as 'cake.' Similar to thickening systems, the performance of a dewatering process is typically measured by the solids content of the dewatered cake and the solids capture of the process (i.e., the amount of solids that are not recycled to the liquid stream treatment process in the removed water). The primary technologies used for dewatering are belter filter presses (BFPs), centrifuges, rotary presses, and screw presses. These technologies are described in more detail below.

#### 3.2.3.1 Belt Filter Presses

BFPs are a similar technology to GBTs and consist of layers of belts used to dewater biosolids. The sludge is first conveyed onto a belt that allows water to drain by gravity. In the second stage, the biosolids are pressed between two belts to force excess water out. Odor containment and control and additional wash water are required. Figure 3-12 is an image of a typical BFP.

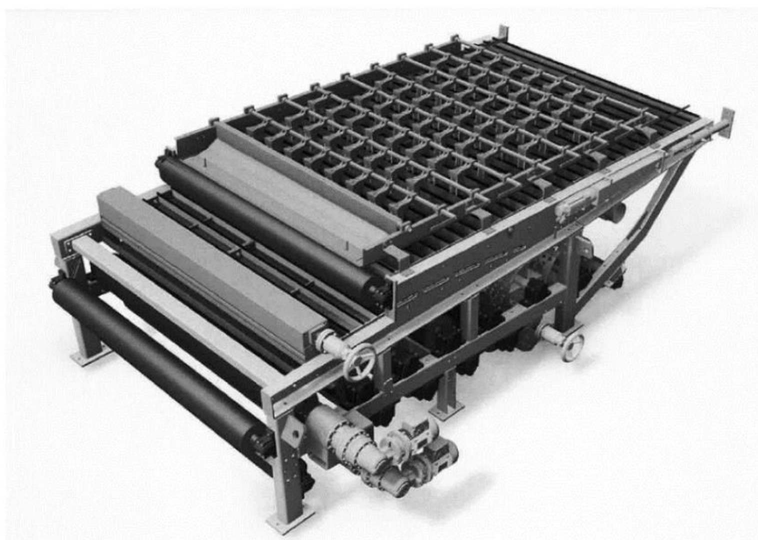

**Figure 3-12. BFP drawing**

*Courtesy of Andritz.*

When using polymer, BFPs can typically produce cake with 18 to 23 percent solids content with a solids capture of 95 percent. The main advantages of using BFPs are the low power consumption and relatively simple operation. The main disadvantages are the high wash water requirements, increased potential for odors, and the lower cake solids percentage compared to other technologies.

#### 3.2.3.2 Centrifuges

The City currently utilizes centrifuges to dewater thickened sludge prior to the incineration process. As with thickening centrifuges previously discussed, centrifuges use high speed rotation (several thousand rpm) to separate solids from liquid. The cake is discharged to the end of the centrifuge using an internal scroll conveyor. Figure 3-13 is a photograph of one of the existing dewatering centrifuges installed at Post Point.



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Figure 3-13. Post Point dewatering centrifuge

When using polymer, centrifuges can typically produce cake with 20 to 30 percent solids content and a solids capture rate of 95 percent. The main advantages of using centrifuges are the high solids concentrations that can be achieved in a relatively small footprint. The main disadvantages are high energy consumption, high operating costs, relatively loud equipment operation, and high polymer requirements.

A potential disadvantage to using centrifuges for dewatering is the risk of pathogen regrowth in the cake. Recently, some facilities that dewater using high-speed centrifuges have observed regrowth of indicator organisms of pathogens (i.e., fecal coliform) after dewatering, which could result in the final biosolids product being unclassified (losing Class B status) or dropping classification from a Class A to a Class B product. This is believed to be caused by the high shear induced within the centrifuge increasing the availability of organic material for consumption by active organisms remaining in the cake. This can result in a marked increase in indicator organisms present in the dewatered cake within a few hours of dewatering, normally tapering off within a few days.

Regrowth has not been observed in all facilities that use centrifuges for dewatering; e.g., the Annacis Island WWTP operated by Metro Vancouver, British Columbia, and the Western Lake Superior Sanitary District WWTP in Duluth, Minnesota, use thermophilic digestion have not seen regrowth. Of facilities that have observed regrowth, only regrowth of indicator organisms has been observed and some, such as the Hyperion WWTP in Los Angeles, California, have made process changes to reduce the potential for regrowth. At this time, the potential for regrowth is not well understood by the industry but is considered a risk, not a fatal flaw, of using centrifuges to dewater biosolids.

#### 3.2.3.3 Rotary Presses

Rotary presses are a relatively new technology used to dewater biosolids. A rotary press feeds polymer-dosed biosolids into a channel and moves it between two parallel rotating filter elements. The filtrate passes through the filter elements and discharges at the bottom of the unit as the flocculated biosolids moves through the channel. The biosolids continue to dewater as they pass around the channel, eventually forming cake at the outlet side of the press. Figure 3-14 is a photograph of rotary presses installed at North Liberty WWTP in Iowa.



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Figure 3-14. Rotary Presses at North Liberty Treatment Plant

Rotary presses can produce cake with solids contents between 18 to 26 percent. The main advantages are the low odor potential, small footprint, and low power consumption. The main disadvantages are the low solids concentration achieved and their relatively limited existing applications at wastewater treatment facilities.

#### 3.2.3.4 Screw Presses

A screw press consists of a flocculation tank and tapered screw with a surrounding screen. Biosolids conveyed down the length of the screw are dewatered through compression of the solids between the tapered screw and the reducing diameter of the surrounding screen. Filtrate that is removed from the solids passes through the screen. Polymer requirements are similar to a BFP, and additional wash water is required to clean the screen. Figure 3-15 is an image of a screw press installed at Tacoma's Central Treatment Plant.

Figure 3-15. Screw press at Tacoma Central Treatment Plant

The typical dewatering performance is similar to a rotary press with expected solids contents between 18 to 26 percent. The main advantages are the low power consumption and self-contained units requiring limited odor control. The main disadvantages are the limited equipment capacity (requiring more units for the same capacity) and limited existing applications.

### 3.2.3.5 Recommendations

As described in earlier sections, the City's current incineration process already includes a dewatering step prior to incineration, using high-speed centrifuges. Table 3-4 lists the characteristics of the existing dewatering equipment.

Table 3-4. Characteristics of Existing Dewatering Equipment at Post Point

| Parameter | Dewatering |
|---|---|
| Technology | Centrifuge |
| Number of Units | 2+1 |
| Installed | 2012 (1993 for backup unit) |
| Capacity | |
| Hydraulic (gpm) | 123 |
| Loading (lb/hr) | 2,800 |
| Solids Concentration (%-TS) | 22 |

Table 3-5 provides the proposed dewatering design criteria for the new solids facility at Post Point.



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| Table 3-5. Proposed Design Criteria for Dewatering Equipment | | |
|---|---|---|
| Parameter | Dewatering | Comments |
| Number of Units | n+1 | One redundant unit |
| Firm Capacity, total | | |
| Hydraulic (gpm) | 140 | Represents peak 3-day flow |
| Loading (lb/hr) | 1,760 | Represents peak 3-day load |
| Solids Concentration (%-TS) | 22 | Assumed |

The existing centrifuges have sufficient capacity and redundancy to meet the proposed design criteria. However, the backup centrifuge may need to be replaced due to age before the design year is reached. Reuse of the existing dewatering equipment is largely influenced by the final facility layouts. Conveying dewatered cake long distances can be difficult and costly so it is typical to locate dewatering and cake storage/truck loadout equipment in close proximity to each other.

Of the dewatering technologies described, BFPs, centrifuges, and screw presses are best suited for the City's dewatering needs. These technologies are widely used in the industry and have proven, reliable dewatering performance that best meets the City's needs. Manufacturers for these technologies were contacted to compare more detailed size and cost information. The BFP and screw press options have a higher capital cost, cannot produce as dry a cake as a centrifuge, and require a larger footprint than centrifuges. BFPs and screw presses have the benefit of lower operating costs, however, and with the limited hauling distance to the planned off-site processing facility, this results in an overall lower life-cycle cost for these technologies as compared to centrifuges. Whereas the risk of pathogen indicator organism regrowth is high with centrifuges, regrowth has rarely been seen with BFP and screw press installations. This factor, and the disadvantages associated with centrifuges (particularly the risk of pathogen regrowth), lead to centrifuges being eliminated from further consideration.

Screw presses and BFPs had similar capital and operating costs, energy consumption, and footprint requirements. Ultimately, screw presses were recommended over BFPs for inclusion in the Post Point comprehensive biosolids alternatives due to the slightly better performance expected (in terms of dewaterability, solids capture, and wash water consumption) and the ease with which odors can be captured and treated with the screw press technology.

The existing centrifuges have sufficient remaining useful life and capacity to dewater biosolids from a new digestion process throughout the design period. Replacement of these units was assumed for this evaluation because the thickening equipment is assumed to be replaced. Replacing both processes reduces the implementation complexity of the construction period, allows the new processes to be collocated in a new solids handling facility, and optimizes the selection for the City's needs (i.e., dewatering for a Class A end product used locally rather than for optimal incineration operation). Similar to the thickening process selection, if reducing short-term construction costs becomes a driver for the Project, reuse of the existing centrifuges should be reevaluated. The recommendation to replace existing dewatering units with screw presses will be further evaluated in conjunction with Operations staff input during development of the Facility Plan in Phase 3 of the Project.

### 3.2.4 Struvite Management and Recovery

The current Post Point secondary treatment process is designed to promote the growth of phosphorous accumulating organisms to enhance solids settlability. As part of the digestion process, phosphorous stored



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within phosphorous accumulating organism cells is released and can combine with magnesium and ammonium ions to form struvite precipitation.

The magnitude of struvite formation varies at each WWTP. However, struvite scaling of solids treatment and handling equipment and piping can be a significant operation and maintenance (O&M) issue. If left unchecked, struvite formation can lead to mechanical equipment and piping failure resulting in the need for costly repairs or replacement.

Common design practices, such as specifying smooth walled (glass lined) pipes, long radius elbows, and minimal turbulence will decrease struvite scaling opportunities. Even with these design elements, a number of plants observe struvite accumulation in areas of the solids handling processes. To mitigate the risk of struvite formation at Post Point, three common methods of struvite management were considered, including removal through maintenance, preventative control, and resource recovery. **Error! Reference source not found.** shows a typical process flow diagram of struvite removal through maintenance and preventative control.

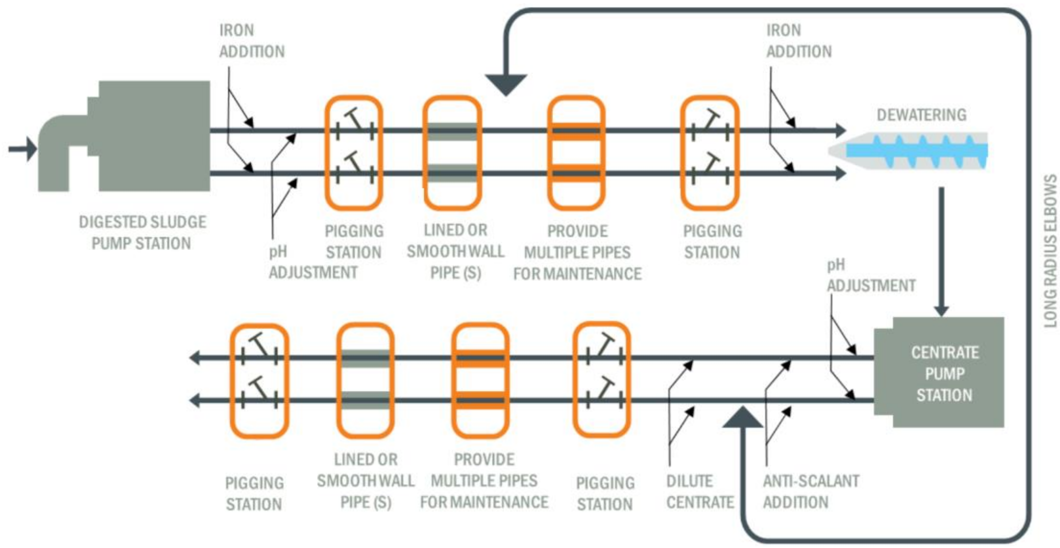


**Figure 3-16. Struvite removed through maintenance and preventative control methods**

### 3.2.4.1 Removal through Maintenance

Maintenance to manage struvite typically involves periodic inspection and cleaning of the digesters, and acid cleaning/pigging of the solids supernatant return piping. The required frequency and extent of these activities can only be determined following startup and operation. As shown in **Error! Reference source not found.** above, certain design features can be installed to facilitate maintenance including piping redundancy and strategically placed cleanouts in problematic areas, such as digester transfer and dewatering return piping. This method of struvite management is relatively low cost; however, the annual O&M cost of struvite removal can be high, depending on plant-specific conditions.

### 3.2.4.2 Preventative Control

Struvite precipitation can be prevented by minimizing the opportunity to reach a high concentration. Common methods to achieve this, as shown in above in Figure 3-16, include the addition of ferric chloride to the digested sludge transfer lines to encourage precipitation as ferric phosphate, and the dilution of



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phosphorous in the dewatering return lines using plant water (W3). This is also a relatively low-cost method of struvite management and is often used in conjunction with routine maintenance activities.

#### 3.2.4.3 Resource Recovery

The nutrients that are released from sludge solids to form struvite are valuable components of fertilizer. Struvite recovery options harvest these nutrients for reuse, which can significantly reduce the amount of struvite scaling on pipes and mechanical equipment. Proprietary processes for struvite recovery include Airprex (which recovers struvite from the digested sludge), and Ostara (which recovers struvite from the dewatering return). The nutrients harvested by both processes are typically sold as a fertilizer amendment under a long-term contract involving the equipment supplier. Figure 3-17 is a photograph of the struvite recovery system at the Durham Advanced Wastewater Treatment Facility in Oregon.

**Figure 3-17. Ostara system at Durham Advanced Wastewater Treatment Facility**

#### 3.2.4.4 Recommendation

Although the magnitude of struvite formation is unknown at Post Point, some level of struvite management will likely be needed. Table 3-6 summarizes benefits and drawbacks of the three alternatives presented above.

**Table 3-6. Comparison of Struvite Handling Options**

| Parameter | Removal through maintenance | Preventative control | Resource recovery |
|---|---|---|---|
| Benefit | • Lowest upfront construction cost<br>• Minimizes footprint | • Low upfront construction cost<br>• Small footprint | • Potential to generate revenue from fertilizer sales<br>• Recovering a natural resource is most compatible with the City's goals<br>• By routinely removing struvite from the system, the struvite formation elsewhere is minimized |
| Drawbacks | • Potentially high O&M costs due to the need for frequent cleaning<br>• Potential failures of equipment or pipe clogs that impact process performance | • Potentially high O&M cost due to the need for chemicals<br>• Additional chemical handling requirements<br>• Potential to increase overall solids production due to chemical sludge generated during preventative chemical addition | • Highest capital costs<br>• Relatively large footprint for recovery processes<br>• Additional O&M associated with recovery process<br>• Reliable market for struvite not yet established (potential impacts from regulatory classification of struvite)<br>• Relatively few proven installations |

For Phase 2 planning, a combination of maintenance and preventative control methods is recommended including redundant piping in areas of high likelihood for precipitation, acid washing/pigging stations, and dilution of the dewatering stream with W3. This recommendation provides operational flexibility for managing struvite with a lower initial capital investment. The site footprint should be enlarged to include an area reserved for additional control measures, including struvite recovery, should the magnitude of struvite formation be found to be excessive, resulting in higher O&M costs.

## 3.3 Biogas End Use Alternatives

Biogas is a by-product of biological breakdown of organic material during anaerobic digestion and is principally made up of methane and carbon dioxide. The methane in biogas is a valuable fuel of similar composition to natural gas and is considered a renewable resource because it is biogenic (not a fossil fuel). When biogas is burned, the resulting carbon dioxide emitted is not considered to contribute to GHG emissions, and when used to replace energy from a fossil fuel, counts toward a net reduction in GHG emissions equal to what would have been emitted by the offset fossil fuel.

A variety of biogas end-uses were considered during Phase 1 planning including heating with boilers, flares, combined heat and power (CHP) or cogeneration, and upgraded renewable natural gas (RNG) for vehicle fueling or pipeline injection. The flares and boilers are recommended as necessary and/or as backup systems to the other end use alternatives that more efficiently and effectively reuse the biogas generated by digestion. Boilers are used as backup heat with CHP systems and would be required for digester heating with RNG systems. Flares are a necessary backup for safe burning of biogas for all gas-use systems to handle gas production spikes or if other systems fail or need to be shut down for maintenance. As a result, boilers and flares are included in all digestion alternatives.

For the purpose of Phase 2 planning analysis, two additional beneficial biogas use alternatives—CHP and RNG with pipeline injection—were considered, both well proven approaches. A RNG fueling station alternative involves gas treatment processes that are similar to RNG with pipeline injection, but also requires on-site pressurized gas storage. A system as large as Bellingham's would also require a relatively large fleet of compressed natural gas-fueled vehicles to make full use of the biogas, and this requirement may limit overall feasibility.



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### 3.3.1 Cogeneration

Cogeneration (i.e., CHP) is the process of burning fuel to create electricity while capturing the heat that is produced as a by-product. WWTPs typically use the generated heat to maintain target digester temperatures and for space heating needs within the treatment plant. Electricity produced can be used on site and/or can be sold to the local electrical utility by feeding it back into the distribution grid. Without substantial supplemental feedstocks for co-digestion, power generated from CHP is well below plant power needs and is most commonly used within the plant.

Conventional reciprocating engines, fuel cells, and microturbines can be used for CHP at municipal WWTPs. Phase 1 recommended engines over fuel cells and microturbines based on previous economic analyses for similarly sized applications. To prevent fouling of the equipment and comply with emission requirements, a typical cogeneration train also includes a digester gas conditioning system prior to being utilized by the engines.

Puget Sound Energy (PSE), the local electrical supplier to the City, has an established Green Options program designed to promote renewable energy programs. As of 2018, renewable energy sources make up 9 percent of PSE's power. PSE has set a goal of reaching 15 percent by 2020, with a 50-percent reduction of its carbon emissions by 2040. PSE receives renewable power converted from biogas generated by four digesters processing dairy manure in Whatcom County.

Under a power purchase agreement, the City and PSE could enter into a long-term contract in which the City is obligated to offset or sell up to a certain amount of electricity to PSE. Any amount produced by the City beyond that amount could be utilized by/sold for other uses. Under the offset program, electricity pricing will vary over time with the utility's electricity rates. Utility trend rates have been observed to increase over time, thereby potentially leading to more favorable offset values in the future. Under an electricity export program, the value or price would be fixed for the term of the agreement, providing revenue certainty to the generators.

Use of the cogeneration system would also allow for cost offsets, in the form of renewable energy certificates or credits, to be available as part of the sale of the electricity. Renewable energy creditss are tradeable energy commodities that signify 1,000 kilowatt hours (kWh) of electricity was generated using renewable energy. These credits track renewable energy through the electric grid and allow entities to purchase the use of renewable energy. These credits are typically "bundled" with the electricity and sold as a combined product, which is a premium value over non-renewable electricity. In addition, PSE may be open to providing capital funding for constructing a green energy system through their new construction grants for commercial and industrial customers. These opportunities could be investigated further during Phase 3.

### 3.3.2 Renewable Natural Gas and Pipeline Injection

The technology for upgrading and compressing gas into renewable natural gas (RNG) is well-established and used widely at landfills and at more wastewater treatment plants nationwide. Upgrading involves removal of carbon dioxide and other contaminants from the biogas, resulting in nearly pure methane, comparable in composition and thermal value to natural gas.

King County's South Treatment Plant has upgraded and injected biogas into a nearby pipeline since 1986. The City of Tacoma's Central Treatment Plant is currently in the final stages of design to implement a biogas injection system in collaboration with their local utility. Pipeline injection of biogas has become more popular during the past decade due to the following economic revenue incentives designed to reduce the country's dependency on foreign oil while reducing carbon footprint:

- The Renewable Fuel Standard program was created under the Energy Policy Act of 2005 and established the first renewable fuel volume mandate in the United States. The program requires oil and gas producers to purchase specified amounts of fuel credits each year to increase the amount of renewable fuel used. Each 77,000 British thermal units (BTUs) of biogas used for vehicle fuel generates a renewable credit, each tracked with a renewable identification number (RIN). RINs are traded on the open market, and their value is dependent upon the price of oil and the renewable volume obligation, which is the amount of RINs obligated parties have to purchase.

- The Low Carbon Fuel Standard (LCFS) program was created under California's Assembly Bill 32 (Global Warming Solutions Act of 2006) Scoping Plan. The LCFS mandates a 10 percent reduction in the carbon intensity of transportation fuel in California by 2020. Under the LCFS, clean fuel providers can earn credits. These credits can be sold for cash to certain compliance-based buyers in California which include, among many other parties, California's oil refineries and electric utilities. The LCFS credits vary depending on the carbon intensity of the conversion pathway. The LCFS has been adopted in California and Oregon. LCFS legislation has been introduced in Washington and British Columbia.

At RNG facilities, after upgrading, biogas is typically pressurized, odorized, and injected directly into the pipeline of a utility for use with its gas products. Based on initial discussions, the local utility (Cascade Natural Gas Corporation) is interested in the potential of injecting RNG into their distribution network. Initial discussions suggest that an injection point may be located within approximately 0.5 miles from Post Point. Additional meetings are necessary to determine the utility's requirements for gas quality, connection point, and costs associated with this alternative.

A typical biogas facility produces gas at the composition shown below in Table 3-7, prior to and following upgrading. A typical biogas treatment system schematic is shown in Figure 3-18.

**Table 3-7. Summary of Biogas Composition**

| Constituent | Raw Biogas Concentration (ppm) | RNG Concentration (ppm) |
|---|---|---|
| Methane | 40-70% | 98-99% |
| Carbon Dioxide | 25-55% | 0-1% |
| Nitrogen | 0-5% | 0-1% |
| Oxygen | 0-2% | 0-1% |
| Hydrogen Sulfide | 0-2% | 0-1% |
| Total Siloxanes | <1% | 0-1% |

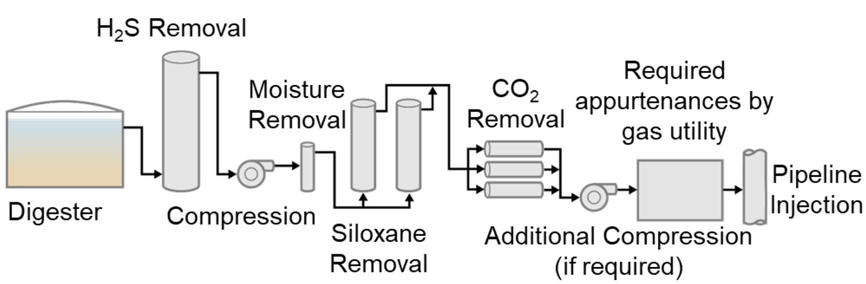


**Figure 3-18. Typical treatment skid for biogas upgrading and conditioning**

### 3.3.3 Recommendations

Both beneficial biogas end use alternatives, CHP and RNG, support the City's implemented philosophies. The City's 2007 Climate Action Plan stipulated a goal of reducing GHG emissions from municipal sources by 70 percent from Year 2000 through Year 2020, and included emissions from sources such as electricity, natural gas, and fleet. The City recently adopted a resolution to develop 100 percent renewable energy targets (Resolution 2018-06) with biogas listed as a renewable energy.

Both biogas end use alternatives are evaluated in the Phase 2 TBL+ analysis. While preliminary conversations with each of the local utilities were positive, further coordination during Phase 3 of the Project is needed to continue developing both alternatives and confirm the utilities' requirements can be cost-effectively implemented. Specific technologies can also be evaluated and selected during Phase 3.

## 3.4 Biosolids Product Alternatives

In Phase 1 of the Project, the City adopted a conceptual biosolids management program that includes implementing anaerobic digestion at Post Point and implementing off-site composting or off-site topsoil blending to produce a soil amendment product to market locally. To market a biosolids soil product to the general public, the product must meet the USEPA Part 503 regulations for a Class A product, requiring biosolids to be treated with a "Process to Further Reduce Pathogens."

This section describes the Class A composting and soil blending end-use options for biosolids produced by the stabilization technologies described in section 3.1 and discusses a regulatory framework for these options.

### 3.4.1 Composting

Composting is the most common method used to produce Class A biosolids. To meet the criteria for Class A, composted biosolids must meet pathogen reduction limits, comply with required sampling and analysis protocols, maintain compost temperature and retention time records, and meet product labeling requirements.

Biosolids can be composted with sawdust, wood chips, yard clippings, storm debris, food waste, manure or crop residues, and food processing wastes. The final composted product provides nutrients and organic matter and sequester carbon, thereby conserving resources, restoring soils, and combating climate change. Professional landscapers and master gardeners use composted biosolids for landscaping new homes and businesses. Home gardeners also find composted biosolids to be an excellent alternative to typical fertilizer.

Due to site constraints at Post Point, an off-site location would be required for a compost system. The off-site location would need to be able to support windrow, aerated static pile, or in vessel methods of composting. Windrow composting is a process that aerates long rows of biosolids and organic material, either manually or mechanically. This method is typical for large volumes of biosolids which require a significant amount of space but in turn yields a high volume of end-product. Aerated static pile composting is a quicker composting method that mixes biosolids and organic waste in one large pile rather than rows. Loosely piled bulking agents like wood chips or shredded newspaper are used to help aerate the piles since they allow air to flow through. Blowers and fans can also be used to assist aeration by mechanically aerating the piles. With in-vessel composting, biosolids and organic material are fed into a drum or silo which mechanically aerates the material by turning and mixing. This method is suitable for any volume of biosolids since the composting vessels can be designed for any capacity.

Figure 3-19 below shows the basic layout for an off-site composting facility. Processing the biosolids would require space for composting, curing, and screening; a biofilter for odor control; and compost and bulking



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agent storage. The site would also include an administration/operations building and space for maintenance staff. The total estimated site footprint would be approximately 10 acres.

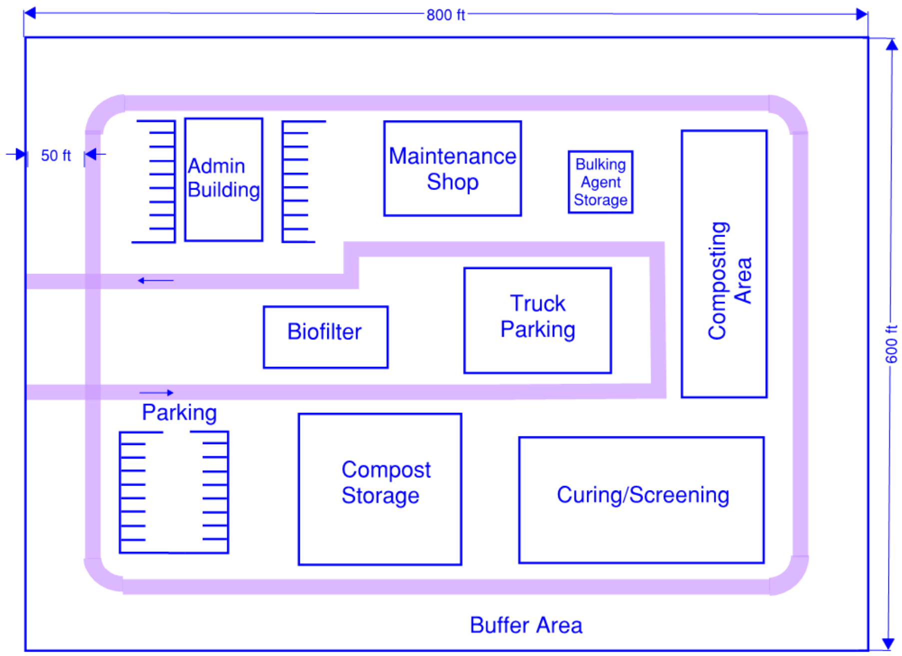


Figure 3-19. Off-site composting facility layout

### 3.4.2 Top Soil Blending

Producing manufactured soils is a specialized class of biosolids product development. The feedstock for a soil blending product must be a Class A biosolids cake. The Class A biosolids are blended with a mixture of sawdust/bark and sand to produce a product that can be publicly distributed in bag or bulk form. The City of Tacoma produces a product called TAGRO which is comprised of two parts Class A dewatered cake, two parts sawdust, and one-part sand. The composition of the manufactured soils could potentially be custom tailored to meet customer and landscaping needs.

An off-site location would be required for soil blending due to Post Point site constraints. The process requires space for pre-mixing biosolids cake, sawdust, sand, or other material. Then the pre-mix is fed into a shredder which shreds and mixes the material to produce a final product. Figure 3-20 below shows the basic components required as part of a soil blending facility. An administration/operations building and maintenance shop would be included and processing space would require a mixing floor, storage, and product packing. The total estimated site footprint is about 10 acres.



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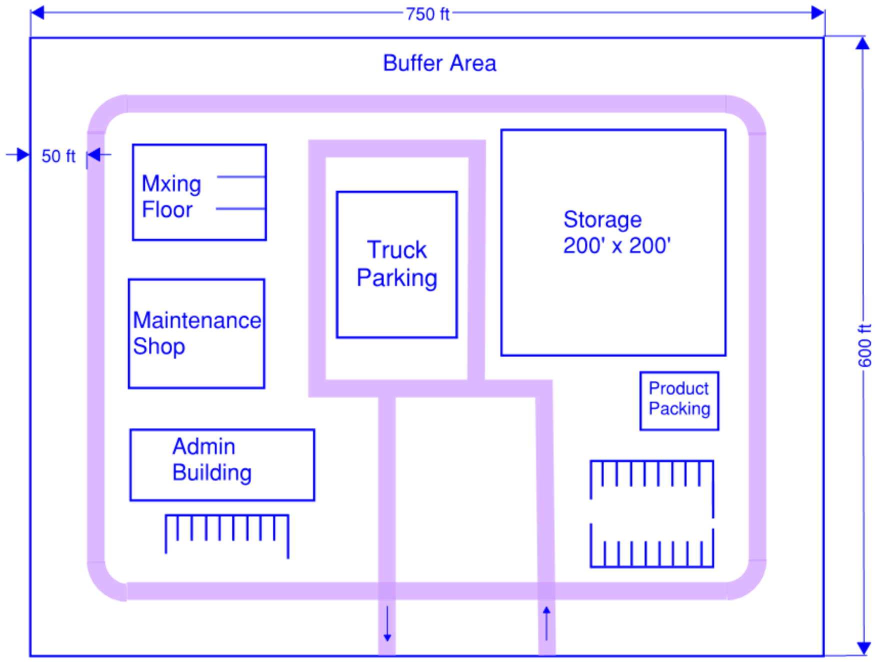


**Figure 3-20. Off-site soil blending facility layout**

### 3.4.3 Regulatory Requirements

As previously discussed, to market a biosolids soil product to the general public, the product must meet the USEPA Part 503 regulations for a Class A product, requiring the biosolids to be treated with a "Process to Further Reduce Pathogens." To meet Class A requirements, the selection of a biosolids product processing alternative must also be considered and integrated with the Post Point digestion system. To achieve a final Class A product, any digestion alternative that results in Class B biosolids would need to include composting at the off-site facility. Alternatives that achieve Class A through digestion could utilize the soil blending alternative, which would require less energy, site space, and material handling.

Preliminary discussions with regulatory authorities indicated that soil blending operated by the City may require significantly increased testing to confirm the final product achieves the Class A standard. This testing would be needed to confirm that the materials mixed with the Class A biosolids (i.e., the sand and sawdust/wood chips) did not reintroduce pathogens or other contaminants that would result in the final product not meeting Class A standards. Because the composting process is a treatment method, this type of testing is not needed for that alternative.

A possible alternative would be for the City to transfer the Class A biosolids cake to a private operator for final processing. Treatment would be considered complete at the point of transfer, from a regulatory perspective, so the private operator could operate under a separate permit and market a final soil blend product. Private operation may provide other financial and risk mitigation benefits to the City as well.

Continued discussions with the Washington State Department of Ecology, consideration of private operations, and further evaluation of off-site processing alternatives is recommended in Phase 3 of the Project.



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# Section 4: Development of Alternatives

Based on the processes described in previous sections, four alternatives were developed that are representative of the different approaches to applying the screened and short-listed stabilization technologies, and biosolids and biogas end uses. Each alternative is described in further detail below including a conceptual process flow diagram and preliminary site layout.

## 4.1 Common Elements of Post Point Biosolids Facilities

An aerial site photograph of Post Point is shown below in Figure 4-1 with the proposed location for the on-site components of the biosolids management alternatives shown in the red box.

**Figure 4-1. Aerial site photograph showing the location of proposed biosolids project improvements at Post Point**

All the alternatives considered included a number of biosolids treatment common elements. These elements include:

- Increased standby power capacity to supply power critical equipment added in the new solids treatment facilities
- Sludge screening (described in section 3.2.1)
- RDT equipment (described in section 3.2.2)
- Digested sludge storage tank
- Screw press dewatering equipment (described in section 3.2.3)
- Struvite management system (described in section 3.2.4)

- Cake storage and loadout
- Waste gas burners (described in section 3.3)
- Odor control equipment for the new facilities
- Site work, soil remediation, and yard piping necessary for the new facilities
- Demolition of existing equipment

The descriptions below do not specifically identify these common elements, but they were included in all alternatives as part of the construction cost, operating cost, and energy and mass balance estimates.

In addition, all alternatives included a new integrated administration facilities to update the functional use and provide a public interface for the treatment plant. Figure 4-2 shows a preliminary conceptual drawing of the proposed new integrated administration facilities.

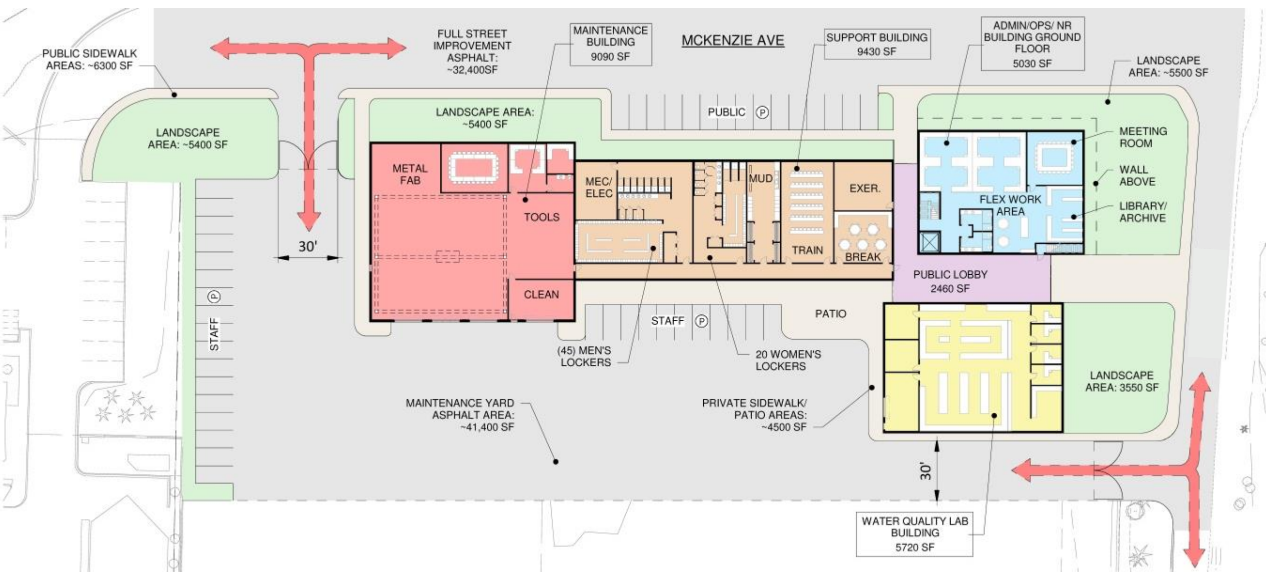


**Figure 4-2. Conceptual site layout of integrated administration facility**

The site is located on a highly visible corner and can serve as a gateway for the plant. Two proposed entrances, shown in Figure 4-2 on Fourth Street and Mckenzie Avenue, allow for vehicular circulation and public access. These access points allow for separation of truck traffic from pedestrian and small vehicle traffic. New public sidewalks are recommended for public safety and connection with surrounding trails. The redevelopment provides over 20,000 square feet of green space connecting with the Lower Padden Creek and Larrabee Trail systems. The proposed site provides additional parking for the public and plant staff. A security fence is extended from the existing campus to include the public edge of the new administration complex.

The administration facilities are broken into four distinct groups: maintenance shop, support building, administration/operations, and the water quality laboratory building. Due to the increase of public work employees centralized at this site to support WTP, WWTP, lift stations, and pump stations, this new facility will address the shortage of office space for City employees and will consolidate the public works and natural resources groups. The conceptual floor plan shown in Figure 4-2 was developed based on benchmarking information from other plant expansions to provide high-level planning and identify potential building volumes and associated costs. In Phase 3 of the Project, the building requirements and design will be further refined to reflect City input, values, and budget.

## 4.2 Alternative 1: Class B Mesophilic Digestion and Composting

The first alternative considered would utilize mesophilic digestion to produce a Class B cake. The cake would be transported to an off-site facility to be composted into a Class A final product for local beneficial use. Two variants of this alternative were considered to beneficially utilize digester gas: Alternative 1A would utilize the digester gas in a CHP process to produce renewable electricity and heat, while Alternative 1B would utilize a biogas upgrading process to generate RNG for use as a renewable vehicle fuel (distributed via the existing Cascade Natural Gas Corporation pipeline system). Figures 4-3 and 4-4 are simplified process flow diagrams of the two variants.

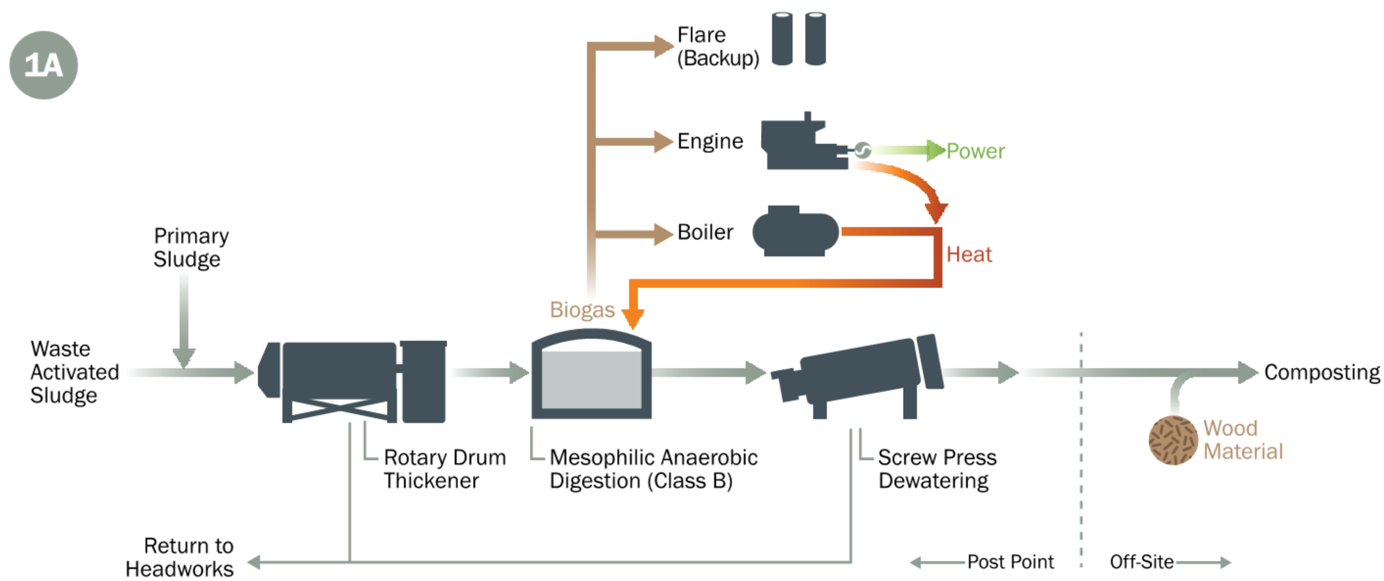


**Figure 4-3. Alternative 1A process flow diagram**

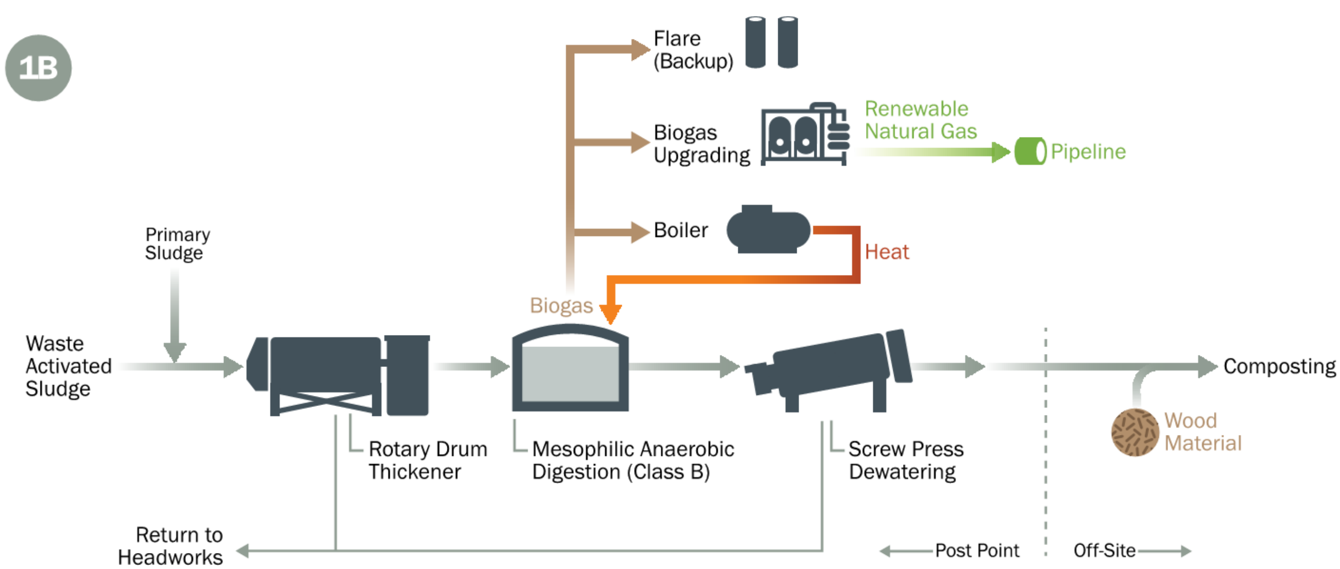


**Figure 4-4. Alternative 1B process flow diagram**


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Figure 4-5 shows a conceptual site layout for the facilities envisioned as part of this alternative. The site layout was developed with the intent to demonstrate approximate site area requirements and a potential approach for routing trucks through the loadout facilities.

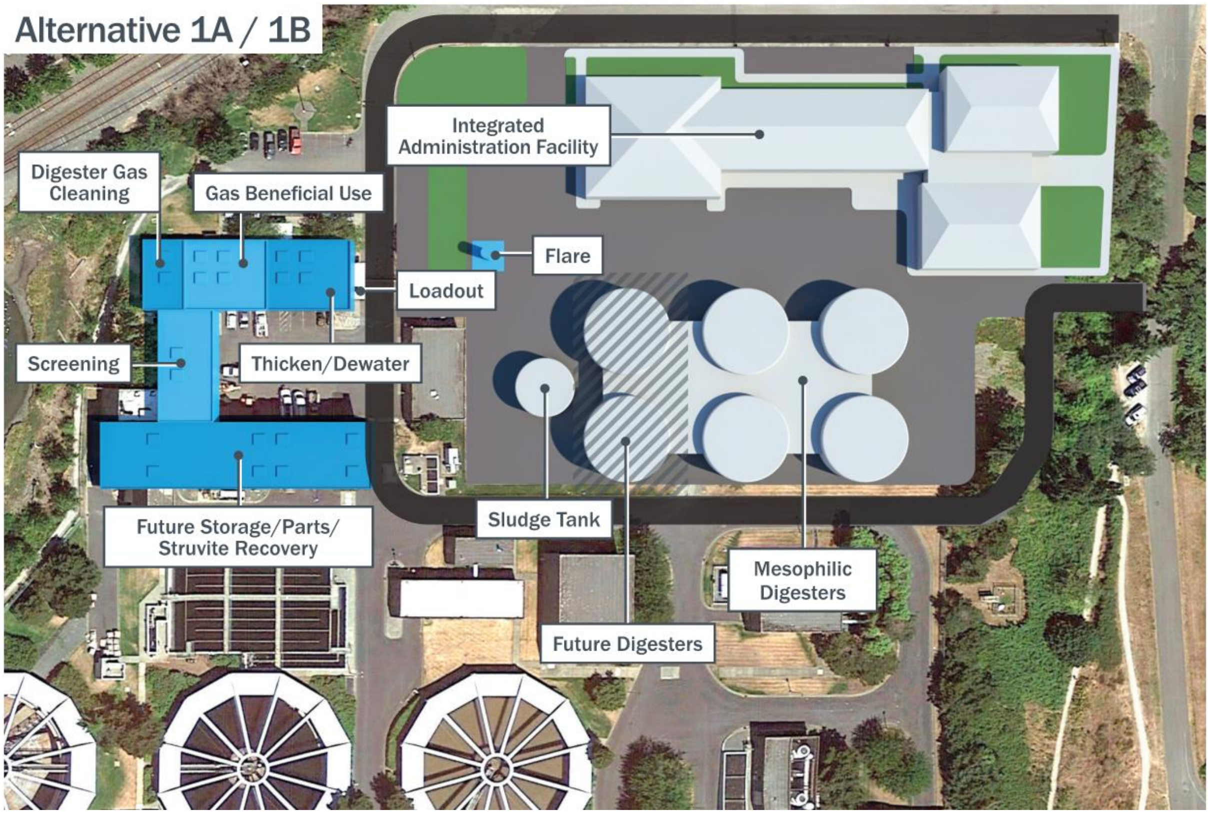


Figure 4-5. Alternative 1A/1B preliminary site layout

## 4.3 Alternative 2: Class B TPAD and Composting

Alternative 2 would also produce a Class B cake but would utilize a TPAD process instead of mesophilic digestion. Similar to Alternative 1, the Class B cake would be transported to an off-site composting facility to generate a Class A compost. This alternative would give the benefit of increased volatile solids reduction and increased biogas generation but would not meet the standard for a Class A cake without the use of batch tanks. Space would be reserved at the site, however, for future construction of batch tanks should the City choose to implement Class A digestion.

As with Alternative 1, two variants of Alternative 2 were considered to evaluate the difference between a CHP biogas utilization process (Alternative 2A) and a biogas upgrading process (Alternative 2B). Conceptual process flow diagrams are below in Figures 4-6 and 4-7.



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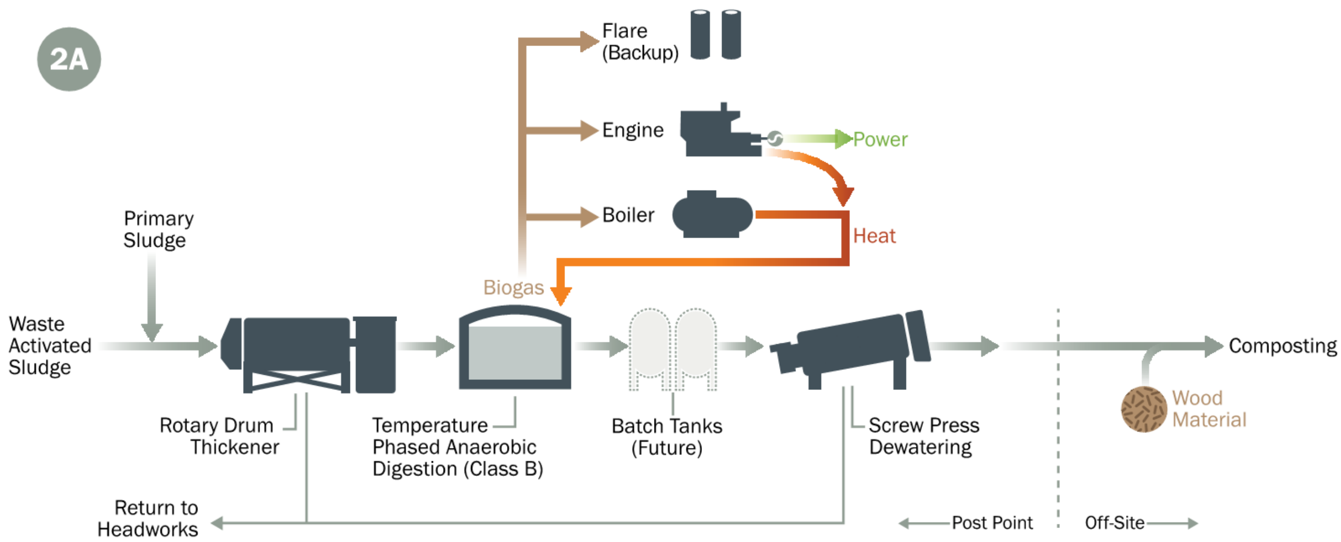


**Figure 4-6. Alternative 2A process flow diagram**

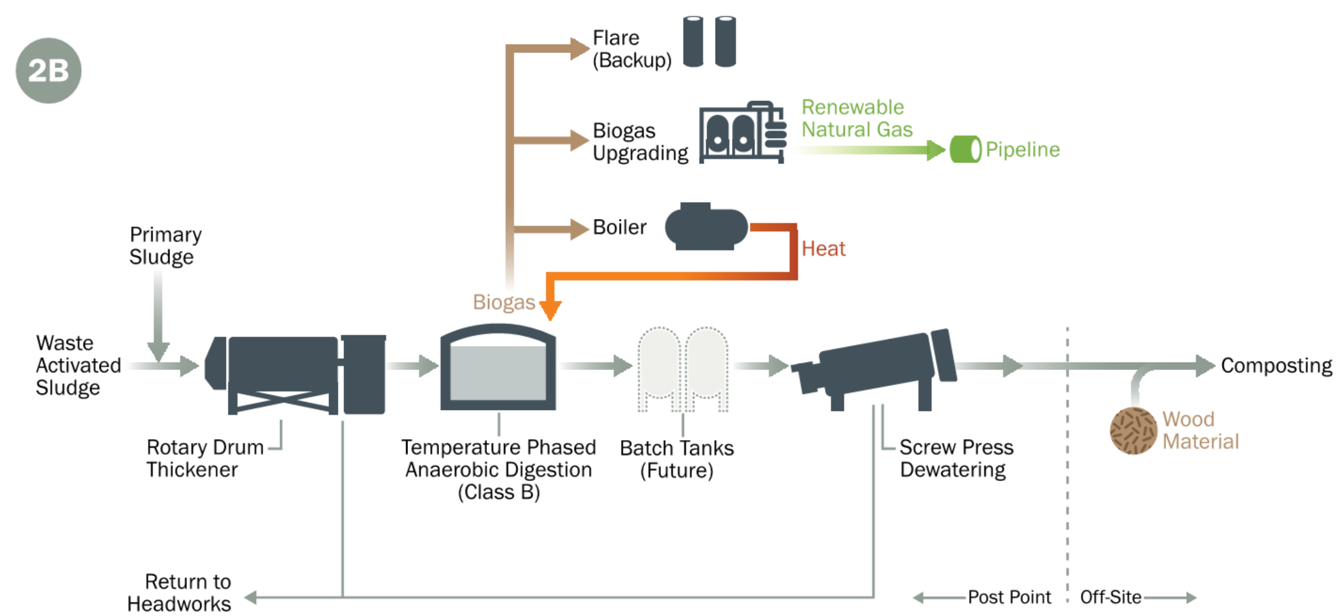


**Figure 4-7. Alternative 2B process flow diagram**

Figure 4-8 shows a conceptual site layout for the facilities envisioned as part of this alternative. The primary difference in the site layout for Alternative 2 compared to Alternative 1 is the reserved space for future batch tanks, allowing the City to convert to Class A digestion in the future if desired.



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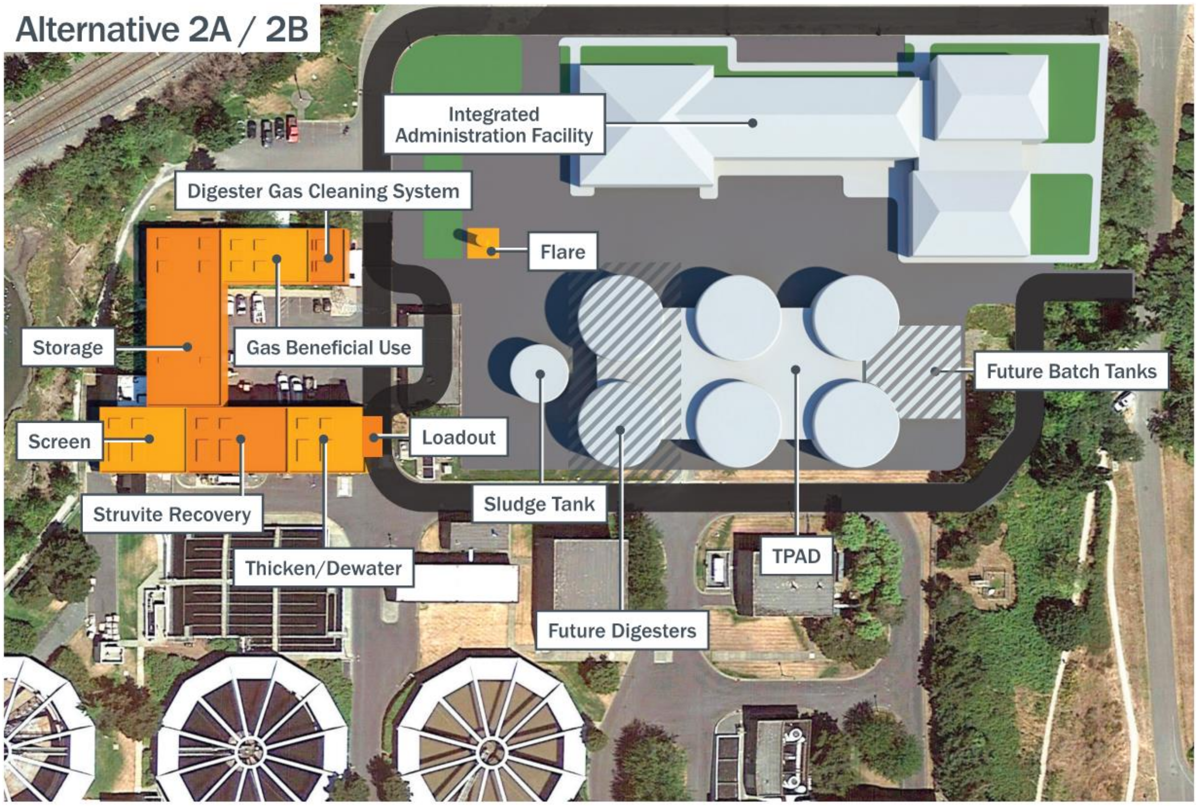


**Figure 4-8. Alternative 2A/2B preliminary site layout**

## 4.4 Alternative 3: Class A TPAD and Soil Blending

Alternative 3 is nearly identical to Alternative 2, except the batch tanks would be built as part of the Project rather than being reserved for a future project. This would result in a Class A digestion process at Post Point. With Class A cake, the off-site solids processing facility would not need to compost the solids to achieve a Class A product for local beneficial use. Instead, a soil blending process as described in section 3.4.2 could be utilized.

As with the other alternatives, two variants were considered for the two biogas end use options. Alternative 3A considers the use of a CHP facility to produce renewable electricity and heat from the plant's biogas while Alternative 3B considers the use of a biogas upgrading process. Conceptual process flow diagrams for both alternatives are shown in Figures 4-9 and 4-10.



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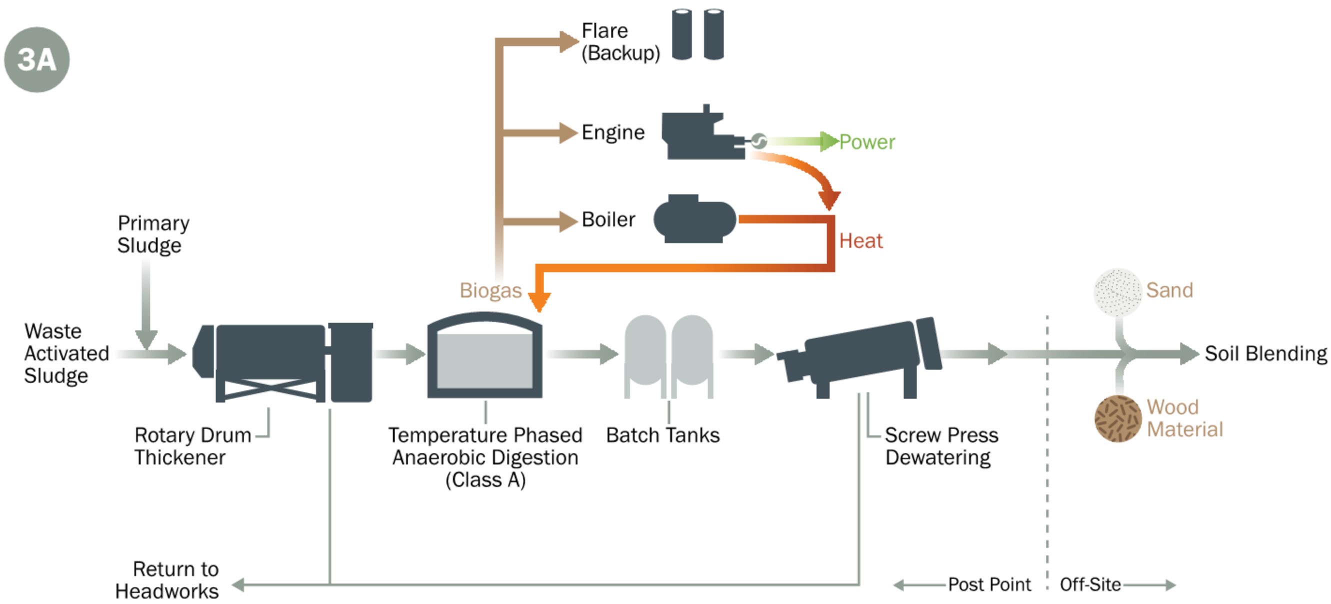


**Figure 4-9. Alternative 3A process flow diagram**

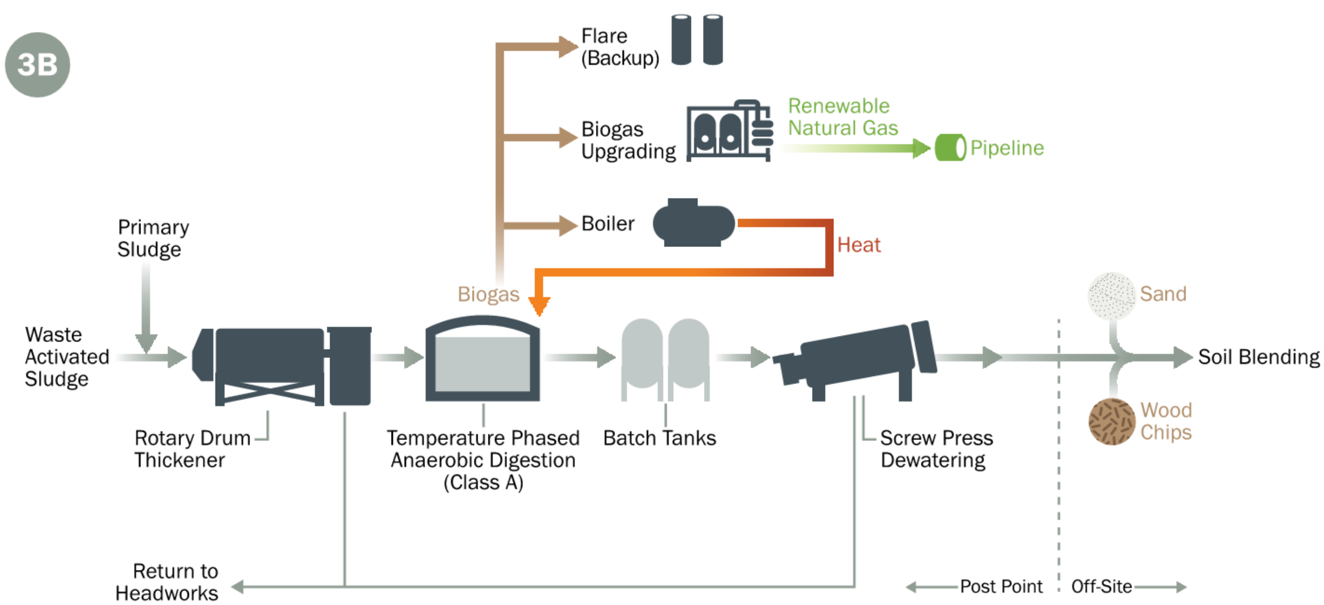


**Figure 4-10. Alternative 3B process flow diagram**

Figure 4-11 is a preliminary site layout for Alternative 3. This layout is identical to the layout presented for Alternative 2 except the batch tanks are shown as part of the current Project rather than reserved space for future construction/placement.


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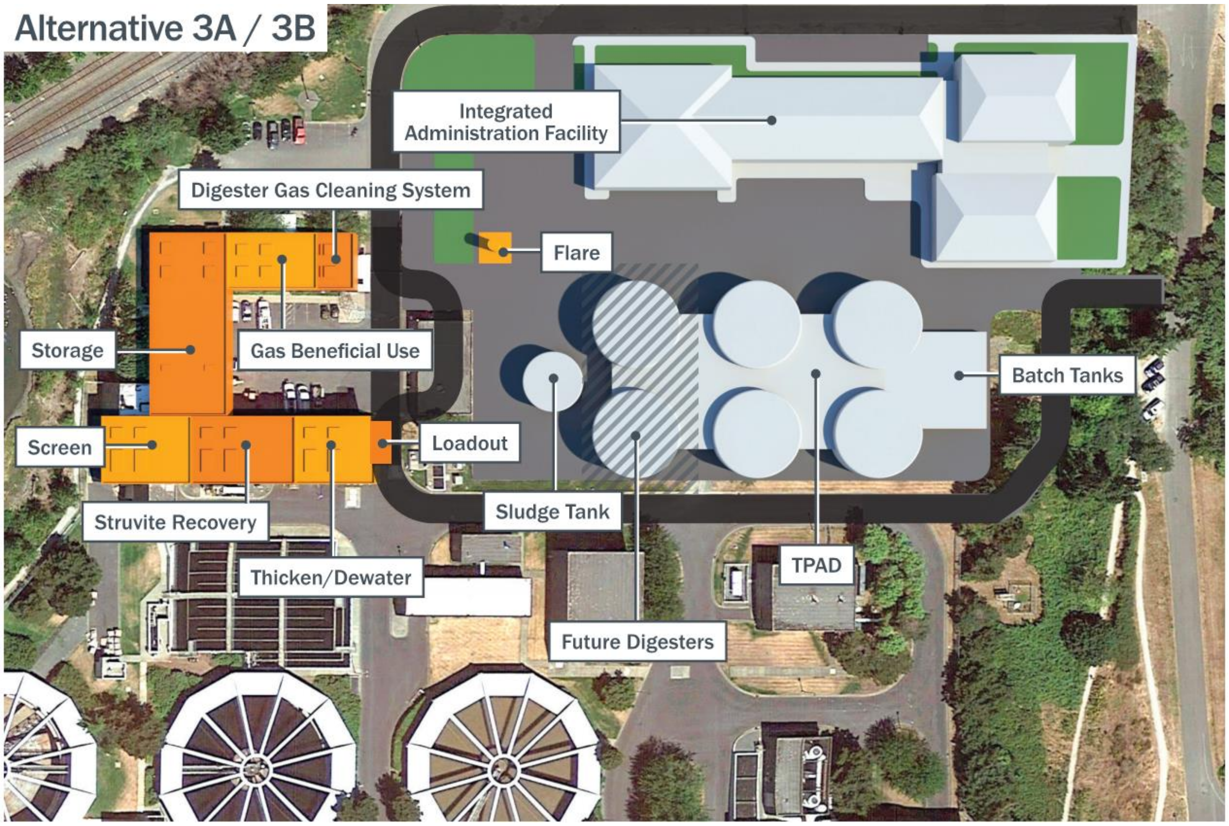


**Figure 4-11. Alternative 3A/3B preliminary site layout**

## 4.5 Alternative 4: Class A Aerobic-Anaerobic Digestion and Soil Blending with Biogas Upgrading

Alternative 4 uses ATAD/TPAD (as described in Section 3.1.5) for the main stabilization process. This process is Class A digestion, which means that, similar to Alternative 3, the off-site solids processing facility would utilize soil blending rather than composting to produce a final Class A product for local end use.

The ATAD process would generate sufficient heat for process heating. Therefore, consideration of a CHP facility for beneficial gas use was not appropriate. Instead, only one biogas end use alternative was considered—a biogas upgrading process to generate RNG that would be injected into the Cascade Natural Gas Corporation pipeline. Figure 4-12 is a conceptual process flow diagram for this alternative.

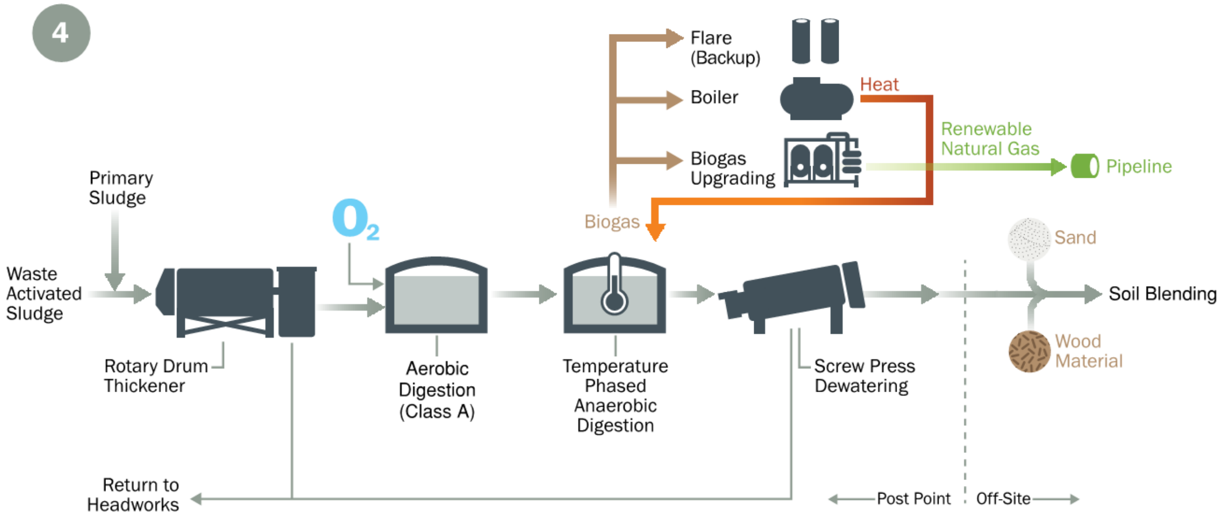


**Figure 4-12. Alternative 4 process flow diagram**

A preliminary site layout was developed for Alternative 4 (shown in Figure 4-13). The layout is essentially identical to that for Alternative 3. The aerobic digesters are a similar size and configuration as the batch tanks shown in Alternative 3. Thus, there are no significant differences to the general layout and facility sizes.

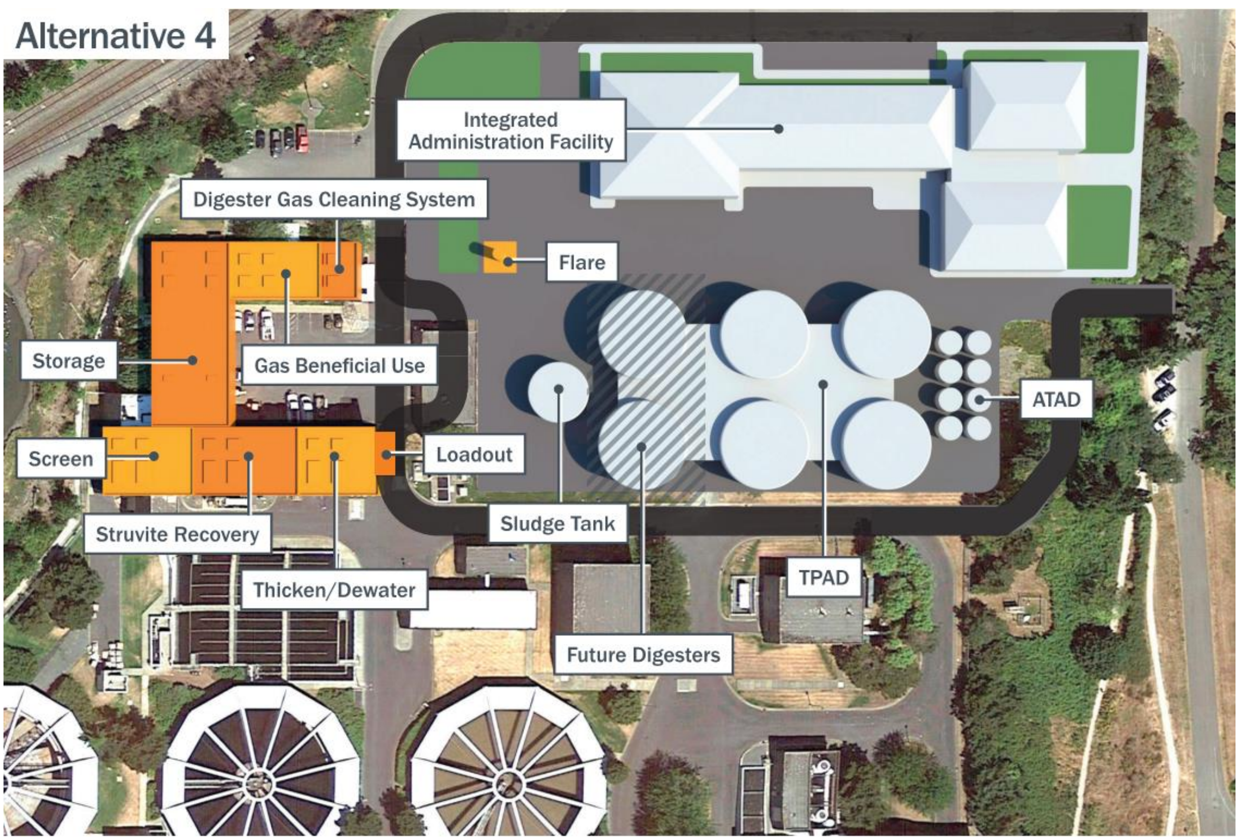


**Figure 4-13. Alternative 4 preliminary site layout**



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# Section 5: Solids, Energy, and GHG Evaluation

After the four detailed alternatives were defined, a technical evaluation of the relative solids, energy, and GHG emissions for each alternative was completed. As done during Phase 1 of this study, Brown and Caldwell's Solids-Water-Energy-Evaluation Tool (SWEET) was used to evaluate the mass and energy balance and the performance of proposed alternatives. SWEET tracks volatile solids, inert solids, and water through potential process alternatives, and considers the energy required to power and heat those processes. This allows for energy production and material recovery to be estimated based on the expected flows and loads to the facility (identified in Section 2). It also allows for estimation of the carbon footprint of each alternative based on the mass and end use of recovered materials and the energy profile of each process.

The following sections describe the results of the evaluations using SWEET. The results of these evaluations provide the input into the TBL+ evaluation described in Section 6.

## 5.1 Mass and Energy Results

Mass and energy outputs for each alternative were developed using the same approach used during Phase 1. Several assumptions were made to complete the mass and energy balances (summarized in Appendix A:); however, four assumptions of note are listed below.

- **Average conditions.** The calculated values were based on 2035 solids flows and loads at average annual conditions (see section 2.2) which represents the average operating condition at the mid-point of the 20-year planning period. Therefore, the values presented do not represent the peak or minimum values that can be expected either early or late in the planning period or within any given year.
- **Biosolids end use diversity.** For all alternatives, a single representative end use profile was assumed to calculate the mass and energy balances. In practice, the City will likely need and desire a diversity of end uses to limit the risk of a single end use becoming no longer available.
- **Off-site facility location.** All alternatives assume that dewatered cake is trucked from Post Point to an off-site facility for further processing. The off-site facility is assumed to be within 10 miles of Post Point.
- **Natural gas consumption.** The calculations assume that alternatives in which digester gas is upgraded to RNG, the plant would consume non-renewable natural gas to meet heating needs. The plant could use digester gas or natural gas for plant and process heating, however, using natural gas maximizes the cost effectiveness of these alternatives (RNG can be sold for more than the cost to purchase non-renewable natural gas).

The mass and energy outputs from the SWEET model are summarized in Table 5-1. Detailed mass and energy emission calculations for each alternative are included in Appendix A:.

**Table 5-1. Summary of Mass and Energy Outputs from the SWEET (2035 Flows and Loads)**

| Parameter | Alt 1A<br>Class B Meso Compost Gas to Cogen | Alt 1B<br>Class B Meso Compost Gas to Pipeline | Alt 2A<br>Class B TPAD Compost Gas to Cogen | Alt 2B<br>Class B TPAD Compost Gas to Pipeline | Alt 3A<br>Class A TPAD Blend Gas to Cogen | Alt 3B<br>Class A TPAD Blend Gas to Pipeline | Alt 4<br>Class A ATAD Blend Gas to Pipeline |
|---|---|---|---|---|---|---|---|
| Biosolids produced (WT/d) | 51 | 51 | 46 | 46 | 46 | 46 | 45 |
| Biosolids trucking required (trucks/d) | 1.7 | 1.7 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Total trucking required [1] (trucks/d) | 4.8 | 4.8 | 4.3 | 4.3 | 3.6 | 3.6 | 3.5 |



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| Table 5-1. Summary of Mass and Energy Outputs from the SWEET (2035 Flows and Loads) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | Alt 1A | Alt 1B | Alt 2A | Alt 2B | Alt 3A | Alt 3B | Alt 4 |
| | Class B Meso Compost Gas to Cogen | Class B Meso Compost Gas to Pipeline | Class B TPAD Compost Gas to Cogen | Class B TPAD Compost Gas to Pipeline | Class A TPAD Blend Gas to Cogen | Class A TPAD Blend Gas to Pipeline | Class A ATAD Blend Gas to Pipeline |
| Vehicle fuel consumed (gal/d) | 42 | 42 | 38 | 38 | 37 | 37 | 38 |
| Final biosolids product[2] (WT/d) | 86 | 86 | 77 | 77 | 105 | 105 | 104 |
| Final biosolids product[2] (cy/d) | 123 | 123 | 110 | 110 | 122 | 122 | 120 |
| Electricity consumed (kWh/d) | 12,700 | 14,000 | 12,400 | 14,000 | 10,300 | 12,000 | 18,700 |
| Electricity produced (kWh/d) | 21,000 | 0 | 23,200 | 0 | 23,200 | 0 | 0 |
| Natural gas consumed (scfd) | 7,200 | 32,800 | 7,200 | 72,300 | 7,200 | 72,300 | 7,200 |
| Renewable natural gas produced (scfd) | 0 | 187,200 | 0 | 206,600 | 0 | 206,600 | 126,400 |
| Net energy produced (MMbtu/hr) | 0.9 | 4.0 | 1.3 | 3.3 | 1.6 | 3.6 | 2.9 |

1. *Total trucking includes biosolids trucking and trucking of mixing agents (e.g., wood chips, sand, etc.) to off-site facility for composting or soil blending process*
2. *Final product: compost or soil blend*

Table 5-1.13 facilitates some initial observations about the relative difference between the alternatives:

- The amount of biosolids produced, and therefore the amount of trucking required between Post Point and the off-site solids processing facility, is fairly similar among all of the alternatives. The range between the trucking values reported amounts to roughly one additional truck per week.
- Greater levels of solids treatment results in lower amounts of final product. Class B TPAD and composting results in the least final product both in terms of weight and volume. The soil blending alternatives result in more final product by weight but similar amount by volume (which is typically how compost and topsoil are sold).
- The electricity consumption is fairly consistent among the alternatives with the exception of Alternative 4 (which requires significant additional electricity for the ATAD process). The biogas upgrading alternatives (1B, 2B, and 3B) require more electricity to be consumed than their cogeneration counterpart (Alternatives 1A, 2A, and 3A) because the gas upgrading process equipment requires increased electrical consumption.
- The net energy balance was calculated to compare the difference of consumption and production of natural gas and electricity. The gas upgrading options have a better net energy balance meaning they result in more net energy (electricity and natural gas combined) than the CHP alternatives.
- This analysis assumes no heat recovery for TPAD options. Heat recovery between the thermophilic and mesophilic stages could reduce natural gas consumed and increase natural gas produced to similar levels as with mesophilic digestion. Heat recovery options will be further explored in Phase 3 of the Project.



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## 5.2 Greenhouse Gas Emission Results

In addition to the mass and energy balance, GHG emissions for each alternative were developed based on 2035 solids flows and loads at average annual conditions. GHG inventories for the proposed alternatives are developed based on GHGs emitted during operation of the biosolids treatment facilities, and transportation and final use of biosolids.

Emission scopes and factors are based on the guidelines published by The Client Registry and Intergovernmental Panel on Climate Change and updated with recent publications. Emissions are divided into three categories representing the relative control that the owner has over them:

- **Scope 1** emissions are direct from sources owned by the agency (e.g., emissions from fuel consumed by the City, fugitive emissions from the City's facilities)
- **Scope 2** emissions are indirect from sources owned by the agency (e.g., emissions from the production of electricity consumed by the City)
- **Scope 3** emissions are from the manufacturing of materials used by the City (e.g., polymer used for dewatering)

Not all Scope 3 emissions have been accounted for in the comparison of alternatives at this time. The significant Scope 3 emissions that are relatively different between the alternatives have been included. However, as an example, emissions from the production of concrete and steel to construct new solids processing facilities have not been accounted for since they are relatively equal for all alternatives.

The GHG emissions from each alternative are presented in Table 5-2. Detailed GHG emission calculations for each alternative are shown in Appendix A:. The electricity produced by a CHP system, carbon sequestration, and fertilizer substitution from land application of biosolids products is presented as a negative GHG emission or carbon credits.

**Table 5-2. Summary of GHG Emissions (2035 Flows and Loads), Metric Tons of Equivalent Carbon Dioxide per Year**

| Scope | Parameter | Alt 1A | Alt 1B | Alt 2A | Alt 2B | Alt 3A | Alt 3B | Alt 4 |
|---|---|---|---|---|---|---|---|---|
| | | Class B Meso Compost Gas to Cogen | Class B Meso Compost Gas to Pipeline | Class B TPAD Compost Gas to Cogen | Class B TPAD Compost Gas to Pipeline | Class A TPAD Blend Gas to Cogen | Class A TPAD Blend Gas to Pipeline | Class A ATAD Blend Gas to Pipeline |
| Scope 1 | Consumption of natural gas | 140 | 640 | 140 | 1,400 | 140 | 1,400 | 140 |
| | Consumption of vehicle fuel | 160 | 160 | 140 | 140 | 140 | 140 | 140 |
| | Fugitive emissions | 320 | 210 | 330 | 200 | 330 | 200 | 160 |
| | **Scope 1 total** | **620** | **1,000** | **610** | **1,740** | **610** | **1,740** | **440** |
| Scope 2 | Electricity required | 2,160 | 2,400 | 2,120 | 2,400 | 1,770 | 2,050 | 3,190 |
| | Power generated | (3,590) | 0 | (3,960) | 0 | (3,960) | 0 | 0 |
| | **Scope 2 total** | **(1,430)** | **2,400** | **(1,850)** | **2,400** | **(2,200)** | **2,050** | **3,190** |
| Scope 3 | Production of polymer | 700 | 700 | 660 | 660 | 660 | 660 | 660 |
| | Production of natural gas | 2 | 9 | 2 | 20 | 2 | 20 | 2 |


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| Table 5-2. Summary of GHG Emissions (2035 Flows and Loads), Metric Tons of Equivalent Carbon Dioxide per Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scope | Parameter | Alt 1A | Alt 1B | Alt 2A | Alt 2B | Alt 3A | Alt 3B | Alt 4 |
| | | Class B Meso Compost Gas to Cogen | Class B Meso Compost Gas to Pipeline | Class B TPAD Compost Gas to Cogen | Class B TPAD Compost Gas to Pipeline | Class A TPAD Blend Gas to Cogen | Class A TPAD Blend Gas to Pipeline | Class A ATAD Blend Gas to Pipeline |
| | Production of vehicle fuel | 30 | 30 | 20 | 20 | 20 | 20 | 20 |
| | **Scope 3 total** | **740** | **740** | **690** | **710** | **690** | **710** | **680** |
| Credits | Fertilizer offset | (850) | (850) | (760) | (760) | (700) | (700) | (690) |
| | Carbon sequestration | (1,110) | (1,110) | (1,000) | (1,000) | (920) | (920) | (900) |
| | Gas Upgrading | 0 | (5,460) | 0 | (6,020) | 0 | (6,020) | (3,690) |
| | **Credits total** | **(1,960)** | **(7,420)** | **(1,760)** | **(7,780)** | **(1,620)** | **(7,640)** | **(5,280)** |
| **Total (metric tons/year)** | | **(2,030)** | **(3,270)** | **(2,310)** | **(2,940)** | **(2,520)** | **(3,140)** | **(970)** |

From this analysis, it can be concluded that Alternative 4 (ATAD/TPAD, soil blending, gas upgrading) would have the highest overall GHG emissions among the alternatives evaluated. This alternative lacks the ability to produce electricity and upgrades less digester gas than the other alternatives, resulting in lower gas upgrading credits.

Among the remaining three alternatives, Alternatives 1B and 3B have the least GHG emissions. The following additional conclusions have been made:

- Utilizing biogas as a vehicle fuel offset reduces GHG emissions more than cogeneration.
- Developing a soil blend has a better carbon footprint than developing compost, largely because the composting process requires additional energy input for aeration that is not required for soil blending.
- For alternatives including biogas upgrading, TPAD results in more GHG emissions than mesophilic digestion because the increased energy needed to heat the digesters is greater than the additional biogas produced. For alternatives where cogeneration is used as the main biogas utilization and source of heat, this is not the case because the cogeneration process produces all the heat needed so no additional natural gas is required. However, as discussed in section 5.1 above, this analysis assumes no heat recovery for TPAD options. Heat recovery between the thermophilic and mesophilic stages could reduce natural gas consumed and increase natural gas produced to similar levels as with mesophilic digestion. Heat recovery options will be further explored in Phase 3 of the Project.



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# Section 6: Cost and Schedule Evaluation

This section describes the cost and schedule estimates for the alternatives considered as well as the expected impact on wastewater utility rates. Cost estimates are described for the construction, the project, and the life-cycle costs.

## 6.1 Construction and Project Cost Estimates

Construction costs include contractor-related costs, such as materials, labor, equipment involved in the installation, subcontractor costs, and indirect costs (i.e., contractor mobilization, demobilization, startup, commissioning, warranties, and sales tax). Planning level construction costs for wastewater facilities and associated infrastructure are typically estimated with one or more of the following approaches:

- Cost curves derived from as-built costs of similar systems. This approach is often used at the planning level because project details are undefined and estimates for more than a few general cost items are difficult to identify at this level of project development.
- Detailed quantity estimates for the particular facility. This approach is most effective when materials can be quantified; therefore, it is not often used in early planning stages.
- Major-item quantity estimates with percentage allowances. This approach combines aspects of the first two and uses unit quantities developed for major cost items from similar projects.

Construction costs were developed utilizing the third approach for this planning analysis. The expected level of accuracy for these cost estimates follows the Recommended Practice 18R-97 Cost Estimate Classification System for the Process Industries (Association for the Advancement of Cost Engineering 1998) designation as a “Class 5” estimate with an expected level of accuracy of -50 to +100 percent.

Estimated construction costs are escalated to Year 2023, the anticipated mid-point of construction. Indirect construction cost factors include:

- Estimator’s contingency (30 percent)
- Contractor general conditions (15 percent)
- Contractor overhead and profit (15 percent)
- Escalation to mid-point of construction (3 percent per year)
- Bellingham, Washington, sales tax (8.7 percent)

Project costs include the sum of the construction and non-construction costs required to implement and support the Project. Non-construction costs include additional costs the owner must bear, such as engineering services, planning/management services, permitting and agency support, land acquisition, owner labor, project contingency, and initiatives. Non-construction costs were estimated as percentage allowances of construction costs as follows:

- Engineering, legal, and administration (25 percent)
- Owner’s reserve for change orders (5 percent)
- Land acquisition for blending facility and biosolids storage ($1 million)

Table 6-1 presents estimated construction and project costs in 2023 dollars. This table indicates Alternative 1B has the lowest construction and project cost and Alternative 4 has the highest construction and project costs.



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| Table 6-1. Estimated Construction and Project Costs (2023)* | | | | | | | |
|---|---|---|---|---|---|---|---|
| Biosolids Project Element | Alt 1A<br>Class B Meso Compost<br>Cogen | Alt 1B<br>Class B Meso Compost<br>Pipeline | Alt 2A<br>Class B TPAD Compost<br>Cogen | Alt 2B<br>Class B TPAD Compost<br>Pipeline | Alt 3A<br>Class A TPAD Blend<br>Cogen | Alt 3B<br>Class A TPAD Blend<br>Pipeline | Alt 4<br>Class A ATAD Blend<br>Pipeline |
| Total Core Process | $ 56.0 | $ 56.0 | $ 57.9 | $ 57.9 | $ 56.8 | $ 56.8 | $ 68.9 |
| Total Energy Recovery | $ 24.4 | $ 11.8 | $ 24.4 | $ 11.8 | $ 24.4 | $ 11.8 | $ 11.8 |
| Total Ancillary Systems | $ 7.7 | $ 7.7 | $ 7.7 | $ 7.7 | $ 7.7 | $ 7.7 | $ 12.2 |
| Post Point Site Work & Yard Piping | $ 17.3 | $ 19.6 | $ 17.3 | $ 19.6 | $ 17.3 | $ 19.6 | $ 18.4 |
| Thickening & Dewatering | $ 19.3 | $ 19.3 | $ 19.3 | $ 19.3 | $ 19.3 | $ 19.3 | $ 19.3 |
| Integrated Maintenance/Admin Bldg. | $ 29.3 | $ 29.3 | $ 29.3 | $ 29.3 | $ 29.3 | $ 29.3 | $ 29.3 |
| Demolition & Site Remediation | $ 5.6 | $ 5.6 | $ 5.6 | $ 5.6 | $ 5.6 | $ 5.6 | $ 5.6 |
| **Total Estimated Construction Cost[1,2,3]** | $ 159.5 | $ 149.2 | $ 161.4 | $ 151.0 | $ 160.3 | $ 149.9 | $ 165.2 |
| **Total Estimated Project Cost[4]** | $ 208.4 | $ 194.9 | $ 210.9 | $ 197.3 | $ 209.4 | $ 195.9 | $ 215.9 |

**Costs in millions.*

1. *Values shown are in 2023 collars.*
2. *Estimates are planning level, Class 5 (per AACE International standards) with an expected accuracy range of -50/100%.*
3. *Includes estimator's contingency (30%), general conditions ($15%), overhead and profit (15%), escalation to mid-point (19.4% to 2013), and sales tax (8.7%).*
4. *Includes engineering, legal, and administration (25%), change order reserve (5%), land purchase for off-site at $1M for digestion.*

## 6.2 O&M and Life-Cycle Cost Estimates

O&M costs include labor, supplies, and utility costs for operations, preventive and corrective maintenance, inspections, and parts repair and replacement. O&M costs were based on:

- Historical City costs.
- Vendor-supplied costs.
- The Northeast Guide for Estimating Staffing at Publicly and Privately-Owned Wastewater Treatment Plants published guide (2008).
- Assumptions and calculations, as necessary, to supplement other sources.

Annual O&M costs are based on applying the above information to average annual operating conditions. O&M costs anticipated during the 20-year planning period are summed by calculating their net present worth (NPW) in 2023 dollars.

Common annual expenses include thickening and dewatering, digestion, struvite management, sludge screening, and labor. Alternative dependent expenses include labor and rental fees for trucking materials to the off-site facility, end use contract hauling, end use production, digestion adders, and cogeneration or injection adders and revenue assumptions. Estimated O&M costs are summarized in Table 6-2.



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| Table 6-2. Annual and Present Worth O&M Cost Estimates | | | | | | | |
|---|---|---|---|---|---|---|---|
| Biosolids Project Element | Alt 1A<br>Class B Meso Compost<br>Cogen | Alt 1B<br>Class B Meso Compost<br>Pipeline | Alt 2A<br>Class B TPAD Compost<br>Cogen | Alt 2B<br>Class B TPAD Compost<br>Pipeline | Alt 3A<br>Class A TPAD Blend<br>Cogen | Alt 3B<br>Class A TPAD Blend<br>Pipeline | Alt 4<br>Class A ATAD Blend<br>Pipeline |
| Thickening/Dewatering[1] | $0.43 | $0.43 | $0.43 | $0.43 | $0.43 | $0.43 | $0.43 |
| Digestion[1] | $1.17 | $1.01 | $1.30 | $1.62 | $1.39 | $1.63 | $2.06 |
| Struvite Management[1] | $0.43 | $0.43 | $0.43 | $0.43 | $0.43 | $0.43 | $0.43 |
| Sludge Screening[1] | $0.22 | $0.22 | $0.22 | $0.22 | $0.22 | $0.22 | $0.22 |
| Biosolids End Use[1,2] | $2.50 | $2.46 | $2.30 | $2.22 | $1.46 | $1.46 | $ 1.35 |
| Biogas End Use[1] | $0.20 | $0.26 | $0.30 | $0.28 | $0.22 | $0.28 | $0.22 |
| Power/Biogas Revenue[3] | $(0.26) | $(1.40) | $(0.30) | $(1.51) | $(0.38) | $(1.50) | $(0.92) |
| Total Estimated Annual O&M Cost | $4.70 | $3.40 | $4.70 | $3.70 | $3.80 | $3.00 | $3.80 |
| 20-year Biosolids NPW[4] | $69.9 | $50.6 | $69.9 | $55.1 | $56.5 | $44.6 | $56.5 |

1. *Includes estimator's contingency (30%).*
2. *Biosolids end use net cost for production/revenue: hauling to Boulder Park at $65/WT; local composting at $100/WT; local blending at $30/WT.*
3. *Net biomethane sales: $2.00/therm includes gas and brokered RIN/LCFS credits revenue. Power generation sales: $0.08/kWh.*
4. *Includes engineering, legal & admin (25%) and change order reserve (5%).*
5. *Costs showing in 2017 dollars. Quantities reflect flow and load projections in Year 2035.*
6. *City labor estimates include end use program management/maintenance as well as staff operations, maintenance, and transport. Estimate does not include labor associated with biosolids sales.*
7. *Burdened labor rate of $75/hour; electrical power of $0.08/kWh; natural gas of $0.65/therm; polymer of $1.40/lb.*

The life-cycle costs include initial project costs and present worth of annual O&M and replacement costs. Life-cycle estimate variations are driven largely by biogas alternative use, cogeneration or pipeline injection. Biosolids end-use facilities also create cost variation in annual O&M and construction costs, as shown in Figure 6-1.



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**Figure 6-1. Comparison of life-cycle costs**

Alternative 3B, which includes Class A digestion, biogas upgrading, pipeline injection, and off-site soil blending, has the lowest life-cycle cost of the alternatives.

## 6.3 Rate Impacts

A capital funding analysis was conducted to determine the relative impacts of the alternatives on the City's wastewater rates. Estimated rate impacts were determined in dollars per equivalent residential unit (ERU), which approximates the average level of the City's wastewater rates. The estimated construction and O&M costs developed for Alternative 3B (Class A digestion with off-site soil blending) were used to estimate rate impacts since that alternative had the lowest NPW. If another alternative is selected following the Phase 2 TBL+ evaluation, this rate impact analysis can be adjusted. The complete capital funding analysis can be found in Appendix B.

The total project cost of $195.9 million (in 2023 dollars) was assumed to be funded with 30-year term revenue bonds. The revenue bonds were assumed to have an interest rate of 5 percent and an issuance cost of 1 percent. To calculate the total cost of borrowing, 1 year of debt service was assumed to be held in reserve. Including the debt reserve and issuance cost, the total estimated borrowing cost for the revenue bonds is $212 million. The total estimated 30-year cost is $400 million, with annual debt service costs of $13.8 million.

In addition to funding debt service, the rate impacts of funding annual net O&M costs for Alternative 3B were considered. The project is expected to add approximately $200,000 to the current O&M costs for the incineration process. O&M costs were escalated to 2023 dollars assuming a 3 percent inflation rate per year to match construction costs.

The rate impacts were determined for 2023 to match the mid-point of construction cost in 2023 dollars. The City's 43,687 ERUs served in 2018 were estimated to grow at rate of 1.5 percent per year, for a total of 47,063 ERUs in 2023. The current bi-monthly single-family sewer rate is $43.16 per month. Rates were assumed to increase with inflation at a rate of 3 percent per year (i.e., $50.03 per month in 2023). Funding annual debt service and O&M costs of $14 million would require a rate increase of approximately $25 per



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month per ERU. For planning purposes, it is recommended to account for a rate range impact of $24 to 30 per month per ERU. Monthly rate costs per ERU would increase by 50 percent to approximately $75.

**Table 6-3. Cost Summary for Rate Impacts[1]***

| Parameter | Alt 1A<br>Class B Meso Compost Cogen | Alt 1B<br>Class B Meso Compost Pipeline | Alt 2A<br>Class B TPAD Compost Cogen | Alt 2B<br>Class B TPAD Compost Pipeline | Alt 3A<br>Class A TPAD Blend Cogen | Alt 3B<br>Class A TPAD Blend Pipeline | Alt 4<br>Class A ATAD Blend Pipeline |
|---|---|---|---|---|---|---|---|
| Existing Annual O&M | $2.8 | $2.8 | $2.8 | $2.8 | $2.8 | $2.8 | $2.8 |
| Net Annual O&M Cost | $1.9 | $0.6 | $1.9 | $0.9 | $1.0 | $0.2 | $1.0 |
| 20-Year NPW for Rate Impacts | $242.2 | $205.6 | $244.7 | $213.3 | $227.2 | $199.5 | $233.7 |

**Cost in Millions*

1. *ACCE Class 5*

Figure 6-2 shows existing single-family sewer rates and projected cost per ERU in 2023, including inflation and funding costs for the Project.

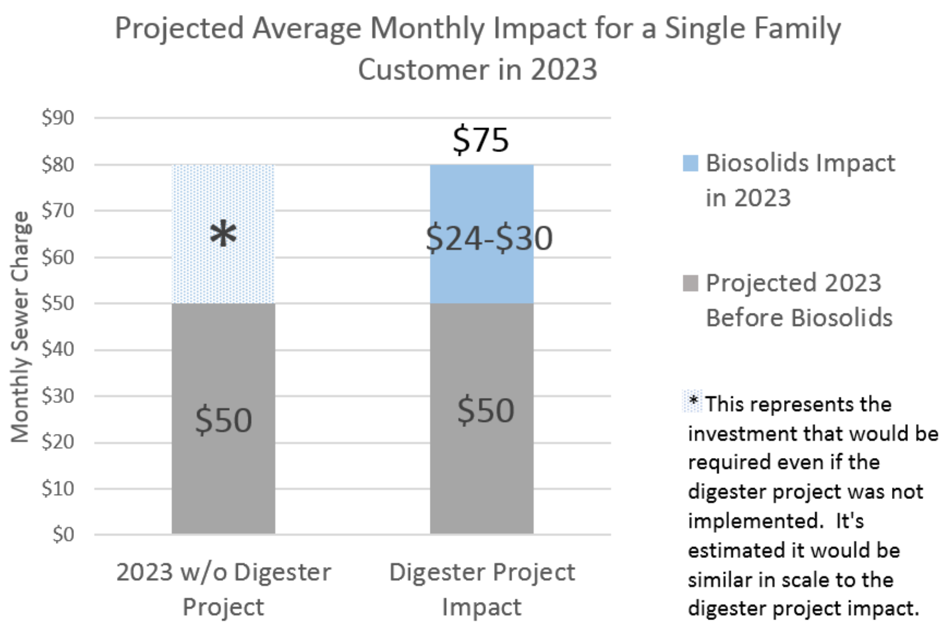


**Figure 6-2. Projected sewer rates**

Funding the new biosolids facilities will have a significant impact on the City's rates. Given the magnitude of the rate increases required fund the Project, it is recommended the City begin increasing rates prior to construction and aggressively pursue grant funding opportunities. This could allow the rate increases to be spread equally over a period of years. Delaying rate increases will make future rate increases more



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disruptive to ratepayers. Increasing rates prior to construction would also allow the City to accumulate funding reserves prior to construction. Increased cash reserves could be used to reduce the amount of debt required to fund the project.

## 6.4 Schedule Implications

Project implementation would likely occur over a 6 to 7-year schedule in the following Phases:

- **Facility Planning and Preliminary Design (2 years).** During 2019 and into 2021, implementation planning and predesign efforts would focus on evaluating and selecting the method of project procurement, refining funding and rate impacts, beginning environmental and permitting efforts, developing initial design to approximately a 30-percent level of completion to facilitate refinement of the cost estimates, and engaging the public. These efforts would be documented in a Facilities Planning Report that meets the requirements of WAC Chapter 173 for approval by the Washington Department of Ecology, and in a Preliminary Design drawing submission.
- **Detailed Design (2 years).** From 2021 to 2022, the detailed design would be developed into biddable construction documents. Concurrently, the team would more fully develop alternatives for biosolids reuse.
- **Construction (3 years).** From 2022 through 2025, the City Council-approved Project would be constructed and commissioned.

# Section 7: Phase 2 TBL+ Evaluation Results

A TBL+ evaluation of the Phase 2 alternatives was conducted using the same methodology established in Phase 1 (For a comprehensive description of the TBL+ process and the evaluation criteria, refer to Phase 1 TM 1). Each of the four criteria categories (environmental, social, financial, and technical) were assigned a total value of 25 points for later consolidation (section 7.5) to come up with overall alternative TBL+ scores. Evaluation criteria in each of the four criteria categories were quantitatively assessed and compared for each individual alternative considered. Each criterion was compared and scored for each alternative by percent, where the most desirable alternative is given 100 percent and other alternatives are given lower scores proportional to their comparison to the best scoring alternative. The alternatives were then scored out of the 25 total points assigned to the criteria category. Scoring was completed by the engineering team and reviewed with City management to ensure the views of all City departments were incorporated. The scoring of alternatives is described by criteria category in the following sections.

## 7.1 Environmental Criteria

The scoring of the alternatives, based on the five environmental criteria, is defined below in Table 7-1.

Key alternatives scoring results are as follows:

- Alternative 1B scored the best carbon footprint; Alternative 4 scored the worst.
- Reduction in air pollutant discharge to minimize human exposure scored similarly with Alternatives 1B, 2B, 3B, and 4 all at the maximum. This is due to lower local emissions from pipeline injection than cogeneration facilities.
- Each alternative similarly recovers energy, heat, nutrients, and organic matter locally.
- Alternative 1B scored the most favorable for net energy usage followed by 3B and 2B. The pipeline injection process minimizes the City's energy use.

- All seven alternatives provide similar impacts to the site's general habitat, heron rookery nests, wetlands, and site storm water.

| Table 7-1. Environmental Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|
| Criterion | Alt 1A<br>Class B Meso Compost Cogen | Alt 1B<br>Class B Meso Compost Pipeline | Alt 2A<br>Class B TPAD Compost Cogen | Alt 2B<br>Class B TPAD Compost Pipeline | Alt 3A<br>Class A TPAD Blend Cogen | Alt 3B<br>Class A TPAD Blend Pipeline | Alt 4<br>Class A ATAD Blend Pipeline |
| E1. Minimizes carbon footprint (GHG emissions) | 62% | 100% | 71% | 90% | 77% | 96% | 30% |
| E2. Protects air quality | 80% | 100% | 80% | 100% | 80% | 100% | 100% |
| E3. Maximizes opportunities for resource recovery | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| E4: Minimizes net energy usage | 23% | 100% | 33% | 83% | 40% | 90% | 73% |
| E5: Protects and improves local habitat | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Total score (25 points possible)** | **18** | **25** | **19** | **24** | **20** | **24** | **20** |

Overall, Alternatives 1B, 2B, and 3B provide the greatest environmental criteria score due to the lowest GHG emissions and energy use profile. Alternative 1A has the lowest score due to high GHG and a poor net energy usage.

It should be noted that the Washington Department of Ecology is currently studying the impacts of nitrogen discharges on Puget Sound habitat. Digestion releases some nitrogen in the dewatering recycle that adds to the nitrogen already in the liquid stream. However, all the biosolids alternatives include digestion and are considered equal with respect to criterion E5, habitat protection. If in the future, Ecology requires nitrogen removal from the plant effluent, digestion recycle side stream treatment and/or full liquid stream treatment enhancements would need to be considered to remove nitrogen.

## 7.2 Social Criteria

Five social criteria were selected to support the City's legacy goals of creating a sense of place while also minimizing local visual impacts (i.e., supports access to quality-of-life amenities). Table 7-2 defines each criterion and the individual scores for each alternative.

Key alternatives scoring results are as follows:

- Alternative 4 requires a higher level and larger volume of odor treatment and, therefore, carries more risk of an odor excursion. In addition, at the off-site facility, a composting process would require more odor treatment than soil blending.
- All alternatives create similar truck traffic from Post Point, between 1.5 to 1.7 truckloads per day.
- All alternatives have the same noise impact, visual impact to the shoreline view corridors, and minimizes exposure to toxins to workers and the public.

Although all alternatives perform very similarly socially, Alternatives 2A, 2B, 3A, and 3B scored the highest social criteria. Alternative 4 scored the lowest due to a potential for nuisance odor, making this a less desirable alternative.

**Table 7-2. Social Criteria**

| Criterion | Alt 1A<br>Class B Meso Compost Cogen | Alt 1B<br>Class B Meso Compost Pipeline | Alt 2A<br>Class B TPAD Compost Cogen | Alt 2B<br>Class B TPAD Compost Pipeline | Alt 3A<br>Class A TPAD Blend Cogen | Alt 3B<br>Class A TPAD Blend Pipeline | Alt 4<br>Class A ATAD Blend Pipeline |
|---|---|---|---|---|---|---|---|
| S1: Minimizes public exposure to noise | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| S2: Minimizes public exposure to odor | 90% | 90% | 90% | 90% | 100% | 100% | 50% |
| S3: Minimizes public exposure to truck traffic | 95% | 95% | 100% | 100% | 100% | 100% | 100% |
| S4: Minimizes local visual impacts | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| S5: Minimizes exposure to toxins | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Total score (25 points possible)** | **24** | **24** | **25** | **25** | **25** | **25** | **23** |

## 7.3 Financial Criteria

Three financial criteria were defined to support the City's legacy goals of quality and responsive services that are efficient, effective, and accountable. Table 7-3 defines each criterion and the individual scores for each alternative. Criteria F1 and F2 analyze the total project 20-year life-cycle without considering net O&M differences.

**Table 7-3. Financial Criteria**

| Criterion | Alt 1A<br>Class B Meso Compost Cogen | Alt 1B<br>Class B Meso Compost Pipeline | Alt 2A<br>Class B TPAD Compost Cogen | Alt 2B<br>Class B TPAD Compost Pipeline | Alt 3A<br>Class A TPAD Blend Cogen | Alt 3B<br>Class A TPAD Blend Pipeline | Alt 4<br>Class A ATAD Blend Pipeline |
|---|---|---|---|---|---|---|---|
| F1: Optimizes system value | 82% | 97% | 82% | 94% | 88% | 100% | 85% |
| F2: Affordability | 82% | 97% | 82% | 94% | 88% | 100% | 85% |
| F3: Minimizes risk of end use market sensitivity | 100% | 90% | 100% | 90% | 100% | 90% | 90% |
| **Total score (25 points possible)** | **22** | **24** | **22** | **23** | **23** | **24** | **22** |



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Key alternatives scoring results are as follows:

- Alternatives 1B, 2B, and 3B provide the best return on investment, with the pipeline injection alternatives (1B and 3B) having lower capital costs.
- Alternative 3B provides the greatest rate affordability and optimizes system value, while Alternatives 1A and 2A provide the least.
- Minimization of the risk of end use market sensitivity are the lowest with cogeneration facilities while pipeline injection facilities create the greatest sensitivity.

Overall, Alternatives 1B, 3A, and 3B provides the greatest financial value and affordability while Alternative 4 provides the least due to higher commodity market volatility, less affordability, and more expensive construction.

## 7.4 Technical Criteria

Four technical criteria were identified and defined to support the City's legacy goals of a quality-responsive City service, as well as supporting a sense of place by providing natural green settings and access to open space. Table 7-4 defines each criterion and the individual scores for each alternative.

**Table 7-4. Technical Criteria**

| Criterion | Alt 1A<br>Class B Meso Compost Cogen | Alt 1B<br>Class B Meso Compost Pipe | Alt 2A<br>Class B TPAD Compost Cogen | Alt 2B<br>Class B TPAD Compost | Alt 3A<br>Class A TPAD Blend Cogen | Alt 3B<br>Class A TPAD Blend Pipe | Alt 4<br>Class A ATAD Blend Pipe |
|---|---|---|---|---|---|---|---|
| T1: Incorporates reliability and proven performance | 97% | 93% | 93% | 90% | 97% | 93% | 87% |
| T2: Minimizes existing process impacts | 100% | 100% | 90% | 90% | 90% | 90% | 90% |
| T3: Provides flexibility for the future | 75% | 75% | 90% | 90% | 100% | 100% | 100% |
| T4: Minimizes implementation complexity | 100% | 100% | 100% | 100% | 96% | 96% | 96% |
| **Total score** (25 points possible) | **23** | **23** | **23** | **23** | **24** | **24** | **23** |

Key alternatives scoring results are as follows:

- Alternative 4 has the lowest reliability and proven performance due to few ATAD installations in operation. Biogas upgrading is also less proven than cogeneration and TPAD is less proven than mesophilic digestion.
- All alternatives minimize the solids and nutrient return impact to the liquid stream; however, higher struvite potential has a minor effect on TPAD and ATAD options.
- Alternative 1A and 1B have lower future adaptability capabilities due to the need for substantial modifications if Class A digestion is required.
- All alternatives have similar implementation risk for solids handling and biogas end use.



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Overall, Alternatives 3A and 3B provide the best technical criteria largely due to the flexibility provided by implementing a Class A digestion process.

As stated above under the discussion of environmental criteria, the Washington Department of Ecology is currently studying the impacts of nitrogen discharges on Puget Sound habitat. If in the future, Ecology requires nitrogen removal from the plant effluent, digestion recycle side stream treatment and/or full liquid stream treatment enhancements would need to be considered to remove nitrogen. Since all biosolids alternatives use approximately the same site space at Post Point for new biosolids processing facilities, all alternatives were considered equal with respect to site space utilization under criterion T3, flexibility for the future. Impacts on site space with respect to any potential requirement for nitrogen removal will be investigated during Phase 3 of the project.

## 7.5 Overall Score

The scores from all four categories were combined to determine a total score for each alternative. Table 7-5 summarizes the score for each category, and the total score for each alternative.

**Table 7-5. Overall Score**

| Criteria | Alt 1A<br>Class B Meso Compost<br>Cogen | Alt 1B<br>Class B Meso Compost<br>Pipeline | Alt 2A<br>Class B TPAD Compost<br>Cogen | Alt 2B<br>Class B TPAD Compost<br>Pipeline | Alt 3A<br>Class A TPAD Blend<br>Cogen | Alt 3B<br>Class A TPAD Blend<br>Pipeline | Alt 4<br>Class A ATAD Blend<br>Pipeline |
|---|---|---|---|---|---|---|---|
| Environmental | 18 | 25 | 19 | 24 | 20 | 24 | 20 |
| Social | 24 | 24 | 25 | 25 | 25 | 25 | 23 |
| Financial | 22 | 24 | 22 | 23 | 23 | 24 | 22 |
| Technical | 23 | 23 | 23 | 23 | 24 | 24 | 23 |
| **Total score** (100 points possible) | **88** | **96** | **89** | **94** | **92** | **97** | **88** |

Alternative 3B performed the highest overall, scoring well in all four categories, followed closely by Alternatives 1B and 2B. Overall, the pipeline injection alternatives provide the best potential for fulfillment of the criteria due to lowest GHG emissions and the financial incentive of RINs. Additionally, Class A digestion is more favorable due to its flexibility to adapt to future regulations and market changes. Alternatives 1A and 4 are the least favorable options.



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# Section 8: Findings and Recommendations

This section summarizes the findings from the Phase 2 TBL+ analysis and provides recommendations for next steps.

## 8.1 Findings

Phase 2 further defined the preferred conceptual alternative to identify the preferred final alternative. The development of the refined anaerobic digestion, solids handling, biogas end use, and final product processing resulted in the following seven conceptual alternatives being developed and analyzed. All alternatives consider an off-site biosolids processing facility due to limited space available at Post Point. The key differentiators for the seven alternatives considered are as follows:

- **Alternative 1A: Class B Mesophilic Digestion and Off-Site Composting with CHP.** This alternative produces Class A biosolids only after it has been composted at an off-site facility. The Class A product can be used locally. The facility would be able to utilize the heat and power generated by the digester gas in the CHP system.
- **Alternative 1B: Class B Mesophilic Digestion and Off-Site Composting with Biogas Upgrading.** This alternative is similar to 1A except the biogas end use is biogas upgrading. The benefits of gas upgrading include greater GHG emissions reductions and more favorable economics.
- **Alternative 2A: Class B TPAD and Composting with CHP.** TPAD improves solids destruction but would still result in Class B biosolids without batch tanks. Only after it has been composted at an off-site facility would the product be Class A. TPAD produces more digester gas which, in this alternative, would be used by a CHP system to produce electricity and heat.
- **Alternative 2B: Class B TPAD and Composting with Biogas Upgrading.** This alternative is similar to 2A except the biogas end use is biogas upgrading. The higher production of digester gas in the TPAD allows more gas to be upgraded and beneficially used.
- **Alternative 3A: Class A TPAD and Soil Blending with CHP.** This alternative produces a Class A product with the use of batch tanks but requires additional processing at an off-site soil blending facility to produce a suitable product that can be used locally. This alternative would beneficially use the biogas in a CHP system.
- **Alternative 3B: Class A TPAD and Soil Blending with Biogas Upgrading.** This alternative is similar to 3A except the biogas end use is biogas upgrading.
- **Alternative 4: Class A Aerobic-Anaerobic Digestion and Soil Blending with Biogas Upgrading.** The digestion process in this alternative is able to produce a Class A product but requires additional biosolids processing at an off-site soil blending facility to produce a product suitable for local use. Because this digestion process generates its own heat, only a biogas upgrading process was considered.

The results of the TBL+ analysis are shown in Figure 8-1. It should be noted that all alternatives scored well in the TBL+ evaluation. This is due to prior screening out of less desirable system components in Phase 1 and the relative similarities between alternatives. However, Alternative 3B (Class A TPAD, soil blending, and gas upgrading) has the highest overall score—receiving 97 points out of a possible 100. Alternatives 1B (mesophilic, composting, gas upgrading) and 2B (Class B TPAD, soil blending, and gas upgrading) have the next highest scores—receiving 96 and 94 points out of a possible 100, respectively.



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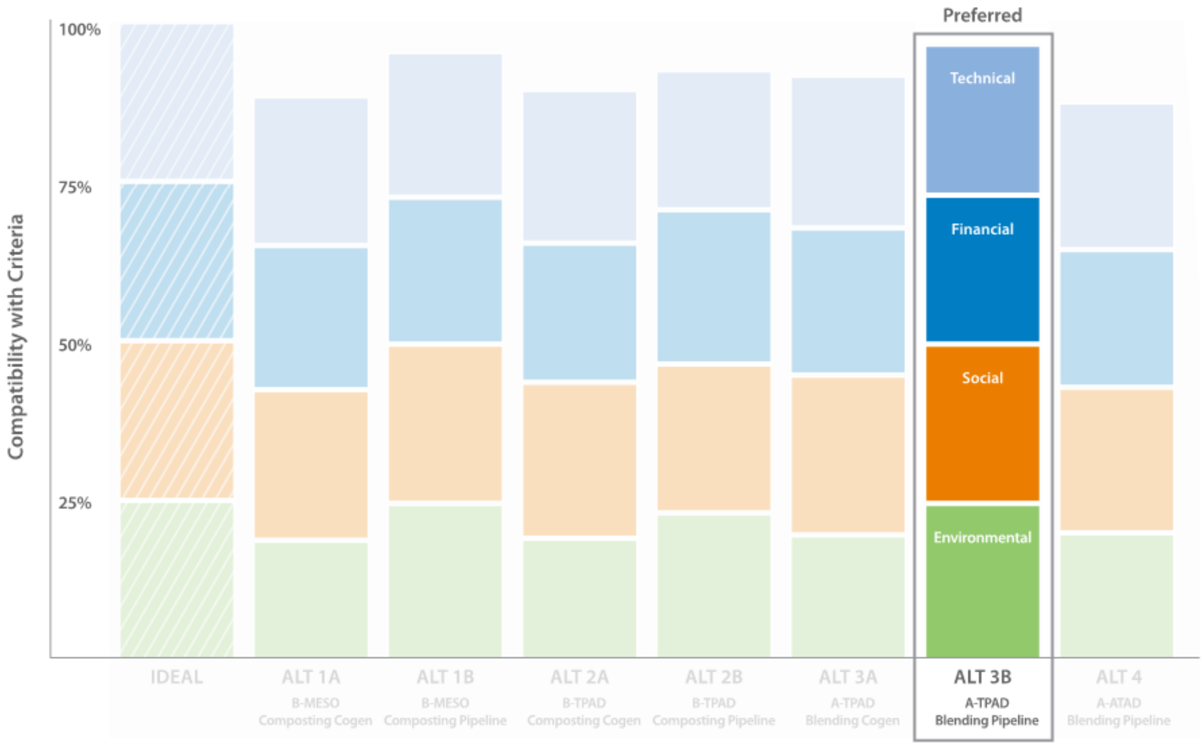


**Figure 8-1. TBL+ results**

## 8.2 Recommendations

Based on the results of the TBL+ analysis and public feedback from Phase 1 for a local Class A product and maximized environmental benefit, Alternative 3B is recommended for further development and analysis. This alternative was identified as the alternative that best meets the City's Legacies and Strategic Commitments and provides the best blend of environmental, social, financial, and technical benefits.

The following next steps are recommended:

- Develop a Biosolids Facility Plan to update the biosolids treatment and disposal chapter and sections in the City's all-inclusive comprehensive 2011 Wastewater Facilities Planning Report. The updated Facilities Plan will address the following:
    - Update population and flow demand and solids production projections.
    - Evaluate impacts of biosolids treatment and recycle streams on operations of existing treatment processes.
    - Finalize building programming and evaluate alternative layouts to optimize integration of new facilities within the Post Point site.
    - Evaluate digester heating and gas utilization alternatives
    - Select screening, thickening, dewatering, and gas upgrading processes
    - Assess off-site biosolids processing options and land acquisition requirements, including a review of potential private partnerships.


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    - Identify permit requirements and Post Point impacts, including upcoming nitrogen removal requirements
    - Develop a construction sequencing plan
    - Update the cost estimate and schedule
    - Conduct a more detailed rate impact study
    - Identify funding assistance opportunities
- Complete a preliminary design of selected alternatives.
- Continue public outreach efforts to inform community stakeholders and solicit input on key project decisions.



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# Appendix A: Solids-Water-Energy Evaluation Tool Assumptions and Results



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## Summary of Bellingham Phase 2 Alternative Outputs

| Bellingham Phase 2 Alternatives | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Alternative** | | **Thickening** | **Stabilization** | **Dewatering** | **Post-Dewatering** | **End Use** | **Gas Use** |
| 1A | Class B | GBT | Meso | Centrifuge | Composting | Soil Amendment | Cogen |
| 1B | Class B | GBT | Meso | Centrifuge | Composting | Soil Amendment | Pipeline |
| 2A | Class B | GBT | TPAD | Centrifuge | Composting | Soil Amendment | Cogen |
| 2B | Class B | GBT | TPAD | Centrifuge | Composting | Soil Amendment | Pipeline |
| 3A | Class A | GBT | TPAD + Batch | Centrifuge | Blending | Soil Amendment | Cogen |
| 3B | Class A | GBT | TPAD + Batch | Centrifuge | Blending | Soil Amendment | Pipeline |
| 4 | Class A | GBT | ATAD + TPAD | Centrifuge | Blending | Soil Amendment | Pipeline |

| Alternative Average Output Summary (Year 2035) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | Alt 1A | Alt 1B | Alt 2A | Alt 2B | Alt 3A | Alt 3B | Alt 4 |
| Dewatered Cake, Wet (WT/D) | 95 | 51 | 51 | 46 | 46 | 46 | 46 | 45 |
| Final Product, Wet (WT/D) | 3 | 86 | 86 | 77 | 77 | 105 | 105 | 104 |
| NG Required (cfh) | 1,130 | 300 | 1,368 | 300 | 3,011 | 300 | 3,011 | 300 |
| Electricity Req. (kW) | 307 | 527 | 585 | 516 | 585 | 431 | 500 | 777 |
| Power Generation (kW) | 0 | 876 | 0 | 966 | 0 | 966 | 0 | 0 |
| Net Power (kW)* | 307 | -348 | 585 | -450 | 585 | -535 | 500 | 777 |
| No. of Trucks Required (trucks/day) | 0.11 | 4.78 | 4.78 | 4.27 | 4.27 | 3.59 | 3.59 | 3.54 |
| Vehicle Fuel Consumed (gal/day) | 9.6 | 41.9 | 41.9 | 37.5 | 37.5 | 37.2 | 37.2 | 37.8 |
| Digester Gas Produced (scfm) | 0 | 253 | 253 | 280 | 280 | 280 | 280 | 171 |
| Methane Produced (scfm) | 0 | 152 | 152 | 168 | 168 | 168 | 168 | 103 |
| Methane Injected into Pipeline (scfm)** | 0 | 0 | 130 | 0 | 143 | 0 | 143 | 88 |
| Polymer Use (kg/day) | 191 | 215 | 215 | 202 | 202 | 202 | 202 | 200 |
| GDE from Gas Upgrading (gal/day) | 0 | 0 | 1,258 | 0 | 1,388 | 0 | 1,388 | 850 |

*Negative net power represents power consumed; positive new power represents power produced

**90% biogas utilized in cogen or upgraded to for pipeline injection. 95% of utilized biogas is recovered and injected into pipeline. Remaining biogas is flared.

| Alternative Average Daily Output Summary (Year 2035) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | Alt 1A | Alt 1B | Alt 2A | Alt 2B | Alt 3A | Alt 3B | Alt 4 |
| Dewatered Cake, Wet (WT/D) | 95 | 51 | 51 | 46 | 46 | 46 | 46 | 45 |
| Final Product, Wet (WT/day) | 3 | 86 | 86 | 77 | 77 | 105 | 105 | 104 |
| Final Product, Wet (cy/day) | | 123 | 123 | 110 | 110 | 122 | 122 | 120 |
| NG Required (cf/day) | 27,120 | 7,200 | 32,842 | 7,200 | 72,252 | 7,200 | 72,252 | 7,200 |
| Electricity Req. (kWh/day) | 7,361 | 12,658 | 14,048 | 12,391 | 14,049 | 10,345 | 12,002 | 18,654 |
| Power Generation (kWh/day) | 0 | 21,019 | 0 | 23,194 | 0 | 23,194 | 0 | 0 |
| Net Power (kWh/day)* | 7,361 | (8,361) | 14,048 | (10,803) | 14,049 | (12,849) | 12,002 | 18,654 |
| No. of Trucks Required (trucks/day) | 0.11 | 4.78 | 4.78 | 4.27 | 4.27 | 3.59 | 3.59 | 3.54 |
| Vehicle Fuel Consumed (gal/day) | 10 | 42 | 42 | 37 | 37 | 37 | 37 | 38 |
| Digester Gas Produced (scfd) | 0 | 364,970 | 364,970 | 402,725 | 402,725 | 402,725 | 402,725 | 246,468 |
| Methane Produced (scfd) | 0 | 218,982 | 218,982 | 241,635 | 241,635 | 241,635 | 241,635 | 147,881 |
| Methane Injected into Pipeline (scfd)** | 0 | 0 | 187,230 | 0 | 206,598 | 0 | 206,598 | 126,438 |
| Polymer Use (kg/day) | 191 | 215 | 215 | 202 | 202 | 202 | 202 | 200 |
| GDE from Gas Upgrading (gal/day) | 0 | 0 | 1,258 | 0 | 1,388 | 0 | 1,388 | 850 |

*Negative net power represents power consumed; positive new power represents power produced

**90% biogas utilized in cogen or upgraded to for pipeline injection. Remaining biogas is flared.

| Energy Balance (Year 2035) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | Alt 1A | Alt 1B | Alt 2A | Alt 2B | Alt 3A | Alt 3B | Alt 4 |
| NG Required (cfh) | (1130.00) | (300) | (1368.40) | (300) | (3010.50) | (300) | (3010.50) | (300) |
| Methane Produced (scfm) | 0 | 152 | 152 | 168 | 168 | 168 | 168 | 103 |
| Methane injected to pipeline (scfm)** | 0 | 0 | 130 | 0 | 143 | 0 | 143 | 88 |
| Net Energy - Natural Gas (btu/hr) | (1,061,070) | (281,700) | 6,040,428 | (281,700) | 5,256,292 | (281,700) | 5,256,292 | 5,504,135 |
| Electricity Req. (kWh/day) | (7360.53) | (12658.03) | (14048.05) | (12391.25) | (14048.54) | (10344.53) | (12001.83) | (18654.08) |
| Power Generation (kWh/day) | 0 | 21019 | 0 | 23194 | 0 | 23194 | 0 | 0 |
| Net Power (kWh/day)* | (7,361) | 8,361 | (14,048) | 10,803 | (14,049) | 12,849 | (12,002) | (18,654) |
| Total Net Energy Balance (MMBtu/hr) | (2.11) | 0.91 | 4.04 | 1.25 | 3.26 | 1.55 | 3.55 | 2.85 |

*Negative net power represents power consumed; positive new power represents power produced

**90% biogas utilized in cogen or upgraded to for pipeline injection. Remaining biogas is flared. Biogas contains 60% methane.

| Alternative Output Summary<br>Greenhouse Gas Emissions, Tonnes CO2e/year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | Alt 1A | Alt 1B | Alt 2A | Alt 2B | Alt 3A | Alt 3B | Alt 4 |
| Scope 1 | 1,778 | 619 | 1,002 | 608 | 1,741 | 607 | 1,741 | 444 |
| Scope 2 | 1,257 | (1,428) | 2,400 | (1,845) | 2,400 | (2,195) | 2,050 | 3,186 |
| Scope 3 | 772 | 735 | 742 | 687 | 705 | 687 | 705 | 682 |
| Credits | 0 | (1,959) | (7,417) | (1,758) | (7,781) | (1,616) | (7,639) | (5,279) |
| Total | 3,807 | (2,033) | (3,274) | (2,308) | (2,935) | (2,517) | (3,143) | (966) |

### Assumptions

Flows and loads based on mid-point average, year 2035
PS dry mass flow is 60% of TS loading
WAS dry mass flow is 40% of TS loading
GBT requires 8 lbs/ton of polymer
Centrifuge requires 25 lbs/ton of polymer
Methane is 60% of the digester gas produced
Based on experience with Annacis Island, heat recovered from co-gen is sufficient to heat digesters to
thermophilic temperature and provide all building heat
For TPAD alternatives, heat is not captured from TPAD heat exchanger
For the ATAD alternative, heat will be recovered to preheat sludge
For cogen alternatives, cogen beneficially utilizes 90% of digester gas produced, remaining gas is flared
For pipeline injection alternatives, 90% of gas produced is sent to the gas upgrading system, remaining gas is flared
For pipeline injection alternatives, gas upgrading system recovered 95% of CH4 sent to the to the gas upgrading system, remaining CH4 is burned in RTO.
For pipeline injection alternatives, the gallon diesel equivalent for CH4 is 7.2 gal/MMBtu.
For pipeline injection alternatives, natural gas will be used to for process heating.
Compost technology is covered ASP with biofilter for odor control
For composting alternatives, the bulking agent (wood chips) to sludge cake ratio is 3:1 by volume.
Compost will reduce sludge VS by 15%.
5% (by weight) of the final product is bulking agent that pass through screening
For soil blending alternatives, the sludge cake: saw dust: sand ratio is 2:1:1 by volume
Hauling distance for compost and soil amendment is 20 miles round trip
Average mileage for transport truck is 5 mpg
Transport truck hold 30 cy of compost
Transport truck hold 30 wet tons of soil blends
Transport truck can hold 54 dry tons of sand
Transport truck can hold 24 dry tons of sawdust
Transport truck can hold 11 dry tons of woodchips
Bulking agent hauling distance is 10 miles round trip.
Assume cogen will require 300 cfh of NG to cover cold weather periods when digester heat is insufficient to heat digesters
Assume ATAD will require 300 cfh og NG to cover cold weather periods when digester heat is insufficient to heat digesters
Compost volume assumes 3.8 cy compost/wt of sludge per calculation on alternative sheet 1A
Compost process assumes 20% recycle of woodchips.

## GHG CALCULATIONS

### Bellingham Phase 2 Alternative Output Summary

**Greenhouse Gas Emissions, Tonne CO2e/year**

| | | Baseline | Alt 1A | Alt 1B | Alt 2A | Alt 2B | Alt 3A | Alt 3B | Alt 4 |
|---|---|---|---|---|---|---|---|---|---|
| Scope 1 | Consumption of Natural Gas | 525 | 139 | 635 | 139 | 1,398 | 139 | 1,398 | 139 |
| | Consumption of Vehicle Fuel | 36 | 156 | 156 | 140 | 140 | 139 | 139 | 141 |
| | Fugitive Emissions | 1,217 | 324 | 210 | 329 | 204 | 329 | 204 | 164 |
| | **Scope 1 Total** | 1,778 | 619 | 1,002 | 608 | 1,741 | 607 | 1,741 | 444 |
| Scope 2 | Electricity Required | 1,257 | 2,162 | 2,400 | 2,117 | 2,400 | 1,767 | 2,050 | 3,186 |
| | Power Generated | 0 | (3,591) | 0 | (3,962) | 0 | (3,962) | 0 | 0 |
| | **Scope 2 Total** | 1,257 | (1,428) | 2,400 | (1,845) | 2,400 | (2,195) | 2,050 | 3,186 |
| Scope 3 | Production of Polymer | 628 | 707 | 707 | 663 | 663 | 663 | 663 | 657 |
| | Production of Natural Gas | 139 | 2 | 9 | 2 | 20 | 2 | 20 | 2 |
| | Production of Vehicle Fuel | 6 | 25 | 25 | 23 | 23 | 23 | 23 | 23 |
| | **Scope 3 Total** | 772 | 735 | 742 | 687 | 705 | 687 | 705 | 682 |
| Credits | Fertilizer Offset | 0 | (846) | (846) | (759) | (759) | (698) | (698) | (688) |
| | Carbon Sequestration | 0 | (1,113) | (1,113) | (999) | (999) | (918) | (918) | (905) |
| | Gas Upgrading (GDE) | 0 | 0 | (5,458) | 0 | (6,023) | 0 | (6,023) | (3,686) |
| | **Credits Total** | 0 | (1,959) | (7,417) | (1,758) | (7,781) | (1,616) | (7,639) | (5,279) |
| | **Total, Tonne CO2e/Year** | **3,807** | **(2,033)** | **(3,274)** | **(2,308)** | **(2,935)** | **(2,517)** | **(3,143)** | **(966)** |
| | **Difference from Baseline** | **0** | **(5,841)** | **(7,081)** | **(6,116)** | **(6,742)** | **(6,324)** | **(6,950)** | **(4,773)** |

## Alt 1A Output Summary

| | |
|---|---|
| Final Product, Wet (WT/D) | 86 |
| NG Required (cfh) | 300 |
| Electricity Req. (kW) | 527 |
| Power Generation (kW) | 876 |
| Net Power (kW)* | -348 |
| No. of Trucks Required (trucks/day) | 4.78 |
| Vehicle Fuel Consumed (gal/day) | 42 |
| Digester Gas Produced (scfm) | 253 |
| Methane Produced (scfm) | 152 |
| Polymer Use (kg/day) | 215 |
| GDE from Gas Upgrading (gal/day) | 0 |

### Primary Sludge

Dry Mass Flow 29203 PPD
TS 3.2%
VS 89%
Calorific Value 10,000 Btu/lb VS

Feedstock Type
Primary Sludge

Energy Consumption
0 hp
90% Efficiency

### WAS

20318 PPD
0.6%
85%
10,000 Btu/lb VS

Feedstock Type
WAS

Energy Consumption
0 hp
90% Efficiency

### Thickening

GBT

97% Capture
5.0% TS

Duty No. 2

Feedstock Type
Combined

Energy Consumption
25 hp
90% Efficiency

Polymer Use
8 lbs/ton

### Stabilization

Digester (Meso)

VSR 58.0%
Duty No. 4

Nat gas usage, cfh
300.00

Sludge Inlet Temp
65 F
Operation Temp
95 F
560 Btu/cf
15 cf/lb VS
1.20 MMBtu/hr

Energy Consumption
55 hp
90% Efficiency
Shell Heat Loss
7%

### Dewatering

Centrifuge

95% Capture
22% TS

Duty No. 2

Energy Consumption
85 hp
90% Efficiency

Polymer Use
25 lbs/ton

### Woodchips

67557 PPD
50.0%
95%
10,000 Btu/lb VS

Feedstock Type
Bulking Agent 1

Energy Consumption
0 hp
100% Efficiency

Transport Fuel Consumption
10 miles
7 mpg

### Composting

Compost

40% TS
VSR 15.0%
Duty No. 1

Energy Consumption
136 hp
90% Efficiency

Transport Fuel Consumption
20 miles
5 mpg
Front Loader Fuel Consumption
0.600 gal/wt

### Cogen

CHP Engine
939
NG LHV

Duty No. 1
Therm Eff. 42%

Nat gas usage, cfh
Biogas Fuel use 90%

Engine Electrical Eff.
39%
Heat Recovery
3.22 MMBtu/hr

Energy Consumption
60 hp
90% Efficiency

### Flare

Duty No. 1

Energy Consumption
0 hp
90% Efficiency

Digester Gas Flared
10%

Brown AND Caldwell

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 38,021 | lb/hr | 191,154 | lb/hr | 40,029 | lb/hr | 39,016 | lb/hr | 4,265 | lb/hr | 4,691 | lb/hr | 7,165 | lb/hr | 7,165 | lb/hr | 7,165 | lb/hr |
| Dry Mass Flow | 1,217 | lb/hr | 2,063 | lb/hr | 2,001 | lb/hr | 988 | lb/hr | 938 | lb/hr | 1,152 | lb/hr | 1,017 | lb/hr | 1,017 | lb/hr | 1,017 | lb/hr |
| | 14.6 | DTPD | 24.8 | DTPD | 24.0 | DTPD | 11.9 | DTPD | 11.3 | DTPD | 13.8 | DTPD | 12.2 | DTPD | 12.2 | DTPD | 12.2 | DTPD |
| VS | 1,083 | lb/hr | 1,802 | lb/hr | 1,748 | lb/hr | 734 | lb/hr | 697 | lb/hr | 900 | lb/hr | 765 | lb/hr | 765 | lb/hr | 765 | lb/hr |
| Water | 36,804 | lb/hr | 189,091 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr | 3,327 | lb/hr | 3,540 | lb/hr | 6,149 | lb/hr | 6,149 | lb/hr | 6,149 | lb/hr |
| TS | 3% | | 1.08% | | 5.00% | | 2.53% | | 22.00% | | 24.55% | | 14.19% | | 14.19% | | 14.19% | |
| VS | 89% | | 87% | | 87% | | 74% | | 74% | | 78% | | 75% | | 75% | | 75% | |
| Wet flow | 76.0 | gpm | 382.0 | gpm | 80.0 | gpm | 78.0 | gpm | 8.5 | gpm | 9.4 | gpm | 14.3 | gpm | 14.3 | gpm | 14.3 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 0 | kW | 0.0 | kW | 41.4 | kW | 182.4 | kW | 140.9 | kW | 0.0 | kW | 113.0 | kW | 49.7 | kW | 0.0 | kW |
| Unit Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -1.28 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 3.22 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -1.28 | MMBtu/hr | -1.28 | MMBtu/hr | -1.28 | MMBtu/hr | -1.28 | MMBtu/hr | 1.93 | MMBtu/hr | 1.93 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 8.52 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -7.66 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 8.52 | MMBtu/hr | 8.52 | MMBtu/hr | 8.52 | MMBtu/hr | 8.52 | MMBtu/hr | 0.85 | MMBtu/hr | 0.85 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.88 | MW | 0.00 | MW |
| No. of Trucks Required | 0 | trucks/day | 0 | trucks/day | 0 | trucks/day | 0 | trucks/day | 0 | trucks/day | 3.07 | trucks/day | 1.71 | trucks/day | 0 | trucks/day | 0 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 4.4 | gal/day | 38 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 253 | scfm | 0 | scfm | 0 | scfm | 0.00 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 152 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 137 | scfm | 15 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 87 | kg/day | 0 | kg/day | 128 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | | Volume Ratio | Wet Weight | Dry Weight |
|---|---|---|---|---|---|---|
| **Wood Chips** | | | | | | |
| Density | 550 | lbs/cy | | 3.00 cy | 1650 lbs | 990 lbs |
| moisture | 60% | dry | | | | |
| **sludge** | | | | | | |
| Density | 1500 | lbs/cy | | 1.00 cy | 1500 lbs | 330 lbs |
| moisture | 22% | dry | | | | |
| **Pre-Compost Blend (target 40% TS)** | | | | | | |
| Density | 787.5 | lbs/cy of mixture | | | | |
| | 0.39375 | Wet Ton/cy of mixture | | | | |
| **Compost Mixture** | | | | | | |
| Volume reduction | 10% | | | based on VSR during composting | | |
| Density | 875.0 | lbs/cy | | | | |
| CY compost/CY sludge | 3.6 | | | | | |
| CY compost/WT sludge | 3.8 | | | assumes 20% recycle | | |
| CY compost/DT sludge | 17.5 | | | | | |
| **Truck Capacity** | | | | | | |
| Dewatered Cake Capaci | 30 | wet tons | | | | |
| Mass of cake | 1500 | lbs/cy | | | | |
| Density of cake | 55.6 | lb/cf | | | | |
| Size of Truck | 1080 | cf | | | | |
| Mass of Woodchips | 550 | lb/cy | | | | |
| Density of Woodchips | 20.37 | lb/cf | | | | |
| Weight of Woodchips | 22000.0 | lb | | | | |
| | **11.00** | **ton** | | | | |

## Alt 1B Output Summary

| | |
|---|---|
| Final Product, Wet (WT/D) | 86 |
| NG Required (cfh) | 1368 |
| Electricity Req. (kW) | 585 |
| Power Generation (kW) | 0 |
| Net Power (kW)* | 585 |
| No. of Trucks Required (trucks/day) | 4.78 |
| Vehicle Fuel Consumed (gal/day) | 42 |
| Digester Gas Produced (scfm) | 253 |
| Methane Produced (scfm) | 152 |
| Polymer Use (kg/day) | 215 |
| GDE from Gas Upgrading (gal/day) | 1258 |

### Primary Sludge

| | | |
|---|---|---|
| Dry Mass Flow | 29203 | PPD |
| TS | 3.2% | |
| VS | 89% | |
| Calorific Value | 10,000 | Btu/lb VS |

Feedstock Type: Primary Sludge

Energy Consumption: 0 hp; 90% Efficiency

### WAS

Dry Mass Flow: 20318 PPD; TS: 0.6%; VS: 85%; Calorific Value: 10,000 Btu/lb VS

Feedstock Type: WAS

Energy Consumption: 0 hp; 90% Efficiency

### Thickening

GBT

97% Capture; 5.0% TS

Duty No. 2

Feedstock Type: Combined

Energy Consumption: 25 hp; 90% Efficiency

Polymer Use: 8 lbs/ton

### Stabilization

Digester (Meso)

939 NG LHV

VSR 58.0%

Duty No. 4

1,368 NG Use, cfh

Sludge Inlet Temp: 65 F

Operation Temp: 95 F

560 Btu/cf

15 cf/lb VS

1.20 MMBtu/hr

Energy Consumption: 55 hp; 90% Efficiency

Shell Heat Loss: 7%

### Dewatering

Centrifuge

95% Capture; 22% TS

Duty No. 2

Energy Consumption: 85 hp; 90% Efficiency

Polymer Use: 25 lbs/ton

### Woodchips

Dry Mass Flow: 67557 PPD; TS: 50.0%; VS: 95%; Calorific Value: 10,000 Btu/lb VS

Feedstock Type: Bulking Agent 1

Energy Consumption: 0 hp; 100% Efficiency

Transport Fuel Consumption: 10 miles; 7 mpg

### Composting

Compost

40% VSR; TS 15.0%

Duty No. 1

Energy Consumption: 136 hp; 90% Efficiency

Transport Fuel Consumption: 20 miles; 5 mpg

Front Loader Fuel Consumption: 0.600 gal/wt

### Biogas Utilization

Pipeline Injection

Duty No. 1

Biogas Fuel use 90%

Energy Consumption: 130 hp; 90% Efficiency

Flare

Duty No. 1

Energy Consumption: 0 hp; 90% Efficiency

Digester Gas Flared: 10%

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 38,021 | lb/hr | 191,154 | lb/hr | 40,029 | lb/hr | 39,016 | lb/hr | 4,265 | lb/hr | 4,691 | lb/hr | 7,165 | lb/hr | 7,165 | lb/hr | 7,165 | lb/hr |
| Dry Mass Flow | 1,217 | lb/hr | 2,063 | lb/hr | 2,001 | lb/hr | 988 | lb/hr | 938 | lb/hr | 1,152 | lb/hr | 1,017 | lb/hr | 1,017 | lb/hr | 1,017 | lb/hr |
| | 14.6 | DTPD | 24.8 | DTPD | 24.0 | DTPD | 11.9 | DTPD | 11.3 | DTPD | 13.8 | DTPD | 12.2 | DTPD | 12.2 | DTPD | 12.2 | DTPD |
| VS | 1,083 | lb/hr | 1,802 | lb/hr | 1,748 | lb/hr | 734 | lb/hr | 697 | lb/hr | 900 | lb/hr | 765 | lb/hr | 765 | lb/hr | 765 | lb/hr |
| Water | 36,804 | lb/hr | 189,091 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr | 3,327 | lb/hr | 3,540 | lb/hr | 6,149 | lb/hr | 6,149 | lb/hr | 6,149 | lb/hr |
| TS | 3% | | 1.08% | | 5.00% | | 2.53% | | 22.00% | | 24.55% | | 14.19% | | 14.19% | | 14.19% | |
| VS | 89% | | 87% | | 87% | | 74% | | 74% | | 78% | | 75% | | 75% | | 75% | |
| Wet flow | 76.0 | gpm | 382.0 | gpm | 80.0 | gpm | 78.0 | gpm | 8.5 | gpm | 9.4 | gpm | 14.3 | gpm | 14.3 | gpm | 14.3 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 0 | kW | 0.0 | kW | 41.4 | kW | 182.4 | kW | 140.9 | kW | 0.0 | kW | 113.0 | kW | 107.7 | kW | 0.0 | kW |
| Unit Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -1.28 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -1.28 | MMBtu/hr | -1.28 | MMBtu/hr | -1.28 | MMBtu/hr | -1.28 | MMBtu/hr | -1.28 | MMBtu/hr | -1.28 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 1.28 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 1.28 | MMBtu/hr | 1.28 | MMBtu/hr | 1.28 | MMBtu/hr | 1.28 | MMBtu/hr | 1.28 | MMBtu/hr | 1.28 | MMBtu/hr |
| Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 8.52 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -7.66 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 8.52 | MMBtu/hr | 8.52 | MMBtu/hr | 8.52 | MMBtu/hr | 8.52 | MMBtu/hr | 0.85 | MMBtu/hr | 0.85 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0 | trucks/day | 0 | trucks/day | 0 | trucks/day | 0 | trucks/day | 0 | trucks/day | 3.07 | trucks/day | 1.71 | trucks/day | 0 | trucks/day | 0 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 4.4 | gal/day | 38 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 253 | scfm | 0 | scfm | 0 | scfm | 0.00 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 152 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 137 | scfm | 15 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 87 | kg/day | 0 | kg/day | 128 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | Volume Ratio | Wet Weight | Dry Weight |
|---|---|---|---|---|---|
| **Wood Chips** | | | | | |
| Density | 550 | lbs/cy | 3.00 | 1650 lbs/cy | 990 lbs/cy |
| moisture | 60% | dry | | | |
| **sludge** | | | | | |
| Density | 1500 | lbs/cy | 1.00 | 1500 lbs/cy | 330 lbs/cy |
| moisture | 22% | dry | | | |
| **Pre-Compost Blend (target 40% TS)** | | | | | |
| Density | 787.5 | lbs/cy of mixture | | | |
| | 0.39375 | Wet Ton/cy of mixture | | | |
| **Compost Mixture** | | | | | |
| Volume Reduction | 10% | | | | |
| Density | 875.0 | lbs/cy | | | |
| CY compost/CY sludge | 3.6 | | assumes 20% recycle | | |
| CY compost/WT sludge | 3.8 | | | | |
| CY compost/DT sludge | 17.5 | | | | |
| | | | | | |
| **Truck Capacity** | | | | | |
| Dewatered Cake Capacity | 30 | wet tons | | | |
| Mass of cake | 1500 | lbs/cy | | | |
| Density of cake | 55.6 | lb/cf | | | |
| Size of Truck | 1080 | cf | | | |
| Mass of Woodchips | 550 | lb/cy | | | |
| Density of Woodchips | 20.37 | lb/cf | | | |
| Weight of Woodchips | 22000.0 | lb/truck | | | |
| | **11.00** | **ton** | | | |

Alt 2A Output Summary

| | |
|---|---|
| Final Product, Wet (WT/D) | 77 |
| NG Required (cfh) | 300 |
| Electricity Req. (kW) | 516 |
| Power Generation (kW) | 966 |
| Net Power (kW)* | -450 |
| No. of Trucks Required (trucks/day) | 4.27 |
| Vehicle Fuel Consumed (gal/day) | 37 |
| Digester Gas Produced (scfm) | 280 |
| Methane Produced (scfm) | 168 |
| Polymer Use (kg/day) | 202 |

## Primary Sludge

1st Feedstock (No referenced)

Dry Mass Flow 29203 PPD
TS 3.2%
VS 89%
Calorific Value 10,000 Btu/lb VS

Feedstock Type
Primary Sludge

Energy Consumption
0 hp
90% Efficiency

## WAS

20318 PPD
0.6%
85%
10,000 Btu/lb VS

Feedstock Type
WAS

Energy Consumption
0 hp
90% Efficiency

## Thickening

GBT

97% Capture
5.0% TS

Duty No. 2

Feedstock Type
Combined

Energy Consumption
25 hp
90% Efficiency

Polymer Use
8 lbs/ton

## Stabilization

TPAD System

**Digester (Thermo)**

VSR 64.0%
Duty No. 2

Nat gas usage, cfh
300.00

Sludge Inlet Temp
65 F
Operation Temp
131 F
560 cf gas/VS
15 cf/lb VS
2.64 MMBtu/hr

Energy Consumption
60 hp
90% Efficiency

Shell Heat Loss
7%

**HEX**

Duty No. 2

Inlet Temperature
135 F
Outlet Temperature
98 F

HEX Efficiency
70 %
1.01 MMBtu/hr

Energy Consumption
20 hp
90% Efficiency

**Digester (Meso)**

VSR 0.0%
Duty No. 2

Sludge Inlet Temp
98 F
Operation Temp
98 F
560 Btu/cf
15 cf/lb VS
0.00 MMBtu/hr

Energy Consumption
30 hp
90% Efficiency

Shell Heat Loss
4%

## Dewatering

Centrifuge

95% Capture
22% TS

Duty No. 2

Energy Consumption
85 hp
90% Efficiency

Polymer Use
25 lbs/ton

## Woodchips

60383 PPD
50.0%
95%
10,000 Btu/lb VS

Feedstock Type
Buling Agent 1

Energy Consumption
0 hp
100% Efficiency

Transport Fuel Consumption
10 miles
7 mpg

## Composting

Compost

40% TS
VSR 15.0%

Duty No. 1

Energy Consumption
123 hp
90% Efficiency

Transport Fuel Consumption
20 miles
5 mpg

Front Loader Fuel Consumption
0.600 gal/wt

## Cogen

**CHP Engine**

939
NG LHV

Duty No. 1
Therm Eff. 42%

Nat gas usage, cfh

Biogas Fuel use 90%

Engine Electrical Eff.
39%
Heat Recovery
3.55 MMBtu/hr

Energy Consumption
60 hp
90% Efficiency

**Flare**

Duty No. 1

Energy Consumption
0 hp
90% Efficiency

Digester Gas Flared
10% scfm

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 38,021 | lb/hr | 191,154 | lb/hr | 40,029 | lb/hr | 38,911 | lb/hr |
| Dry Mass Flow | 1,217 | lb/hr | 2,063 | lb/hr | 2,001 | lb/hr | 883 | lb/hr |
| | 14.6 | DTPD | 24.8 | DTPD | 24.0 | DTPD | 10.6 | DTPD |
| VS | 1,083 | lb/hr | 1,802 | lb/hr | 1,748 | lb/hr | 629 | lb/hr |
| Water | 36,804 | lb/hr | 189,091 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr |
| TS | 3% | | 1.08% | | 5.00% | | 2.27% | |
| VS | 89% | | 87% | | 87% | | 71% | |
| Wet flow | 76.0 | gpm | 382.0 | gpm | 80.0 | gpm | 77.8 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 0 | kW | 0.0 | kW | 41.4 | kW | 99.5 | kW |
| Unit Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -2.83 | MMBtu/hr |
| Total Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -2.83 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 280 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 168 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 87 | kg/day | 0 | kg/day |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 38,911 | lb/hr | 38,911 | lb/hr | 3,812 | lb/hr | 4,193 | lb/hr |
| Dry Mass Flow | 883 | lb/hr | 883 | lb/hr | 839 | lb/hr | 1,029 | lb/hr |
| | 10.6 | DTPD | 10.6 | DTPD | 10.1 | DTPD | 12.4 | DTPD |
| VS | 629 | lb/hr | 629 | lb/hr | 598 | lb/hr | 779 | lb/hr |
| Water | 38,028 | lb/hr | 38,028 | lb/hr | 2,973 | lb/hr | 3,164 | lb/hr |
| TS | 2.27% | | 2.27% | | 22.00% | | 24.55% | |
| VS | 71% | | 71% | | 71% | | 76% | |
| Wet flow | 77.8 | gpm | 77.8 | gpm | 7.6 | gpm | 8.4 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 33.2 | kW | 49.7 | kW | 140.9 | kW | 0.0 | kW |
| Unit Heat Bal. | 1.01 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Process Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 2.74 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 0 | gal/day | 0 | gal/day | 3.9 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 114 | kg/day | 0 | kg/day |

| | | | | | | |
|---|---|---|---|---|---|---|
| Wet Mass Flow | 6,404 | lb/hr | 6,404 | lb/hr | 6,404 | lb/hr |
| Dry Mass Flow | 912 | lb/hr | 912 | lb/hr | 912 | lb/hr |
| | 10.9 | DTPD | 10.9 | DTPD | 10.9 | DTPD |
| VS | 662 | lb/hr | 662 | lb/hr | 662 | lb/hr |
| Water | 5,492 | lb/hr | 5,492 | lb/hr | 5,492 | lb/hr |
| TS | 14.25% | | 14.25% | | 14.25% | |
| VS | 73% | | 73% | | 73% | |
| Wet flow | 12.8 | gpm | 12.8 | gpm | 12.8 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 101.9 | kW | 49.7 | kW | 0.0 | kW |
| Unit Heat Bal. | 0.00 | MMBtu/hr | 3.55 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | -1.82 | MMBtu/hr | 1.73 | MMBtu/hr | 1.73 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Process Fuel Bal. | 0.00 | MMBtu/hr | -8.46 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 9.40 | MMBtu/hr | 0.94 | MMBtu/hr | 0.94 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0.00 | MW | 0.97 | MW | 0.00 | MW |
| No. of Trucks Required | 1.52 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 34 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0.00 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 151 | scfm | 17 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | | | |
|---|---|---|---|---|---|
| **Wood Chips** | | | Volume Ratio | Wet Weight | Dry Weight |
| Density | 550 | lbs/cy | 3.00 | 1650 lbs/cy | 990 lbs/cy |
| moisture | 60% | dry | | | |
| **sludge** | | | | | |
| Density | 1500 | lbs/cy | 1.00 | 1500 lbs/cy | 330 lbs/cy |
| moisture | 22% | dry | | | |
| **Pre-Compost Blend (target 40% TS)** | | | | | |
| Density | 787.5 | lbs/cy of mixture | | | |
| | 0.39375 | Wet Ton/cy of mixture | | | |
| **Compost Mixture** | | | | | |
| Volume reduction | 10% | | based on VSR during composting | | |
| Density | 875.0 | lbs/cy | | | |
| CY compost/CY sludge | 3.6 | | | | |
| CY compost/WT sludge | 3.8 | | assumes 20% recycle | | |
| CY compost/DT sludge | 17.5 | | | | |
| **Truck Capacity** | | | | | |
| Dewatered Cake Capacity | 30 | wet tons | | | |
| Mass of cake | 1500 | lbs/cy | | | |
| Density of cake | 55.6 | lb/cf | | | |
| Size of Truck | 1080 | cf | | | |
| Mass of Woodchips | 550 | lb/cy | | | |
| Density of Woodchips | 20.37 | lb/cf | | | |
| Weight of Woodchips | 22000.0 | lb | | | |
| | **11.00** | **ton** | | | |

| Alt 2B Output Summary | |
|---|---|
| Final Product, Wet (WT/D) | 77 |
| NG Required (cfh) | 3011 |
| Electricity Req. (kW) | 585 |
| Power Generation (kW) | 0 |
| Net Power (kW)* | 585 |
| No. of Trucks Required (trucks/day) | 4.27 |
| Vehicle Fuel Consumed (gal/day) | 37 |
| Digester Gas Produced (scfm) | 280 |
| Methane Produced (scfm) | 168 |
| Polymer Use (kg/day) | 202 |
| GDE from Gas Upgrading (gal/day) | 1388 |

## Primary Sludge

1st Feedstock (No referenced)

| | | |
|---|---|---|
| Dry Mass Flow | 29203 | PPD |
| TS | 3.2% | |
| VS | 89% | |
| Calorific Value | 10,000 | Btu/lb VS |

Feedstock Type: Primary Sludge

Energy Consumption: 0 hp; 90% Efficiency

## WAS

| | |
|---|---|
| 20318 | PPD |
| 0.6% | |
| 85% | |
| 10,000 | Btu/lb VS |

Feedstock Type: WAS

Energy Consumption: 0 hp; 90% Efficiency

## Thickening

GBT

97% Capture
5.0% TS

Duty No. 2

Feedstock Type: Combined

Energy Consumption: 25 hp; 90% Efficiency

Polymer Use: 8 lbs/ton

## Stabilization

TPAD System

**Digester (Thermo)**

939 NG LHV

VSR 64.0%

Duty No. 2

3,011 NG Use, cfh

Sludge Inlet Temp: 65 F

Operation Temp: 131 F

560 cf gas/VS

15 cf/lb VS

2.64 MMBtu/hr

Energy Consumption: 60 hp; 90% Efficiency

Shell Heat Loss: 7%

**HEX**

Duty No. 2

Inlet Temperature: 135 F

Outlet Temperature: 98 F

HEX Efficiency: 70 %

1.01 MMBtu/hr

Energy Consumption: 20 hp; 90% Efficiency

**Digester (Meso)**

VSR 0.0%

Duty No. 2

Sludge Inlet Temp: 98 F

Operation Temp: 98 F

560 Btu/cf

15 cf/lb VS

0.00 MMBtu/hr

Energy Consumption: 30 hp; 90% Efficiency

Shell Heat Loss: 4%

## Dewatering

Centrifuge

95% Capture
22% TS

Duty No. 2

Energy Consumption: 85 hp; 90% Efficiency

Polymer Use: 25 lbs/ton

## Woodchips

| | |
|---|---|
| 60383 | PPD |
| 50.0% | |
| 95% | |
| 10,000 | Btu/lb VS |

Feedstock Type: Bulking Agent 1

Energy Consumption: 0 hp; 100% Efficiency

Transport Fuel Consumption: 10 miles; 7 mpg

## Composting

Compost

40% TS
VSR 15.0%

Duty No. 1

Energy Consumption: 123 hp; 90% Efficiency

Transport Fuel Consumption: 20 miles; 5 mpg

Front Loader Fuel Consumption: 0.600 gal/wt

## Biogas Utilization

**Pipeline Injection**

Duty No. 1

Biogas Fuel 90%

Energy Consumption: 143 hp; 90% Efficiency

**Flare**

Duty No. 1

Energy Consumption: 0 hp; 90% Efficiency

Digester Gas Flared: 10% scfm

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 38,021 | lb/hr | 191,154 | lb/hr | 40,029 | lb/hr | 38,911 | lb/hr | 38,911 | lb/hr | 38,911 | lb/hr |
| Dry Mass Flow | 1,217 | lb/hr | 2,063 | lb/hr | 2,001 | lb/hr | 883 | lb/hr | 883 | lb/hr | 883 | lb/hr |
| | 14.6 | DTPD | 24.8 | DTPD | 24.0 | DTPD | 10.6 | DTPD | 10.6 | DTPD | 10.6 | DTPD |
| VS | 1,083 | lb/hr | 1,802 | lb/hr | 1,748 | lb/hr | 629 | lb/hr | 629 | lb/hr | 629 | lb/hr |
| Water | 36,804 | lb/hr | 189,091 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr |
| TS | 3% | | 1.08% | | 5.00% | | 2.27% | | 2.27% | | 2.27% | |
| VS | 89% | | 87% | | 87% | | 71% | | 71% | | 71% | |
| Wet flow | 76.0 | gpm | 382.0 | gpm | 80.0 | gpm | 77.8 | gpm | 77.8 | gpm | 77.8 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 0 | kW | 0.0 | kW | 41.4 | kW | 99.5 | kW | 33.2 | kW | 49.7 | kW |
| Unit Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -2.83 | MMBtu/hr | 1.01 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -2.83 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 2.83 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr |
| Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 280 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 168 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 87 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 3,812 | lb/hr | 4,193 | lb/hr | 6,404 | lb/hr | 6,404 | lb/hr | 6,404 | lb/hr |
| Dry Mass Flow | 839 | lb/hr | 1,029 | lb/hr | 912 | lb/hr | 912 | lb/hr | 912 | lb/hr |
| | 10.1 | DTPD | 12.4 | DTPD | 10.9 | DTPD | 10.9 | DTPD | 10.9 | DTPD |
| VS | 598 | lb/hr | 779 | lb/hr | 662 | lb/hr | 662 | lb/hr | 662 | lb/hr |
| Water | 2,973 | lb/hr | 3,164 | lb/hr | 5,492 | lb/hr | 5,492 | lb/hr | 5,492 | lb/hr |
| TS | 22.00% | | 24.55% | | 14.25% | | 14.25% | | 14.25% | |
| VS | 71% | | 76% | | 73% | | 73% | | 73% | |
| Wet flow | 7.6 | gpm | 8.4 | gpm | 12.8 | gpm | 12.8 | gpm | 12.8 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 140.9 | kW | 0.0 | kW | 101.9 | kW | 118.8 | kW | 0.0 | kW |
| Unit Heat Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr |
| Unit Process Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -8.46 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr | 0.94 | MMBtu/hr | 0.94 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 2.74 | trucks/day | 1.52 | trucks/day | 0 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 3.9 | gal/day | 34 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0.00 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 151 | scfm | 17 | scfm |
| Polymer Use | 114 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | Volume Ratio | Wet Weight | Dry Weight |
|---|---|---|---|---|---|
| **Wood Chips** | | | | | |
| Density | 550 | lbs/cy | 3.00 cy | 1650 lbs | 990 lbs |
| moisture | 60% | dry | | | |
| **sludge** | | | | | |
| Density | 1500 | lbs/cy | 1.00 cy | 1500 lbs | 330 lbs |
| moisture | 22% | dry | | | |
| **Pre-Compost Blend (target 40% TS)** | | | | | |
| Density | 787.5 | lbs/cy of mixture | | | |
| | 0.39375 | Wet Ton/cy of mixture | | | |
| **Compost Mixture** | | | | | |
| Volume reduction | 10% | | based on VSR during composting | | |
| Density | 875.0 | lbs/cy | | | |
| CY compost/CY sludge | 3.6 | | | | |
| CY compost/WT sludge | 3.8 | | assumes 20% recycle | | |
| CY compost/DT sludge | 17.5 | | | | |
| **Truck Capacity** | | | | | |
| Dewatered Cake Capaci | 30 | wet tons | | | |
| Mass of cake | 1500 | lb/cy | | | |
| Density of cake | 55.6 | lb/cf | | | |
| Size of Truck | 1080 | cf | | | |
| Mass of Woodchips | 550 | lb/cy | | | |
| Density of Woodchips | 20.37 | lb/cf | | | |
| Weight of Woodchips | 22,000 | lb | | | |
| | **11.00** | tons | | | |
| Assumptions | | | | | |
| Fuel Use | 5 | mpg | | | |
| Dewatered Cake | 7 | mpg | | | |
| Woodchips | | | | | |

| Alt 3A Output Summary | |
|---|---|
| Final Product, Wet (WT/D) | 105 |
| NG Required (cfh) | 300 |
| Electricity Req. (kW) | 431 |
| Power Generation (kW) | 966 |
| Net Power (kW)* | -535 |
| No. of Trucks Required (trucks/day) | 3.59 |
| Vehicle Fuel Consumed (gal/day) | 37 |
| Digester Gas Produced (scfm) | 280 |
| Methane Produced (scfm) | 168 |
| Polymer Use (kg/day) | 202 |

## Primary Sludge

1st Feedstock (No referenced)

Dry Mass Flow 29203 PPD
TS 3.2%
VS 89%
Calorific Value 10,000 Btu/lb VS

Feedstock Type
Primary Sludge

Energy Consumption
0 hp
90% Efficiency

## WAS

20318 PPD
0.6%
85%
10,000 Btu/lb VS

Feedstock Type
WAS

Energy Consumption
0 hp
90% Efficiency

## Thickening

GBT

97% Capture
5.0% TS

Duty No. 2

Feedstock Type
Combined

Energy Consumption
25 hp
90% Efficiency

Polymer Use
8 lbs/ton

## Stabilization

TPAD System w/ Batch Tanks

### Digester (Thermo)

VSR 64.0%
Duty No. 2

Nat gas usage, cfh
300.00

Sludge Inlet Temp
65 F
Operation Temp
131 F
560 cf gas/VS
15 cf/lb VS
2.64 MMBtu/hr

Energy Consumption
65 hp
90% Efficiency
Shell Heat Loss
7%

### HEX

Duty No. 2

Inlet Temperature
135 F
Outlet Temperature
98 F

HEX Efficiency
70 %
1.01 MMBtu/hr

Energy Consumption
20 hp
90% Efficiency

### Digester (Meso)

VSR 0.0%
Duty No. 2

Sludge Inlet Temp
98 F
Operation Temp
98 F
560 Btu/cf
15 cf/lb VS
0.00 MMBtu/hr

Energy Consumption
30 hp
90% Efficiency
Shell Heat Loss
4%

## Dewatering

Centrifuge

95% Capture
22% TS

Duty No. 2

Energy Consumption
85 hp
90% Efficiency

Polymer Use
25 lbs/ton

## Post-Dewatering Soil Blending

### Biosolids Cake

Soil Blending

22% TS

Duty No. 1

Energy Consumption
10 hp
90% Efficiency

Transport Fuel Consumption
20 miles
5 mpg
Front Loader Fuel Consumption
0.600 gal/wt

### Saw Dust

18298 PPD
50.0%
95%
10,000 Btu/lb VS

Feedstock Type
Buling Agent 1

Energy Consumption
0 hp
100% Efficiency

Transport Fuel Consumption
10 miles
7 mpg

### Sand

78223 PPD
95.0%
0%
10,000 Btu/lb VS

Feedstock Type
Bulking Agent 2

Energy Consumption
0 hp
90% Efficiency

Transport Fuel Consumption
10 miles
5 mpg

## Cogen

### CHP Engine

939
NG LHV

Duty No. 1
Therm Eff. 42%

Nat gas usage, cfh

Biogas Fuel use 90%

Engine Electrical Eff.
39%
Heat Recovery
3.55 MMBtu/hr

Energy Consumption
60 hp
90% Efficiency

### Flare

Duty No. 1

Energy Consumption
0 hp
90% Efficiency

Digester Gas Flared
10% scfm

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 38,021 | lb/hr | 191,154 | lb/hr | 40,029 | lb/hr | 38,911 | lb/hr | 38,911 | lb/hr | 38,911 | lb/hr |
| Dry Mass Flow | 1,217 | lb/hr | 2,063 | lb/hr | 2,001 | lb/hr | 883 | lb/hr | 883 | lb/hr | 883 | lb/hr |
| | 14.6 | DTPD | 24.8 | DTPD | 24.0 | DTPD | 10.6 | DTPD | 10.6 | DTPD | 10.6 | DTPD |
| VS | 1,083 | lb/hr | 1,802 | lb/hr | 1,748 | lb/hr | 629 | lb/hr | 629 | lb/hr | 629 | lb/hr |
| Water | 36,804 | lb/hr | 189,091 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr |
| TS | 3% | | 1.08% | | 5.00% | | 2.27% | | 2.27% | | 2.27% | |
| VS | 89% | | 87% | | 87% | | 71% | | 71% | | 71% | |
| Wet flow | 76.0 | gpm | 382.0 | gpm | 80.0 | gpm | 77.8 | gpm | 77.8 | gpm | 77.8 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 0 | kW | 0.0 | kW | 41.4 | kW | 107.8 | kW | 33.2 | kW | 49.7 | kW |
| Unit Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -2.83 | MMBtu/hr | 1.01 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -2.83 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 280 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 168 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 87 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 3,812 | lb/hr | 3,812 | lb/hr | 5,337 | lb/hr | 8,768 | lb/hr | 8,768 | lb/hr | 8,768 | lb/hr |
| Dry Mass Flow | 839 | lb/hr | 839 | lb/hr | 1,601 | lb/hr | 4,860 | lb/hr | 4,860 | lb/hr | 4,860 | lb/hr |
| | 10.1 | DTPD | 10.1 | DTPD | 19.2 | DTPD | 58.3 | DTPD | 58.3 | DTPD | 58.3 | DTPD |
| VS | 598 | lb/hr | 598 | lb/hr | 1,322 | lb/hr | 1,322 | lb/hr | 1,322 | lb/hr | 1,322 | lb/hr |
| Water | 2,973 | lb/hr | 2,973 | lb/hr | 3,736 | lb/hr | 3,907 | lb/hr | 3,907 | lb/hr | 3,907 | lb/hr |
| TS | 22.00% | | 22.00% | | 30.00% | | 55.43% | | 55.43% | | 55.43% | |
| VS | 71% | | 71% | | 83% | | 27% | | 27% | | 27% | |
| Wet flow | 7.6 | gpm | 7.6 | gpm | 10.7 | gpm | 17.5 | gpm | 17.5 | gpm | 17.5 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 140.9 | kW | 8.3 | kW | 0.0 | kW | 0.0 | kW | 49.7 | kW | 0.0 | kW |
| Unit Heat Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 3.55 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | 1.73 | MMBtu/hr | 1.73 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Process Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -8.46 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr | 0.94 | MMBtu/hr | 0.94 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.97 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 1.52 | trucks/day | 0.76 | trucks/day | 1.30 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 0.0 | gal/day | 33.5 | gal/day | 1.1 | gal/day | 2.6 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 839 | scfm | 151 | scfm | 17 | scfm |
| Polymer Use | 114 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **sand** | | | 1 Yd Blended | Wet Weight | | | Dry Weight |
| specific gravity | 1.6 | | | | | | |
| mass | 2700 | lbs/yard | 0.25 cy | | 675 lbs | | 641 lbs |
| moisture | 95% | dry | | | | | |
| **sawdust** | | | | | | | |
| mass | 1200 | lbs/yd | 0.25 cy | | 300 lbs | | 150 lbs |
| moisture | 50% | dry | | | | | |
| **sludge** | | | | | | | |
| wet | 1500 | lbs/yd | 0.5 cy | | 750 lbs | | 165 lbs |
| moisture | 22% | dry | | | | | |
| | | | | | | | |
| Total End Product | | | | | | | |
| | 1725 | lbs/cy | | | 1725 lbs | | |
| bulking agent multiplier | 1.15 | | | | 2.3 | | |
| | 0 | pph | | | 1725 lbs/cy | final product | |
| | | | | | 1.15942029 cy/WT | | |
| Soild blend mix ratio: biosolids : saw dust : sand = 2:1:1 by volume | | | | | 0 pph | | |
| | | | | | 64 lbs/cf | | |
| **Truck Capacity** | | | | | 0.8625 Tons | | |
| Dewatered Cake Capacity of Tr | 30 | wet tons | | | | | |
| Mass of cake | 1500 | lbs/yd | | | | | |
| Density of cake | 55.6 | lbs/cf | | | | | |
| Size of Truck | 1080 | cf | 40 cy | | | cy | |
| Mass of Sawdust | 1200 | lbs/yd | | | | lbs | |
| Density of sawdust | 44.44 | lbs/cf | | | | | |
| Weight of sawdust | 48000.0 | lb/truck | | truck capacity of s | 22.2 | | |
| weight of sawdust/truck - dry | 24000 | lb/truck | | | 60000.0 | | |
| | **24.00** | | | | | lbs/yd | |
| | | | | | | lb/cf | |
| | | | | | | lb | capacity of truck is 60,000 lbs |
| Assumptions | | | | Mass of Sand | 2700 | ton | |
| Fuel use | | | | Density of Woodc | 100.00 | | |
| Combined fuel for both sand and sawdust (more for sand; less than sawdust) | 5 | mpg | | Weight of Woodcl | 108000.0 | | |
| unable to fill sand truck to capacity | | | | | **54.00** | | |
| truck fuel | 7 | mpg | | | | | |

Alt 3B Output Summary

| | |
|---|---|
| Final Product, Wet (WT/D) | 105 |
| NG Required (cfh) | 3011 |
| Electricity Req. (kW) | 500 |
| Power Generation (kW) | 0 |
| Net Power (kW)* | 500 |
| No. of Trucks Required (trucks/day) | 3.59 |
| Vehicle Fuel Consumed (gal/day) | 37 |
| Digester Gas Produced (scfm) | 280 |
| Methane Produced (scfm) | 168 |
| Polymer Use (kg/day) | 202 |
| GDE from Gas Upgrading (gal/day) | 1388 |

## Primary Sludge

1st Feedstock (No referenced)

Dry Mass Flow 29203 PPD
TS 3.2%
VS 89%
Calorific Value 10,000 Btu/lb VS

Feedstock Type
Primary Sludge

Energy Consumption
0 hp
90% Efficiency

## WAS

20318 PPD
0.6%
85%
10,000 Btu/lb VS

Feedstock Type
WAS

Energy Consumption
0 hp
90% Efficiency

## Thickening

GBT

97% Capture
5.0% TS

Duty No. 2

Feedstock Type
Combined

Energy Consumption
25 hp
90% Efficiency

Polymer Use
8 lbs/ton

## Stabilization

TPAD System w/ Batch Tanks

### Digester (Thermo)

939
NG LHV

VSR 64.0%
Duty No. 2

3,011 NG Use, cfh

Sludge Inlet Temp
65 F
Operation Temp
131 F
560 cf gas/VS
15 cf/lb VS
2.64 MMBtu/hr

Energy Consumption
65 hp
90% Efficiency

Shell Heat Loss
7%

### HEX

Duty No. 2

Inlet Temperature
135 F
Outlet Temperature
98 F

HEX Efficiency
70 %
1.01 MMBtu/hr

Energy Consumption
20 hp
90% Efficiency

### Digester (Meso)

VSR 0.0%
Duty No. 2

Sludge Inlet Temp
98 F
Operation Temp
98 F
560 Btu/cf
15 cf/lb VS
0.00 MMBtu/hr

Energy Consumption
30 hp
90% Efficiency

Shell Heat Loss
4%

## Dewatering

Centrifuge

95% Capture
22% TS

Duty No. 2

Energy Consumption
85 hp
90% Efficiency

Polymer Use
25 lbs/ton

## Post-Dewatering Soil Blending

### Biosolids Cake

Soil Blending

22% TS

Duty No. 1

Energy Consumption
10 hp
90% Efficiency

Transport Fuel Consumption
20 miles
5 mpg

Front Loader Fuel Consumption
0.600 gal/wt

### Saw Dust

18298 PPD
50.0%
95%
10,000 Btu/lb VS

Feedstock Type
Buling Agent 1

Energy Consumption
0 hp
100% Efficiency

Transport Fuel Consumption
10 miles
7 mpg

### Sand

78223 PPD
95.0%
0%
10,000 Btu/lb VS

Feedstock Type
Bulking Agent 2

Energy Consumption
0 hp
90% Efficiency

Transport Fuel Consumption
10 miles
5 mpg

## Biogas Utilization

### Pipeline Injection

Duty No. 1

Biogas Fuel use 90%

Energy Consumption
143 hp
90% Efficiency

### Flare

Duty No. 1

Energy Consumption
0 hp
90% Efficiency

Digester Gas Flared
10% scfm

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 38,021 | lb/hr | 191,154 | lb/hr | 40,029 | lb/hr | 38,911 | lb/hr | 38,911 | lb/hr | 38,911 | lb/hr |
| Dry Mass Flow | 1,217 | lb/hr | 2,063 | lb/hr | 2,001 | lb/hr | 883 | lb/hr | 883 | lb/hr | 883 | lb/hr |
| | 14.6 | DTPD | 24.8 | DTPD | 24.0 | DTPD | 10.6 | DTPD | 10.6 | DTPD | 10.6 | DTPD |
| VS | 1,083 | lb/hr | 1,802 | lb/hr | 1,748 | lb/hr | 629 | lb/hr | 629 | lb/hr | 629 | lb/hr |
| Water | 36,804 | lb/hr | 189,091 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr |
| TS | 3% | | 1.08% | | 5.00% | | 2.27% | | 2.27% | | 2.27% | |
| VS | 89% | | 87% | | 87% | | 71% | | 71% | | 71% | |
| Wet flow | 76.0 | gpm | 382.0 | gpm | 80.0 | gpm | 77.8 | gpm | 77.8 | gpm | 77.8 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 0 | kW | 0.0 | kW | 41.4 | kW | 107.8 | kW | 33.2 | kW | 49.7 | kW |
| Unit Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -2.83 | MMBtu/hr | 1.01 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -2.83 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 2.83 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr |
| Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr | 0.00 | MMBtu/hr | 9.40 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 280 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 168 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Recovered | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 87 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 3,812 | lb/hr | 3,812 | lb/hr | 5,337 | lb/hr | 8,768 | lb/hr | 8,768 | lb/hr | 8,768 | lb/hr |
| Dry Mass Flow | 839 | lb/hr | 839 | lb/hr | 1,601 | lb/hr | 4,860 | lb/hr | 4,860 | lb/hr | 4,860 | lb/hr |
| | 10.1 | DTPD | 10.1 | DTPD | 19.2 | DTPD | 58.3 | DTPD | 58.3 | DTPD | 58.3 | DTPD |
| VS | 598 | lb/hr | 598 | lb/hr | 1,322 | lb/hr | 1,322 | lb/hr | 1,322 | lb/hr | 1,322 | lb/hr |
| Water | 2,973 | lb/hr | 2,973 | lb/hr | 3,736 | lb/hr | 3,907 | lb/hr | 3,907 | lb/hr | 3,907 | lb/hr |
| TS | 22.00% | | 22.00% | | 30.00% | | 55.43% | | 55.43% | | 55.43% | |
| VS | 71% | | 71% | | 83% | | 27% | | 27% | | 27% | |
| Wet flow | 7.6 | gpm | 7.6 | gpm | 10.7 | gpm | 17.5 | gpm | 17.5 | gpm | 17.5 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 140.9 | kW | 8.3 | kW | 0.0 | kW | 0.0 | kW | 118.8 | kW | 0.0 | kW |
| Unit Heat Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr | -1.82 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr | 2.83 | MMBtu/hr |
| Unit Process Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -8.46 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr | 9.40 | MMBtu/hr | 0.94 | MMBtu/hr | 0.94 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 1.52 | trucks/day | 0.76 | trucks/day | 1.30 | trucks/day | 0 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 33.5 | gal/day | 1.1 | gal/day | 2.6 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 151 | scfm | 17 | scfm |
| Methane Recovered | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 143 | scfm | 16 | scfm |
| Polymer Use | 114 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | | | | |
|---|---|---|---|---|---|---|
| **sand** | | | 1 Yd Blended | Wet Weight | | Dry Weight |
| specific gravity | 1.6 | | | | | |
| mass | 2700 | lbs/yard | 0.25 yd | 675 lbs | | 641 lbs |
| moisture | 95% | dry | | | | |
| **sawdust** | | | | | | |
| mass | 1200 | lbs/yd | 0.25 yd | 300 lbs | | 150 lbs |
| moisture | 50% | dry | | | | |
| **sludge** | | | | | | |
| wet | 1500 | lbs/yd | 0.5 yd | 750 lbs | | 165 lbs |
| moisture | 22% | dry | | | | |
| Total End Product | | | | | | |
| | 1725 | lbs/yd | | 1725 lbs/yd | | |
| bulking agent mult | 1.15 | | | 2.3 | | |
| | 0 | pph | | 0 pph | | |
| | | | | 64 lbs/cf | | |
| Soild blend mix ratio: biosolids : saw dust : sand = 2:1:1 by volume | | | | | | |
| **Truck Capacity** | | | | | | |
| Dewatered Cake C | 30 | wet tons | | | | |
| Mass of cake | 1500 | lbs/yd | | Max load of truck | 60000 lbs | |
| Density of cake | 55.6 | lbs/cf | | Truck capacity of : | 22.22222222 cy | |
| Size of Truck | 1080 | cf | 40 cy | | 60000.00 | |
| Mass of Sawdust | 1200 | lbs/yd | | Mass of Sand | 2700 lbs/yd | |
| Density of sawdus | 44.44 | lbs/cf | | Density of Sand | 100.00 lb/cf | |
| Weight of sawdust | 24000.0 | lb/truck | | Weight of Sand | 108000.0 lb | |
| | **12.00** | | | | **54.00** ton | |

| Alt 4 Output Summary | |
|---|---|
| Final Product, Wet (WT/D) | 104 |
| NG Required (cfh) | 300 |
| Electricity Req. (kW) | 777 |
| Power Generation (kW) | 0 |
| Net Power (kW)* | 777 |
| No. of Trucks Required (trucks/day) | 3.54 |
| Vehicle Fuel Consumed (gal/day) | 38 |
| Digester Gas Produced (scfm) | 171 |
| Methane Produced (scfm) | 103 |
| Polymer Use (kg/day) | 200 |
| GDE from Gas Upgrading (gal/day) | 850 |

## Primary Sludge

1st Feedstock (No referenced)

Dry Mass Flow 29203 PPD
TS 3.2%
VS 89%
Calorific Value 10,000 Btu/lb VS

Feedstock Type: Primary Sludge

Energy Consumption: 0 hp; 90% Efficiency

## WAS

20318 PPD
0.6%
85%
10,000 Btu/lb VS

Feedstock Type: WAS

Energy Consumption: 0 hp; 90% Efficiency

## Thickening

GBT

97% Capture
5.0% TS

Duty No. 2

Feedstock Type: Combined

Energy Consumption: 25 hp; 90% Efficiency

Polymer Use: 8 lbs/ton

## Stabilization

ATAD - TPAD

**ATAD**

VSR 28.0%
Duty No. 1

300 NG Use, cfh

Energy Consumption: 400 hp; 90% Efficiency

**Digester (Thermo)**

VSR 51.0%
Duty No. 2

Sludge Inlet Temp: 135 F
Operation Temp: 135 F
560 cf gas/VS
16 cf/lb VS
0.00 MMBtu/hr

Energy Consumption: 60 hp; 90% Efficiency

Shell Heat Loss: 7%

**HEX**

Duty No. 2

Inlet Temperature: 135 F
Outlet Temperature: 98 F

HEX Efficiency: 70 %
1.01 MMBtu/hr

Energy Consumption: 20 hp; 90% Efficiency

**Digester (Meso)**

VSR 0.0%
Duty No. 2

Sludge Inlet Temp: 98 F
Operation Temp: 98 F
560 Btu/cf
15 cf/lb VS
0.00 MMBtu/hr

Energy Consumption: 30 hp; 90% Efficiency

Shell Heat Loss: 4%

## Dewatering

Centrifuge

95% Capture
22% TS

Duty No. 2

Energy Consumption: 85 hp; 90% Efficiency

Polymer Use: 25 lbs/ton

## Post-Dewatering Soil Blending

**Biosolids Cake — Soil Blending**

22% TS

Duty No. 1

Energy Consumption: 10 hp; 90% Efficiency

Transport Fuel Consumption: 20 miles; 5 mpg

Front Loader Fuel Consumption: 0.600 gal/wt

**Saw Dust**

18037 PPD
50.0%
95%
10,000 Btu/lb VS

Feedstock Type: Buling Agent 1

Energy Consumption: 0 hp; 100% Efficiency

Transport Fuel Consumption: 10 miles; 7 mpg

**Sand**

77108 PPD
95.0%
0%
10,000 Btu/lb VS

Feedstock Type: Bulking Agent 2

Energy Consumption: 0 hp; 90% Efficiency

Transport Fuel Consumption: 10 miles; 5 mpg

## Biogas Utilization

**Pipeline Injection**

Duty No. 1

Biogas Fuel use 90%

Energy Consumption: 88 hp; 90% Efficiency

**Flare**

Duty No. 1

Energy Consumption: 0 hp; 90% Efficiency

Digester Gas Flared: 10% scfm

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 38,021 | lb/hr | 191,154 | lb/hr | 40,029 | lb/hr | 39,540 | lb/hr |
| Dry Mass Flow | 1,217 | lb/hr | 2,063 | lb/hr | 2,001 | lb/hr | 1,512 | lb/hr |
| | 14.6 | DTPD | 24.8 | DTPD | 24.0 | DTPD | 18.1 | DTPD |
| VS | 1,083 | lb/hr | 1,802 | lb/hr | 1,748 | lb/hr | 1,259 | lb/hr |
| Water | 36,804 | lb/hr | 189,091 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr |
| TS | 3% | | 1.08% | | 5.00% | | 3.82% | |
| VS | 89% | | 87% | | 87% | | 83% | |
| Wet flow | 76.0 | gpm | 382.0 | gpm | 80.0 | gpm | 79.0 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 0 | kW | 0.0 | kW | 41.4 | kW | 331.6 | kW |
| Unit Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 0 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 87 | kg/day | 0 | kg/day |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 38,898 | lb/hr | 38,898 | lb/hr | 38,898 | lb/hr | 3,758 | lb/hr | 3,758 | lb/hr |
| Dry Mass Flow | 870 | lb/hr | 870 | lb/hr | 870 | lb/hr | 827 | lb/hr | 827 | lb/hr |
| | 10.4 | DTPD | 10.4 | DTPD | 10.4 | DTPD | 9.9 | DTPD | 9.9 | DTPD |
| VS | 617 | lb/hr | 617 | lb/hr | 617 | lb/hr | 586 | lb/hr | 586 | lb/hr |
| Water | 38,028 | lb/hr | 38,028 | lb/hr | 38,028 | lb/hr | 2,931 | lb/hr | 2,931 | lb/hr |
| TS | 2.24% | | 2.24% | | 2.24% | | 22.00% | | 22.00% | |
| VS | 71% | | 71% | | 71% | | 71% | | 71% | |
| Wet flow | 77.7 | gpm | 77.7 | gpm | 77.7 | gpm | 7.5 | gpm | 7.5 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 99.5 | kW | 33.2 | kW | 49.7 | kW | 140.9 | kW | 8.3 | kW |
| Unit Heat Bal. | 5.97 | MMBtu/hr | 1.01 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | 5.97 | MMBtu/hr | 6.98 | MMBtu/hr | 6.98 | MMBtu/hr | 6.98 | MMBtu/hr | 6.98 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Process Fuel Bal. | 5.75 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 5.75 | MMBtu/hr | 0.00 | MMBtu/hr | 5.75 | MMBtu/hr | 5.75 | MMBtu/hr | 5.75 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 0.00 | trucks/day | 1.50 | trucks/day |
| Vehicle Fuel Consumption | 0 | gal/day | 0 | gal/day | 0 | gal/day | 0 | gal/day | 33.1 | gal/day |
| Digester Gas Produced | 171 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 103 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 0 | kg/day | 113 | kg/day | 0 | kg/day |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Wet Mass Flow | 5,261 | lb/hr | 8,643 | lb/hr | 8,643 | lb/hr | 8,643 | lb/hr |
| Dry Mass Flow | 1,578 | lb/hr | 4,791 | lb/hr | 4,791 | lb/hr | 4,791 | lb/hr |
| | 18.9 | DTPD | 57.5 | DTPD | 57.5 | DTPD | 57.5 | DTPD |
| VS | 1,300 | lb/hr | 1,300 | lb/hr | 1,300 | lb/hr | 1,300 | lb/hr |
| Water | 3,683 | lb/hr | 3,852 | lb/hr | 3,852 | lb/hr | 3,852 | lb/hr |
| TS | 30.00% | | 55.43% | | 55.43% | | 55.43% | |
| VS | 82% | | 27% | | 27% | | 27% | |
| Wet flow | 10.5 | gpm | 17.3 | gpm | 17.3 | gpm | 17.3 | gpm |
| Calorific Value | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS | 10,000 | Btu/lb VS |
| Electrical Demand | 0.0 | kW | 0.0 | kW | 72.7 | kW | 0.0 | kW |
| Unit Heat Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Total Heat Bal. | 6.98 | MMBtu/hr | 6.98 | MMBtu/hr | 6.98 | MMBtu/hr | 6.98 | MMBtu/hr |
| Unit Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum. Aux. Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr |
| Unit Process Fuel Bal. | 0.00 | MMBtu/hr | 0.00 | MMBtu/hr | -5.18 | MMBtu/hr | 0.00 | MMBtu/hr |
| Cum Unit Process Fuel Bal. | 5.75 | MMBtu/hr | 5.75 | MMBtu/hr | 0.58 | MMBtu/hr | 0.58 | MMBtu/hr |
| Generated Steam | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr | 0 | lb/hr |
| Power Generation | 0.00 | MW | 0.00 | MW | 0.00 | MW | 0.00 | MW |
| No. of Trucks Required | 0.75 | trucks/day | 1.29 | trucks/day | 0 | trucks/day | 0.00 | trucks/day |
| Vehicle Fuel Consumption | 2.1 | gal/day | 2.6 | gal/day | 0 | gal/day | 0 | gal/day |
| Digester Gas Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Produced | 0 | scfm | 0 | scfm | 0 | scfm | 0 | scfm |
| Methane Utilized | 719 | scfm | 0 | scfm | 92 | scfm | 10 | scfm |
| Polymer Use | 0 | kg/day | 0 | kg/day | 0 | kg/day | 0 | kg/day |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **sand** | | | 1 Yd Blended | | Wet Weight | | Dry Weight |
| specific gravity | 1.6 | | | | | | |
| mass | 2700 | lbs/yard | 0.25 | yd | 675 | lbs | 641 lbs |
| moisture | 95% | dry | | | | | |
| **sawdust** | | | | | | | |
| mass | 1200 | lbs/yd | 0.25 | yd | 300 | lbs | 150 lbs |
| moisture | 50% | dry | | | | | |
| **sludge** | | | | | | | |
| wet | 1500 | lbs/yd | 0.5 | yd | 750 | lbs | 165 lbs |
| moisture | 22% | dry | | | | | |
| Total End Product | | | | | | | |
| | 1725 | lbs/yd | | | 1725 | lbs/yd | |
| bulking agent | 1.15 | | | | 2.3 | | |
| | 0 | pph | | | 0 | pph | |
| | | | | | 64 | lbs/cf | |

Soild blend mix ratio: biosolids : saw dust : sand = 2:1:1 by volume

| | | | | | | |
|---|---|---|---|---|---|---|
| **Truck Capacity** | | | | | | |
| Dewatered Ca | 30 | wet tons | | | | |
| Mass of cake | 1500 | lbs/yd | | | | |
| Density of cak | 55.6 | lbs/cf | | Truck capacity of s | 22.22222222 | cy |
| Size of Truck | 1080 | cf | 40 cy | | 60000 | lbs |
| Mass of Sawdu | 1200 | lbs/yd | | Mass of Sand | 2700.00 | lbs/yard |
| Density of saw | 44.44 | lbs/cf | | Density of Sand | 100.00 | lb/cf |
| Weight of saw | 24000.0 | lb/truck | | Weight of Sand | 108000.0 | lb |
| | **12.00** | | | | **54.00** | ton |

# Appendix B: Capital Funding Analysis (FCS Group)

FCS GROUP
Solutions-Oriented Consulting

# | Memorandum

**To:** City of Bellingham
Tadd Giesbrecht, Brown & Caldwell

**Date:** February 20, 2019

**From:** Gordon Wilson, Project Manager
Tage Aaker, Project Manager

**RE** Bellingham Resource Recovery Project Capital Funding Analysis

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## I.A. INTRODUCTION

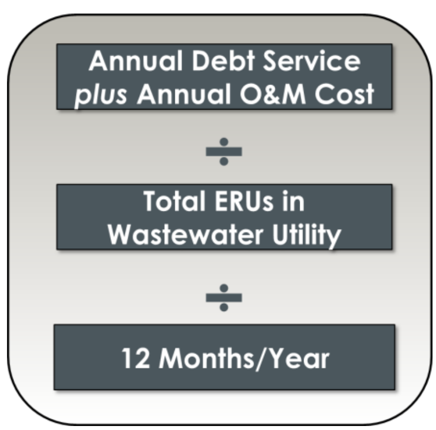
According to a 2017 draft memorandum prepared by Brown & Caldwell ("Post Point Biosolids Planning: Preferred Conceptual Alternatives Selection"), the City of Bellingham currently uses multiple-hearth furnaces (MHFs) to incinerate the wastewater residual solids recovered from the Post Point Wastewater Treatment Plant. Because of the age of the existing MHFs and the desire to employ a more sustainable solids management solution, the City has initiated a study of alternative means of managing its solids. This desire has led to the Post Point Biosolids Planning project to evaluate an alternative approach to solids management and develop implementation options.

This memo evaluates how the cost of a resource recovery facility would affect the City's wastewater rates. The form of that answer will be in terms of "dollars per equivalent residential unit (ERU) per month." The average cost per ERU roughly approximates the average level of rates. The City currently bills on a bi-monthly basis, so two months of this impact would be incorporated into any given bill.

## I.B. OVERVIEW OF COST PER ERU METHODOLOGY

Because the resource recovery facility cost is substantial and cannot be funded from reserves, we assume that it will be funded with debt. This allows the City to spread the cost of the facility over a long time horizon. **Exhibit 1** summarizes the methodology to estimate the monthly impact to an ERU.

**Exhibit 1: Determining the Monthly Impact per ERU**




Firm Headquarters
Redmond Town Center
7525 166th Ave NE, Ste D-215
Redmond, Washington 98052

Locations
Washington | 425.867.1802
Oregon | 503.841.6543
Colorado | 719.284.9168

## I.C. FACILITY COST ESTIMATE

The cost of constructing a new resource recovery facility has been estimated by Brown & Caldwell. The total estimated construction cost is $195,900,000 in 2023 dollars.

## I.D. DEBT SERVICE ASSUMPTIONS

This capital cost must be converted into an annual payment in order to evaluate the impact per ERU. For this exercise, revenue bond funding is assumed, based on a 30-year term, 5% interest rate, and 1% issuance cost. Current interest rates are closer to 4%. However, the construction year is 2023, and this debt issue would be larger than usual and longer than the typical 20-year term. So to be conservative, we assumed 5%. We also assumed that a year's worth of debt service would be held in reserve.

After accounting for an issuance cost of 1%, as well as the assumed debt reserve, the total amount that is initially borrowed is estimated to be about $211.8 million, as shown in **Exhibit 2**. **Exhibit 2** also shows the resulting debt service, which is estimated to be $13.8 million per year. The total 30-year cost is estimated to be about $400 million, after accounting for interest costs.

**Exhibit 2: Annual Debt Service**

| Financing Assumptions | | |
|---|---|---|
| Term (years) | | 30 |
| Interest Rate | | 5.00% |
| Issuance Cost | | 1.00% |
| Reserve Assumption | | Annual Debt Service |
| **Digestion / Biosolids Project** | | |
| Loan Amount Needed | | |
| Project Cost | $ | 195,900,000 |
| Issuance Cost | | 2,117,956 |
| Reserve Required | | 13,777,605 |
| Total Cost | $ | 211,795,561 |
| Annual Debt Service | **$** | **13,777,605** |
| 30-Year Financing Cost | $ | 399,550,550 |
| *Includes interest, assumes final year of debt service is funded by reserve.* | | |

## I.E. NET ANNUAL OPERATING & MAINTENANCE COST

According to Carollo Engineers, serving as a subconsultant to Brown & Caldwell, the resource recovery project is expected to add about $200,000 in operating and maintenance (O&M) costs, net of the existing incinerator O&M costs and net of revenue from the sale of composting products. This estimate is in 2017 dollars.

## I.F. WASTEWATER EQUIVALENT RESIDENTIAL UNITS

Based on data provided by City staff, there are currently 43,687 ERUs served by the City of Bellingham as of 2018, including those served indirectly through the Lake Whatcom Water and Sewer District. See **Appendix A** for more details.

## I.G. ALIGNING THE COST & ERU ELEMENTS

All three pieces of data—capital costs, O&M costs, and ERUs—represent different years. The capital costs are in 2023 dollars, the O&M costs are in 2017 dollars, and the ERU numbers are as of 2018. In order to provide a monthly impact, these elements must be aligned. Because the capital cost estimates are in 2023 dollars, we adjusted the other two elements to the year 2023 as well. To do this, we made the following assumptions.

- ERUs: Based on recent historical data provided by the City, we estimated annual ERU growth to be 1.5% per year. As a result, we estimated that there would be just over 47,000 ERUs in 2023.
- Construction Project: These costs were already provided in 2023 dollars. The annual debt service estimate is based on the $195.9 million construction cost estimate.
- O&M Cost: These cost estimates were provided in 2017 dollars by Carollo Engineers. We escalated the estimate to 2023 using a 2.5% inflation rate per year.
- Annual Cost: The combined debt service and O&M is projected to be $14.0 million per year.
- Single Family monthly sewer cost: The 2018 bi-monthly single family sewer rate was $86.32 (shown in **Appendix B**), which is equivalent to a monthly cost of $43.16. We assumed without the resource recovery project cost, the City of Bellingham would increase rates at about 3% per year, slightly higher than a CPI-based inflation assumption. By 2023, this would mean an average single family cost $50.03/month, or $100.07 per bi-month.

The results of these assumptions are shown on **Exhibit 3**.

**Exhibit 3: Aligning the Cost Elements**

| Elements | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|
| ERUs | | 43,687 | 44,342 | 45,007 | 45,683 | 46,368 | 47,063 |
| *ERU growth (based on 2016-18 ERUs in COB)* | | | 1.50% | 1.50% | 1.50% | 1.50% | 1.50% |
| Resulting Annual Debt Service from Construction Project | | | | | | | $ 13,777,605 |
| O&M Cost | $ 200,000 | $ 205,000 | $ 210,125 | $ 215,378 | $ 220,763 | $ 226,282 | $ 231,939 |
| *Inflation (based on historical CPI)* | | 2.50% | 2.50% | 2.50% | 2.50% | 2.50% | 2.50% |
| Total Annual Cost | | | | | | | $ 14,009,544 |
| Bi-Monthly Single Family Sewer Rate | | $86.32 | | | | | |
| Monthly Single Family Sewer Cost | | $43.16 | $44.45 | $45.79 | $47.16 | $48.58 | $50.03 |
| *Excluding Resource Recovery Project* | | | 3.00% | 3.00% | 3.00% | 3.00% | 3.00% |

## I.H. MONTHLY IMPACT ON AN ERU

**Exhibit 4** shows that annual debt service and O&M adds $24.81 per month per ERU.

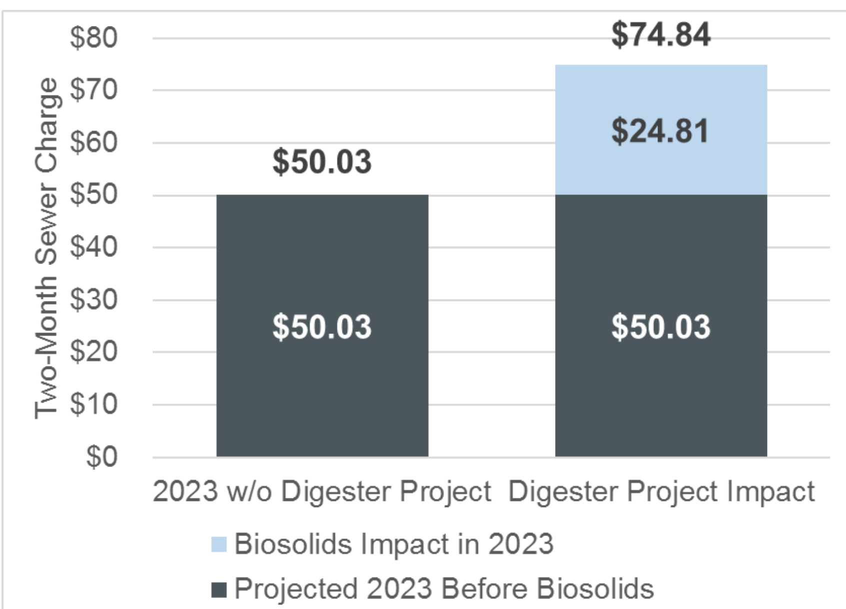
**Exhibit 4: ERU Monthly Impact**

| Impact to an Equivalent Residential Unit | | |
|---|---|---|
| **Digestion / Biosolids Project** | | |
| Estimated Impact in 2023 | | |
| Annual Debt Service | $ | 13,777,605 |
| Incremental Annual O&M | $ | 231,939 |
| Annual Cost Increase | $ | 14,009,544 |
| Estimated Wastewater Utility ERUs in 2023 | | 47,063 |
| Annual Impact | | $297.67 |
| Monthly Impact | | **$24.81** |

## I.I. TOTAL IMPACT ON ERU CHARGE

We are assuming that one ERU is equivalent to a single family customer, which currently is charged $86.32 every two months, or an average of $43.16 per month. We projected that this monthly cost would increase to just over $50 by 2023 due to inflation alone. **Exhibit 5** shows the incremental impact of adding $24.81 per month for the resource recovery project. It would increase the monthly cost per ERU to $74.84, a 50% increase over what that cost would be absent the project.

**Exhibit 5: Monthly Impact for a Single Family Customer in 2023**



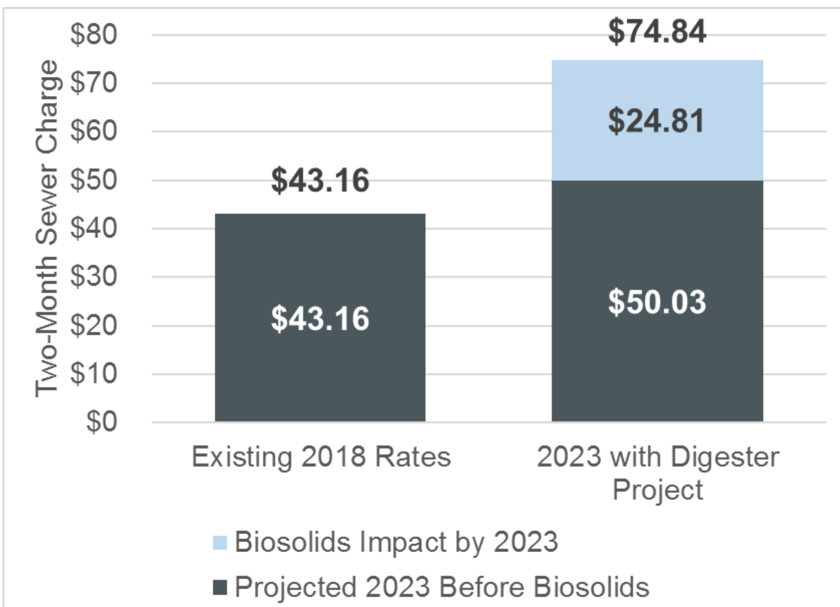
## I.J. SUMMARY OBSERVATIONS

Existing cash reserves are insufficient to cover a project of this magnitude, so debt must be issued to finance it. This facility is expected to add operating costs as well, above what the City currently pays to operate the incinerator plant. This analysis does not take into account any debt service coverage requirements that may be connected with a revenue bond issue of this size.

To cover annual debt service and O&M costs, based on the cost estimates provided by Brown & Caldwell and Carollo, a single family customer's rates would need to be about 50% higher than they would be without the project. To the extent that the project cost can be offset by existing cash reserves, grants, or low-cost state loans instead of revenue bonds, the impact could be less.

The previous chart looked at the monthly cost per ERU in 2023, with and without the resource recovery project. The next chart, **Exhibit 6**, shows a different comparison: the 2023 cost per ERU with the project, compared with today's 2018 single family monthly cost. By looking at the impact of *both* the resource recovery project plus normal inflation (assumed here at 3% per year), we see that the cumulative increase would need to be 73% over the five-year period from 2018 to 2023.

**Exhibit 6: Monthly Impact of Both Inflation and Resource Recovery Project, 2018-2023**




Because of the magnitude of these rate increases, if the City decides to move ahead with this project, it would be advisable to start annual adjustments to the rates well in advance of 2023. Over a five-year period beginning in 2019 and continuing through 2023, a cumulative rate increase of 73% above existing rates can be accomplished by five equal increases of 11.6%. For a project of this scale, every year of delay in adjusting rates makes the eventual rate increases more disruptive. Beginning the rate increases in advance of 2023 would also allow the accumulation of reserves, which would reduce the amount of debt from what is shown here.

# APPENDIX A: SOURCE OF ERU ESTIMATE

DEPARTMENT OF ECOLOGY
State of Washington

**WASTEWATER DISCHARGE PERMIT FEE PROGRAM**
**Residential Equivalent (RE) Calculation Form for Municipal/Domestic Facilities that Sell Sewer Services to Other Municipalities**
**Form 2**
**For Fiscal Year 2019**
**(July 1, 2018 – June 30, 2019)**

**Section 1. Identifying Information BELLINGHAM, CITY OF**

**Section 5. Calculation of Total Number of Residential Equivalents**

| | | |
|---|---|---|
| 5A. | Number of residential equivalents the facility serves in its own service area (from line 3I). | 39,373 |
| 5B. | Number of residential equivalents the facility serves in other municipalities (from line 4B). | 4314 |
| 5C. | Total number of residential equivalents (line 5A plus line 5B). | 43,687 |
| 5D. | Enter the number from line 5C on line 6A in Section 6. | |

**Section 6. Total Residential Equivalents**

| | | |
|---|---|---|
| 6A. | Number of residential equivalents from line 5C in Section 5. | 43,687 |
| | **This number will be used to calculate your permit fee for fiscal year 2019** | |

**Section 7: Certification of Information**

*I hereby certify with my signature that all information contained in this form and in supporting documents are true and correct. I understand that any omissions or misrepresentations will result in revision of both current and previously granted fee determinations.*

Signature

Date

# APPENDIX B: 2018 BI-MONTHLY WASTEWATER RATES

## 2018
## BI-MONTHLY UTILITY BILLING RATES

### Metered Water - Sewer - Stormwater - Lake Whatcom Watershed

*City of Bellingham utility rates increase effective January 1, 2018. Rate increases are approved by City Council and included in Chapter 15 of the Bellingham Municipal Code (BMC). For information about rates, billing, low-income senior and disabled citizen discounts and payment methods, visit our website at www.cob.org/utilities.*

**This rate sheet provides 2018 rates for bi-monthly billing.**
**Base rates for monthly billing are one half of the bi-monthly base rates.**
*1 CCF (100 cubic feet) = 748 gallons*

### METERED WATER

Water rates are based on the cost to provide drinking water.

| SINGLE FAMILY *Includes individually metered residential units and resale services* | | **Base Rates** | NON-SINGLE FAMILY & IRRIGATION *Includes shared meters, multi-family, condominiums, commercial, industrial and institutional services* | |
|---|---|---|---|---|
| INSIDE CITY | OUTSIDE CITY | Meter Size | INSIDE CITY | OUTSIDE CITY |
| Base Rate | | | Base Rate | |
| $ 42.92 | $ 64.38 | ⅝" | $ 61.72 | $ 92.58 |
| $ 59.04 | $ 88.56 | ¾" | $ 88.02 | $ 132.03 |
| $ 91.28 | $ 136.92 | 1" | $ 140.64 | $ 210.96 |
| $ 171.96 | $ 257.94 | 1 ½" | $ 272.12 | $ 408.18 |
| $ 268.72 | $ 403.08 | 2" | $ 429.94 | $ 644.91 |
| $ 526.82 | $ 790.23 | 3" | $ 850.76 | $ 1,276.14 |
| $ 817.16 | $ 1,225.74 | 4" | $ 1,324.20 | $ 1,986.30 |
| $ 1,623.66 | $ 2,435.49 | 6" | $ 2,639.32 | $ 3,958.98 |
| | | 8" | $ 4,217.40 | $ 6,326.10 |
| | | 10" | $ 6,584.28 | $ 9,876.42 |
| | | 12" | $ 8,951.76 | $ 13,427.64 |

| SINGLE FAMILY | | **Consumption Rates** | NON-SINGLE FAMILY | |
|---|---|---|---|---|
| INSIDE CITY | OUTSIDE CITY | Meter Size | INSIDE CITY | OUTSIDE CITY |
| Per 1 CCF | | | Per 1 CCF | |
| $1.94 | $2.91 | ALL | $1.97 | $2.96 |
| | | | IRRIGATION | |
| | | | $2.60 | $3.90 |

## SEWER

Sewer rates are based on the cost of service to treat wastewater.

| SINGLE FAMILY | | Base Rates | NON-SINGLE FAMILY | | | |
|---|---|---|---|---|---|---|
| *Rate Class 1* | | | *Rate Classes 2-4* | | *Rate Classes 5* | |
| INSIDE CITY<br>Base Rate | OUTSIDE CITY<br>Base Rate | | INSIDE CITY<br>Base Rate<br>Up to 16 CCF | OUTSIDE CITY<br>Base Rate<br>Up to 16 CCF | INSIDE CITY<br>Base Rate<br>Up to 16 CCF | OUTSIDE CITY<br>Base Rate<br>Up to 16 CCF |
| $86.32 | $129.48 | | $86.32 | $129.48 | $130.46 | $195.69 |
| SINGLE FAMILY | | Volume Rates | NON-SINGLE FAMILY | | | |
| N No Volume Rate | | | INSIDE CITY<br>Per 1 CCF above 16 | OUTSIDE CITY<br>Per 1 CCF above 16 | INSIDE CITY<br>Per 1 CCF above 16 | OUTSIDE CITY<br>Per 1 CCF above 16 |
| | | | $6.07 | $9.11 | $9.40 | $14.10 |

## STORMWATER

Stormwater rates are based on the costs of service for prevention and clean-up of water pollution, flooding, and to meet state and federal water resource regulations.

| FOOTPRINT | IMPERVIOUS SURFACE AREA | RATE |
|---|---|---|
| Small Footprint | less than 1,000 sq. ft. | $13.16 |
| Medium Footprint | 1,001-2,999 sq. ft. | $21.91 |
| Impervious Surface greater than 3,000 sq. ft. | | $ 0.00730 per sq. ft. of total impervious surface |
| *Impervious surface means a hard surface area that either prevents or slows the entry of water into the soil. For complete definition, see BMC 15.16.010.* | | |

## LAKE WHATCOM WATERSHED

The Lake Whatcom Watershed Land Acquisition and Preservation Program Charge funds land acquisition and other land preservation measures in the Lake Whatcom Watershed to help preserve water quality.

| SINGLE FAMILY | | Base Rates | NON-SINGLE FAMILY & IRRIGATION | |
|---|---|---|---|---|
| INSIDE CITY<br>Base Rate | OUTSIDE CITY<br>Base Rate | Meter Size<br>ALL | INSIDE CITY<br>Base Rate | OUTSIDE CITY<br>Base Rate |
| $26.92 | $40.38 | | $ 11.22 | $ 16.83 |
| SINGLE FAMILY | | Consumption Rates | NON-SINGLE FAMILY & IRRIGATION | |
| No consumption rate for single family. Consumption is based off of the Water Consumption line item on your utility bill. | | tion is based off of the | INSIDE CITY<br>Per 1 CCF | OUTSIDE CITY<br>Per 1 CCF |
| | | | $ .7137 | $ 1.07 |

2018 METERED WATER, SEWER, STORMWATER and LAKE WHATCOM WATERSHED RATES Page 2 of 2