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FOOD TO ENERGY CO-DIGESTION FEASIBILITY STUDY

Final Feasibility Report

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VERSION CONTROL

Revision No	Date Issued	Description
0	10/31/2019	Final Feasibility Report submitted.
1	01/17/2020	Added: Appendix F Total Project Cost Estimates, Appendix G Monte Carlo Analysis and language clarifying project costs used in analyses only comprise direction construction costs.

ACRONYMS AND ABBREVIATIONS

AOC	Abnormal Operating Conditions
ASU	Arizona State University
BMP	Biochemical Methane Potential
Cf	Cubic Feet
CH_4	Methane
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2e	CO_2 emissions equivalents
COD	Chemical Oxygen Demand
CFR	Code of Federal Regulations
DGE	diesel gallon equivalence
DIGs	Anaerobic Digesters
dtpd	Dry tons per day
EPA	Environmental Protection Agency
FOG	Fat, Oil, and Grease
fps	Feet Per Second
GBTs	Gravity Belt Thickeners
GHG	Greenhouse Gas
gpm	gallons per minute
gpd	gallons per day
H_2S	Hydrogen Sulfide
HHV	Higher Heating Value
HP	horsepower
kWh	kilowatt hour
lbs	pounds
mmBtu	One Million British Thermal Units
MT	metric tons
NG	Natural Gas
NH_4-N	Ammonia Nitrogen
NWWRP	Northwest Water Reclamation Plant
OLR	Organic Loading Rate
O&M	Operations and Maintenance
OSW	Organic Solid Waste
PS	Primary Sludge
PSA	Pressure Swing Absorption
psig	pounds per square inch
RIN	Renewable Index Number
RNG	Renewable Natural Gas
SCFH	Standard Cubic Feet per Hour
SCFM	standard Cubic Feet per minute
sCOD	Soluble Chemical Oxygen Demand
SRT	Solids Retention Time
TAS	Thickened Waste Activated Sludge
tCOD	Total Chemical Oxygen Demand
TKN	Total Kjeldahl Nitrogen
TOX	Thermal Oxidizer
tpd	tons per day
TS	Total Solids
TSS	Total Suspended Solids
VS	Volatile Solids
VSS	Volatile Suspended Solids
VSR	Volatile Solids Reduction
WAS	Waste Activated Sludge
wt	wet tons

1 OVERVIEW

Project Description

Organic waste represents approximately 33% of a typical municipal solid waste stream and is a major source of fugitive methane when disposed of in landfills. Co-digestion of this organic waste in an anaerobic digester is a more sustainable solution than landfills, with multi-tiered benefits including increased biogas production for energy use, reduced organic hauling distances in trucks, reduction of landfill space consumed, and reduction in fugitive methane emissions. To further explore co-digestion, the City of Mesa has engaged Arcadis to perform this feasibility study and conceptual design effort to determine the requirements and benefits of an organics to biogas energy program. The program includes leveraging synergistic relationships across multiple agencies within the City of Mesa operations. Spearheaded by the Environmental Management and Sustainability department being pursued in conjunction with the WWTP and city owned natural gas utility, the City of Mesa is in a unique position to execute a food waste-to-energy program with minimal reliance on outside entities. Collaborations are also underway with the adjacent City of Tempe and its unique grease collective as another potential partner supplying fats, oils, and grease (FOG) for co-digestion. The project team also includes the Biodesign Institute at Arizona State which is conducting bench scale biomethane potential (BMP) testing on the various food waste and FOG feedstocks being proposed for collection and diversion to anaerobic digestion.

The goal of the City of Mesa Food to Energy Feasibility Study is to determine the technical, operational, and financial feasibility of a food waste and FOG co-digestion program at the Northwest Water Reclamation Plant (NWWRP). As part of this effort, the Environmental Management and Sustainability department would collect, and process organic waste feedstocks sourced from its service district such as post-consumer food waste and source separated organics from large institutional cafeterias. From these feedstocks the Environmental Management and Sustainability department would generate an engineered organic slurry ideal for digestion. A mixture of this slurry and FOG from Tempe will be fed to digesters at the NWWRP to enhance the production of renewable biogas. This biogas can then be used for the purposes of on-site electric production and/or the production of renewable natural gas (RNG). The Food to Energy Program concept design has been developed in coordination with recommendations from the concurrent NWWRP Facility Evaluation project focused on improving operational aspects and the treatment efficiency of the plant.

Task Summary

The scope of work for the City of Mesa Food to Energy Feasibility Study is organized into the nine tasks completed by Arcadis, Arizona State University (ASU) Biodesign Swette Center for Environmental Biotechnology (BSCEB), Energy Vision, and Raftelis. Within this Feasibility Report Document, the work from Tasks 2 through 7 is summarized. This Report includes summaries and major outcomes of each task level effort. There are detailed technical memorandum documents associated with the task level items which are included as appendices and can be referenced for more in-depth information on specific tasks. The tasks included in the study are as follows:

- Task 1: Project Management
- Task 2: High Strength Waste Feedstock Analysis
- Task 3: Evaluate Waste Pre-Processing Facility Requirements
- Task 4: Evaluate NWWRP Anaerobic Digestion Capabilities
- Task 5: Food Waste and FOG Co-Digestion Bench-Scale Testing Management
- Task 6: Evaluation of Potential Project Incentives versus Biogas End Uses
- Task 7: Financial Feasibility Evaluation
- Task 8: Feasibility Report Document

Following the Task 2-7 level summaries, this report then presents overall findings and conclusions regarding co-digestion feasibility at NWWRP.

Task 2: High Strength Waste Feedstock Analysis

The City of Mesa conducted an analysis of the available feed stock in Mesa was conducted using data and information from the collection of food waste samples, waste audits, and data from the Environmental Protection Agency, Maricopa Association of Governments (MAG) Employer Database, and D &B Hoover's.

Samples from local food waste generators, including restaurants, grocery stores, and institutional kitchens, were obtained and collected by the City, then analyzed by the Biodesign Swette Center for Environmental Biotechnology (BSCEB) at Arizona State University for the purpose of understanding the nature and composition of the OSW and to analyze the suitability for co-digestion in anaerobic digesters.

Food waste audits of 6 commercial establishments were conducted to better understand of the quantities of food waste and the amount of food waste disposed of relative to solid waste. Understanding this information could lead to optimizing food waste collection services and reduce solid waste services, thereby lower disposal costs to customers.

The City also conducted analysis to develop a service delivery model to collect food waste. The total amount of food waste available within City limits was modelled and hypothetical collection routes were generated. Operating and capital costs associated with collection were estimated in order to develop rates that would cover collection costs.

Task 3: Evaluate Waste Pre-Processing Facility Requirements

A conceptual design was developed for implementing a food waste and FOG receiving and processing operation at the City's Center Street Yard. This is the site of the existing Household Hazardous Materials facility, storage, and training yard utilized by multiple City departments with the opportunity for future expansion. Based on the results of Task 2 and in conjunction with Task 4, target characteristics/specifications were developed for the final slurry product to be produced by a Center Street Food Waste Pre-Processing Facility (Pre-Processing Facility). The proposed Pre-Processing Facility is anticipated to be a stand-alone structure for receiving the

HSW from municipalities in the region and other private sector haulers, processing food waste and/or FOG into an engineered slurry product, storing the final product, and loading for transfer to the NWWRP.

Arcadis prepared a Concept Memorandum outlining requirements for a Pre-Processing facility as well as a facility site layout; building floorplan and elevations; manufacturer cut sheets for all equipment, tanks, piping, and appurtenances; and a concept level opinion of associated costs. It is important to note that the concept level opinion of associated costs only includes direct construction costs; for total project costs including engineering and construction and management costs, please refer to Appendix F. Information from this Concept Memorandum was also used as a major component of the financial feasibility analysis covered in Task 7.

Task 4: Evaluate NWWRP Anaerobic Digestion Capabilities

The existing solids handing, anaerobic digestion, and biogas systems at the NWWRP were examined, along with plant process data and findings from the NWWRP Facility Evaluation (also being conducted by Arcadis). This effort focused on determining the capacity and logistics of accepting co-digestion HSW feedstocks at the NWWRP and injecting this material into the digesters without disrupting operations. Evaluation of the existing digestion system identified HSW feedstock loading limits, HSW receiving equalization and pumping needs, anticipated outcomes of increased biogas production from co-digestion as well as impacts and potential risks to the existing NWWRP solids process operations. The evaluation also identified necessary support facilities for a complete co-digestion operation, including HSW receiving equalization and biogas transmission, conditioning, and storage. Multiple biogas end use outlets were examined including Cogeneration and RNG.

Arcadis prepared a Concept Memorandum based on evaluation of the NWWRP anaerobic digestion system and its capacity to accept HSW and utilize additional biogas. This document included layout figures for the potential systems evaluated; manufacturer cut sheets for gas conditioning and other equipment; and a concept level opinion of associated costs. As with costs evaluated in Task 3, all costs evaluated in Task 4 only include direct construction costs; total project costs including engineering and construction management costs can be found in Appendix F. Information from this Concept Memorandum is a major component of the financial feasibility analysis covered in Task 7.

Task 5: Food Waste and FOG Co-Digestion Bench Scale Testing

This was an ASU BSCEB led task performed in collaboration with the City of Mesa staff and Arcadis to construct and operate bench scale digesters for testing of co-digestion of food waste and FOG. ASU bench testing was conducted with the purpose of determining site specific parameters for NWWRP operations including feedstock digestibility, optimal loading rates, biogas production potential, biogas characteristics, and key monitoring parameters for maintaining digester stability.

This bench testing included one-year of operation of multiple bench-scale anaerobic digesters seeded with NWWRP primary and waste activated sludge. Various loadings of OSW and FOG were then added to the digesters to simulate proposed co-digestion operations. Part of the bench scale testing included comprehensive sampling of the parameters affected by addition of OSW and FOG, and interpretation of the results in terms of applicability to the proposed full-scale co-digestion operations.

Task 6: Evaluation of Potential Project Incentives versus Biogas End Uses

Under this Task, Arcadis collaborated with Energy Vision to identify and quantify incentives associated with each potential biogas end use examined under Task 4. Incentives included power utility rate schedule advantages, grant funding for cogeneration projects, renewable identification numbers (RINs) under the Federal Renewable Fuel Standard Program, and Low Carbon Fuel Standard (LCFS) credits from the California LCFS program. This analysis was used to establish the apparent best value end use(s) for biogas evaluated under Task 7.

Task 7: Financial Feasibility Evaluation

Based on the results of Tasks 2 through 6, Arcadis developed a comprehensive solids and energy flow model that dynamically tracks the major physical, chemical, energy, and financial components of a new food waste to biogas energy program. Arcadis collaborated with Raftelis to use this comprehensive model to prepare financial feasibility evaluation for various scenarios or versions of projects aimed at enhancing the use of biogas produced at NWWRP both with and without co-digestion. The financial feasibility evaluations included the conceptual life-cycle costs associated with the capital improvements, potential savings from avoided costs resulting from co-digestion implementation, potential RIN credits and tipping fee revenue, and a preliminary estimate of return on investment (ROI) for each scenario examined. All analyses were performed using direct construction costs only and do not include soft costs such as design and construction management costs. The preliminary estimate of ROI encompasses potential project incentives and identified the apparent best approach for co-digesting HSW and maximizing the value end use for biogas.

2 FINDINGS AND CONCLUSIONS

High Strength Waste Feedstock Analysis

The City of Mesa conducted an analysis of the existing food waste sources within the City to determine the feasibility of collecting 44 tons (the excess anaerobic digestion capacity at the Northwest Water Reclamation Plant) of food waste per day. The analysis was conducted using data and information from the collection of food waste samples, waste audits, and data from the Environmental Protection Agency, Maricopa Association of Governments (MAG) Employer Database, and D &B Hoover's. For the purposes of the feasibility study the City limited collection to commercial establishments that generate food waste during their normal business practices. The analysis was limited to commercial establishments due to contamination concerns from residential collection. The quality of the food waste collected was prioritized over quantity to minimize grit and other operational complications at the Northwest Water Reclamation Plant.

According to data sources the City of Mesa has 966 commercial establishments that generate approximately 37 tons of food waste per day. Almost all the food waste generating businesses within city limits would have to subscribe to the City's food waste collection service to collect enough food waste to fill the excess anaerobic digestion capacity at the Northwest Water Reclamation Plant. The City can collect 84.5% of the tons needed at a competitive rate. The requirement to have such a large percentage of commercial establishments led the City to examine alternative sources outside the City to fill the excess capacity. Currently several small food waste collection services are offered in the Phoenix-metro area. Services are typically delivered to businesses with a sustainability or zero waste initiatives and food waste is either composted or used as animal feed. The City would have to develop partnerships with other waste haulers and surrounding communities in order to collect enough food waste to fill the excess capacity at the Northwest Water Reclamation Plant.

The service delivery model developed focused on determining the most cost-effective manner to collect food waste. The City chose to prioritize offering a service that would result in lower disposal costs to customers in order to incentivize participation. There are currently no mandates to divert organic materials from landfills in Arizona, therefore in order to increase program participation the City chose to pursue a service delivery model that offered customers lower disposal costs. The City does recognize that some businesses would opt for higher disposal costs in order to meet corporate sustainability or zero waste goals. During the project the City was contacted by two large companies interested in subscribing to food waste collection services. However, in order to collect the amount of food waste needed the City would have to develop a service that was attractive to businesses without sustainability or zero waste goals. After all costs are accounted for the City can charge a rate for food waste collection that is lower than solid waste collection rates. However, once solid waste service is added to food waste collection service, customers will typically incur higher disposal costs than if they were to landfill all material. This holds true even though solid waste service levels are reduced due to the diversion of food waste.

As part of the High Strength Waste Feedstock Analysis, the City also conducted an organic solid waste (OSW) collection pilot conducted in collaboration with bench digestion testing performed by Arizona State University (ASU). Under the OSW collection pilot, commercial food waste samples were collected from five representative waste generators from various industry types from the Mesa service area. A description of the OSW generators and the results of the preliminary feedstock analysis are summarized in Table 1 below.

Table 1. OSW Collection Pilot Testing Waste Details

Industry Type	Waste Characterization	Observed Contamination
Grocery	Bakery, Deli (meats, sandwiches, sides), Produce (vegetables)	Rigid plastic food containers, cartons,
Cafeteria & Restaurant Kitchens	Produce (vegetables)	Film plastics, Flexible plastic beverage containers

Industry Type	Waste Characterization	Observed Contamination
Food Bank	Packaged foods (meat, canned vegetables, baked goods), Produce (fruits & vegetables)	Metal cans, Rigid and flexible plastic containers, Cartons, Film plastics
Cafeteria Kitchen	Prepared meals (meat, carbohydrates, produce)	Food wrappings, Flexible plastic beverage containers
Grease Interceptor Waste	Fats, Oil, Grease, White water	Sediment, utensils

The City established a temporary pre-processing facility at Center Street Hazardous Household Materials (HHM) Facility to pre-process food waste from the five waste generators for use in the ASU bench digestion testing. ASU analyzed the characteristics of the OSW and grease interceptor waste containing fats, oils and grease (FOG). The average values from the ASU testing are summarized in Table 2 below.

Table 2. ASU OSW and FOG Characteristics

Food Waste Characteristics	OSW ASU Bench Test Values	FOG ASU Bench Test Values	Unit
Total Solids	23%	3.8%	%
VSS/TSS	93.5%	88.5%	%
pH	4.28	4.48	

Based on the OSW collection pilot results, which included visual examination, it is anticipated that both the OSW and FOG streams will contain considerable amounts of contamination. While food waste characteristic guidelines for the generators are being established by the City in the collection contracts, de-contamination will be required as part of waste pre-processing in order to allow the mixed waste slurry to be fed into the digesters at NWWRP.

After pre-processing, OSW and FOG will be combined, forming the high strength waste (HSW) slurry to be transferred from the pre-processing facility to NWWRP. This transfer will be performed via tanker truck with vehicles designed to transfer and pump liquified loads in a sealed containment vessel to minimize odor and the risk of spills. A total solids (TS) percentage of 10% - 15% should be targeted for HSW slurry to be delivered to NWWRP in order to both ensure pumpability and minimize hauling loads between facilities. Dilution of food waste may be accomplished to some extent using FOG, but this is dependent upon the volume and characteristics of FOG available. If the HSW stream exceeds 15% TS after FOG addition, the HSW can be further diluted with onsite water stores, potable or non-potable.

Food Waste and FOG Co-Digestion Bench-Scale Testing

Arizona State University (ASU) Swette Center for Environmental Biotechnology operated six bench scale digesters with the goal of replicating full scale co-digestion practices to the greatest extent possible. Each reactor was 2-litres maintained at 37°C and used blended, thickened sludge obtained from Mesa NWWRP as the baseline influent substrate. All six reactors were initially seeded with only municipal sludge and allowed to reach steady state operations.

After seeding of all reactors, the experimental reactors were batch fed with thickened sludge and pre-processed OSW, obtained through the City of Mesa pre-processing pilot, three days a week. Some experimental reactors received FOG from Tempe in similar batch feed modes. Gas and effluent liquid samples were taken the same days as feeding. The influent streams (thickened sludge, OSW, and FOG), bench reactors, and effluent liquid were measured for pH, temperature, TS, TSS, VSS, alkalinity, TCOD, SCOD, ammonium, TKN, total phosphorus, soluble phosphorus, gas composition, VFAs, anions including sulfate, proteins, carbohydrates, crude lipids, and free fatty acids of influent and effluent streams.

Several reactors experienced souring during the experimental testing, which provided the opportunity to assess the limits of organic loading and batch feeding operations. Some of the limitations of the bench scale reactors were that the small volumes of the reactors made it difficult to simultaneously control SRT and organic loads to mimic full scale conditions. The nature of the laboratory experiments also necessitated batch feeding, while full scale operations would be a steady and constant feed regimen. Finally, because of schedule constraints, it was not possible to acclimate reactors to organic waste loads in a stepwise manner, whereas full scale operations will be slowly acclimated over time up to the maximum target loading rates.

During the experimental phase, adjustments were made to organic loading rates to the bench scale reactors to match the recommended limit of 35% of total digester load from HSW. This adjustment appeared to help bench scale operations and reduce the rate of reactors going sour. The reactor deemed to best represent full scale operations was named “Target Loading 1 Reactor” which was fed with baseline levels thickened sludge and also fed diluted OSW to a level that the OSW load was 35% of the total reactor loading. It should be noted that the addition of diluted OSW dropped the reactor SRT to 17.2 days while the control was maintained at 25.9 days, which is representative of current plant conditions. Table 3 below summarizes the Target Loading 1 reactor results versus the control reactor.

Table 3. “Target Loading 1” Reactor Comparison to the Control Reactor

Parameter	Control Reactor	Target Loading 1 Reactor	Unit
Organic Loading Rate	0.097	0.143	lb VS/cf/day
VS / TS Ratio	67%	73%	%
Soluble COD	1,562	3,676	mg COD/L
Total COD	30,930	35,889	mg COD/L
Volatile Solids Reduction	49.0%	50.4%	% VS
Biogas Yield	18.5	26.0	cf/lb VS destroyed day
Energy Content	535	565	BTU/cf
Ammonium Nitrogen	1,009	1,090	mg NH_4-N/L

Parameter	Control Reactor	Target Loading 1 Reactor	Unit
Orthophosphate	530	590	mg PO_4/L
Total Phosphorus (TP)	600	690	mg PO_4/L
pH	7.4	7.4	
Alkalinity	4,582	4,728	mg/L

As expected, the reactor loaded with OSW had higher COD levels and higher VS/TS ratios than the control. There did not appear to be a significant change in volatile solids reduction (VSR) between the reactors, with both reactors at approximately 50% VSR, this difference could be due in some part to the reduced SRT levels in the Target Loading 1 reactor. Biogas Yield did show an appreciable difference, however, with the Target Loading 1 reactor showing a 40% increase over the control reactor, indicating a significant increase in biogas production levels. Reactor nutrient loads showed modest elevations in both Ammonia and ortho-P for the Target Loading 1 reactor, but it should be noted that these levels in the control reactors were significantly elevated over what is observed in the full-scale operations at NWWRP. Finally, pH levels and alkalinity appeared stable within the Target Loading 1 reactor, giving support that the full-scale co-digestion system should be able to operate at the recommended loadings without major upsets.

Waste Pre-Processing Facility

Center Street Yard (2412 North Center Street, Mesa, AZ) was selected as the location for the HSW Pre-Processing Facility because the site is both owned by the City and located near Northwest Water Reclamation Plant (NWWRP). The site is considered sufficiently distant from surrounding neighborhoods and commercial properties for noise to not be a primary concern. Handling and processing of OSW and FOG will create offensive odors that can attract vectors such as insects, birds and rodents, and, as a result, the Pre-Processing facility design will require odor control systems and most facility components will be located indoors.

A concept site layout of the solid waste transfer station at Center Street Yard is shown in Figure 1.

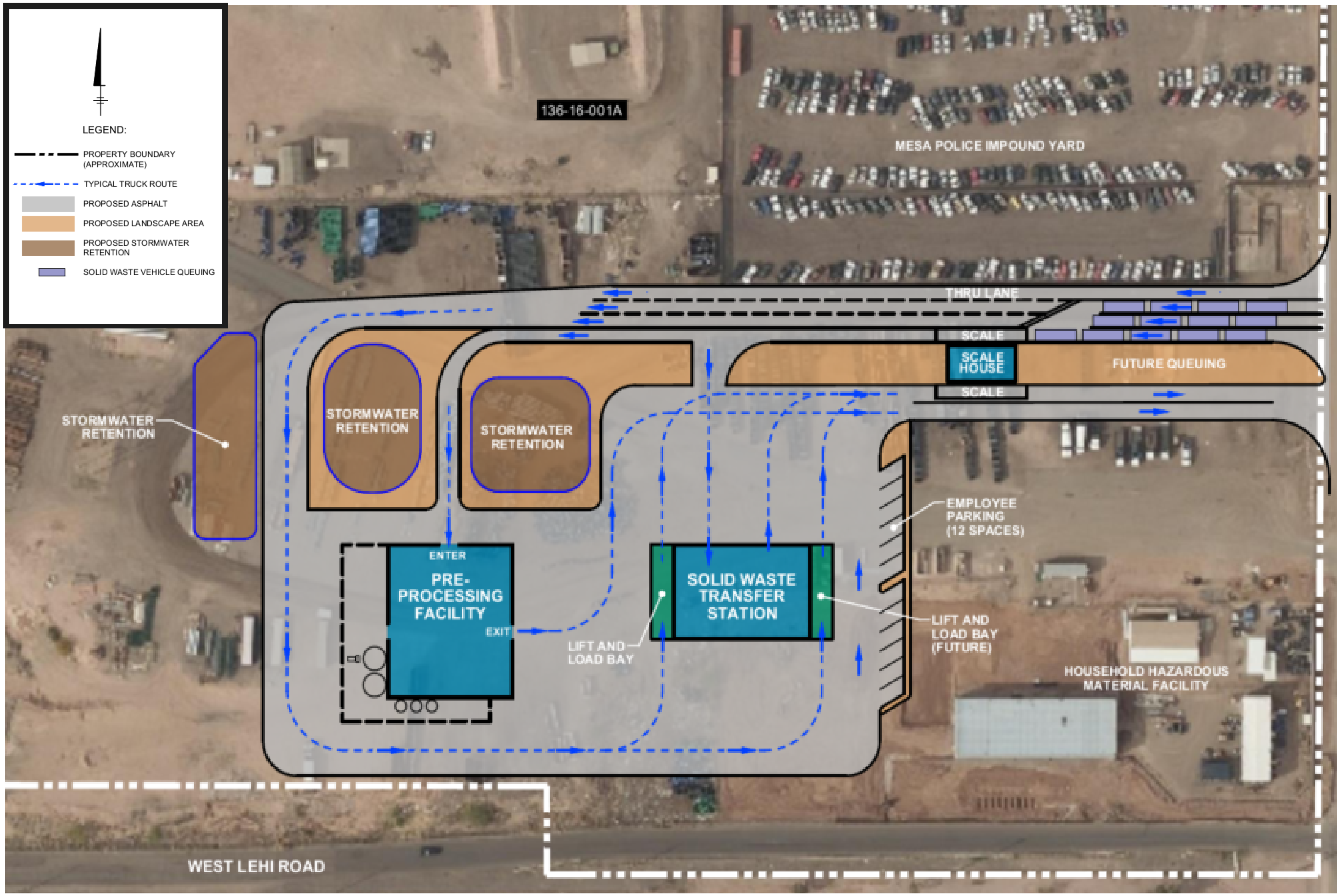

Figure 1. Center Street Yard Solid Waste Transfer Station Concept Site Layout

The City explored transporting locally sourced food waste to the Pre-Processing Facility utilizing City solid waste vehicles. As a result, the Pre-Processing Facility must be configured for deliveries from a variety of transport container types. FOG will be transported to the site directly by the Tempe grease trap pumpers as a contractual requirement.

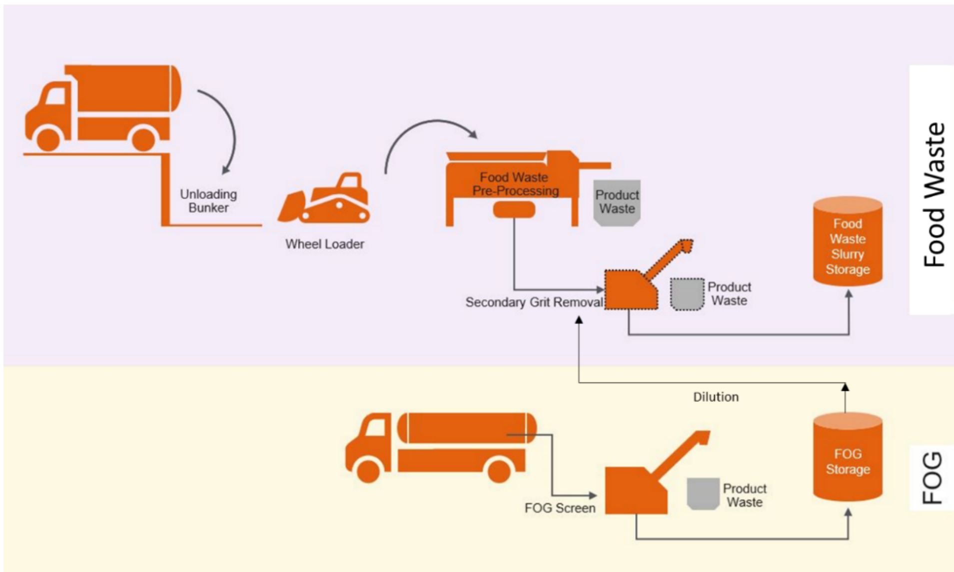

Figure 2 Food Waste and FOG Process Flow Diagram

The Pre-Processing Facility building will consist of a grade level entry with a stepped lower area for food waste receiving and processing, as is shown in the 'Food Waste' process flow diagram in Figure 2 above. Other building area separations will be based on operating function to minimize conflicts between moving vehicles and operations staff to increase facility safety.

The NWWRP digestion capabilities analysis determined that NWWRP could accept a maximum of approximately 44 tpd OSW and 10,000 gpd FOG on a 5-days per week basis. Therefore, the Pre-Processing Facility layout and equipment will be designed to accommodate collection and processing of up to 50 tons of OSW feedstock per day, a high-capacity FOG pre-processing system, and tankage for blending with food waste slurry. Processing of OSW feedstock is based on collection frequency, the volume to be processed is more directly related to processing equipment size rather than building size. Accommodating future processing needs is best accomplished by providing adequate space for future equipment upsizing or duplication. The processing equipment selected may accommodate a greater daily volume than initially required since equipment manufacturers offer a limited size range for these types of machines.

Several equipment manufacturers provide similar equipment components, performance characteristics, such as function, approximate dimensions, materials of construction and applicable design criteria, can vary depending on throughput speed and types of contamination. Each unit consists of the distinctive components: Feed Hopper, Auger, Mill, Screw, and Slurry Pump. Each comparative unit has a processing rate of 0-20 TPH and similar contaminant removal capabilities. The Ecoverse Tiger HS55, shown in Figure 3 below, was selected as the recommended processing unit because it has the smallest footprint, lowest power draw and the highest contamination removal efficiency of all the OSW pre-processing equipment evaluated under this study. Communications with other facilities operating the Ecoverse system reported thorough satisfaction with the long-term performance of these units.

Figure 3. Ecoverse Tiger HS55

Historic aerial photographs show that the Center Street Yard was an area previously used for agriculture and then as a landfill from the late 1940s – the 1960s. Additional investigations will need to be conducted for the specific site locations selected for the Pre-Processing Facility as well as for other planned site uses. Investigations should include additional subsurface investigations regarding potential remediation of buried trash in locations of permanent buildings as well as traffic areas under dynamic loads from frequent large vehicle traffic. A preliminary cost estimate for construction of the solid waste transfer station at Center Street Yard is shown in Table 4 below. Table 4 only includes direct construction costs, meaning that design and construction management costs are excluded; for total project construction costs including design and construction management, please refer to Appendix F.

Table 4. Center Street Yard Solid Waste Transfer Station Preliminary Cost Estimate

Component	Total Cost[1]	Total Cost -30%	Total Cost +50%
Sitework[2]	$624,000	$436,800	$936,000
Pre-Processing Facility Building	$4,582,500	$3,207,800	$6,873,800
Depackaging System	$766,800	$536,800	$1,150,200
Grit Screening	$49,000	$34,300	$73,500
FOG Receiving	$427,700	$299,400	$641,600
Storage, Pumping Systems & Piping (FOG, HSW, etc.)	$250,000	$175,000	$375,000
Subtotal	**$6,700,000**	**$4,690,100**	**$10,050,100**
Indirect/Other Costs[3]	**$1,983,200**	**$1,388,200**	**$2,974,800**
Subtotal	**$8,683,200**	**$6,078,300**	**$13,024,900**
Contingency (20%)	$1,736,600	$1,215,600	$2,604,900
Total Estimated Probable Construction Cost	**$10,419,800**	**$7,293,900**	**$15,629,800**

[1]The following items are excluded from the Opinion of Probable Construction Cost:

- Geotechnical Investigation & Site Remediation
- Design and Permit Fees
- Construction management Services
- Rolling Equipment, Dumpsters, and Misc. Ancillary Items
- Control System Programming

[2]Assumes only sitework for Pre-Processing Facility as stand-alone installation without adjacent similar facilities.

[3]Includes General Conditions, Overhead, Mob/Demob, Bonds, Insurance and Profit.

NWWRP Anaerobic Digestion Capabilities

The two anaerobic digesters at the Northwest Water Reclamation Plant (NWWRP) have excess organic solids loading capacity which provides the potential for OSW and FOG that would otherwise be landfilled to be diverted to NWWRP and co-digested to increase biogas production. OSW contains energy in the form of fats, proteins and carbohydrates. Of the three, fats yield the most biogas when anaerobically digested, followed by proteins then carbohydrates. While waste streams rich in fats and proteins such as meats and dairy will yield more biogas than carbohydrate streams, these types of feedstocks need to be kept in balance with sludge and carbohydrates to limit build-up of long chain fatty acids and ammonium in digesters. As a result, for optimal co-digestion performance, organic waste streams containing relatively equal parts fats, proteins and carbohydrates are recommended.

As discussed in the Waste Pre-Processing section, imported OSW will be decontaminated for inert and/or heavy material such as plastics, wood, metals, and glass. Controlling the types of contamination present in the OSW before it arrives at pre-processing will greatly reduce the likelihood that contamination will end up in the processed organic stream. OSW from industrial food manufacturing will contain minimal physical contamination, however, it is important to ensure that the industrial waste will not introduce heavy metals, detergents or other soluble contaminants that can be harmful to an anaerobic digester. Unlike industrial organic waste, Pre and Post-consumer waste will primarily contain physical rather than soluble contamination. Pre-consumer OSW will typically contain plastics and packaging that are removed with a high degree of efficiency by the pre-processing equipment while post-consumer waste contains more varied contamination that introduces the highest likelihood of contamination entering the processed organics stream. While a degree of variability between organic waste streams on a day to day basis is expected, the above guidelines are general best practice targets for OSW slurry to promote optimal co-digestion performance.

While diverting HSW yields economic benefits both from the additional biogas production and avoided tipping fees, HSW loading to the digesters must be limited since overloading a digester can upset digestion stability. To determine the HSW loading limits to the digester, Arcadis considered 4 best-practice digestion limits, summarized in Table 5 below.

Table 5. Digester Best-Practice Limits

Digestion Parameter	Target	Unit
Solids Residence Time	20	Days
Organic Loading Rate	0.185	lbs VS/cf/day
Organic Mass Fraction	35%	%
Ammonium Concentration	1,500	mg NH4-N/L

Using the above parameters, Energy Flow Modelling results indicated that organic mass fraction, which is the mass fraction of HSW in the total digester feeding load, is the limiting factor for HSW loading to the digesters. At a 35% organic mass fraction, HSW loading rates to the digester are:

- 22 tpd OSW and 5,000 gpd FOG to 1 digester
- 44 tpd OSW and 10,000 gpd FOG to both digesters

A 10-15 % TS concentration is recommended for the bio-slurry to be transported to the NWWRP for injection into digesters. This concentration range was selected to both minimize the volume of slurry transported while still ensuring slurry pumpability. Once the organic waste has been processed at the pre-processing facility, the resultant slurry will be approximately 20-30 %TS and will be diluted to 10-15 %TS using FOG or dilution water if enough volume of FOG is not available. FOG is an acidic organic waste source that will typically have a pH of approximately 4-5. Waste streams with pH in this range are not anticipated to be problematic to digestion stability given the relatively small volumes compared to sludge and sufficient digester alkalinity. Imported waste streams with more extreme pH values need to be considered carefully, especially in large volumes. Additionally, to avoid large pH swings or shock loads, it is important for the HSW to be equalized at the NWRRF and fed to the digesters at a small and consistent flow rate. It is also recommended that the HSW addition be kept below a 35% mass fraction of total volatile solids (VS) fed to the digester.

Two alternatives for receiving the HSW at NWWRP were proposed. First, NWWRP could utilize the currently unused 50,000-gallon primary sludge (PS) wet well as an equalization tank, as shown in Figure 4 below.

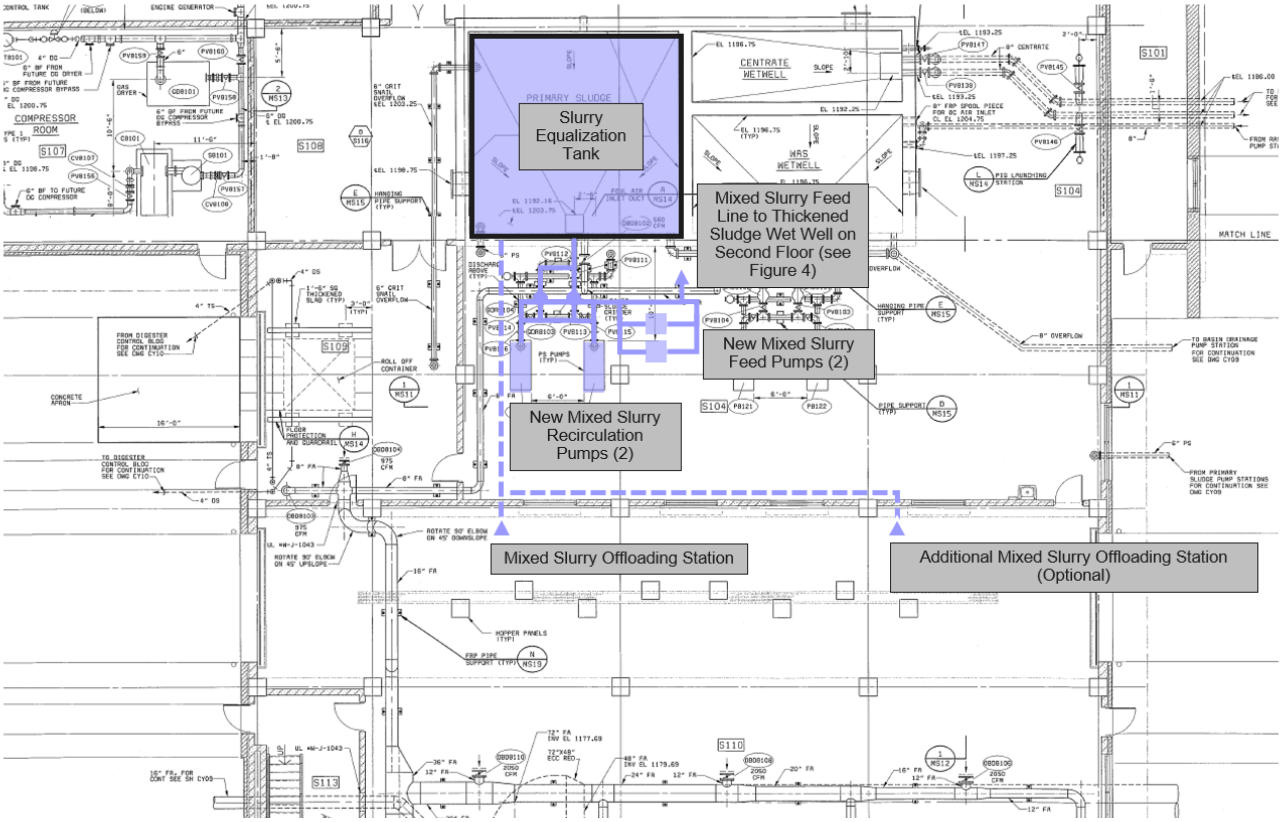

Figure 4. Primary Sludge Wet Well Equalization

Second, NWWRP could pump HSW into the thickened sludge wet well and the existing thickened sludge wet well pumps would pump the mixed sludge/HSW stream into the digesters.

While the recommended HSW loading rates were set to minimize the risk of digester upset, since HSW characteristics will vary, it is recommended that NWWRP monitor the following parameters in both the digesters and in the food waste equalization tank:

- pH
- Volatile Fatty Acid Concentrations
- Alkalinity
- Feed Rate
- Volatile Solids

If NWWRP receives HSW with parameters that are anticipated to be problematic, the HSW should be diverted to the facility headworks for treatment. Additionally, to ensure digester stability when first beginning co-digestion, HSW loading rates will be gradually ramped up to allow the digester(s) time to acclimate to the increased volatile solids loading rates.

At 44 tpd OSW and 10,000 gpd FOG to both digesters, Arcadis estimated an average of 278 scfm of biogas production. While NWWRP currently uses its biogas in a CHP engine system, Federal and State incentives for renewable vehicle fuel make upgrading biogas to pipeline/vehicle grade renewable natural gas (RNG) for use in CNG vehicles a financially viable and environmentally sustainable alternative end use for biogas.

Potential Project Incentives and Biogas End Uses

The transportation sector is currently the highest value market opportunity for wastewater derived biogas due to high value credits associated with its use in the transportation sector. CHP does not currently have similarly valuable credits meaning that the economic benefits of using biogas is primarily tied to the electric power cost offsets.

Two renewable fuels incentives programs were considered under this feasibility study: The Environmental Protection Agency's (EPA) Renewable Fuel Standard (RFS) and California's Low Carbon Fuel Standard (LCFS). Both programs require a physical or theoretical physical pathway linking the RNG source to the vehicle fuel end user. The LCFS requires that the RNG be consumed in California, meaning that, to qualify for LCFS credits, RNG must be injected into a utility transmission line with a theoretical physical pathway to California.

Under the Federal Renewable Fuel Standards (RFS) program, biogas generated from digested sludge qualifies for D3 RIN credits, whereas all biogas produced via digesters performing co-digestion with other feedstocks, including OSW and FOG, qualifies for D5 RIN credits. The distinction has significant economic implications since the value of D3 RINs is considerably greater than D5 RINs, as is show in Figure 5.

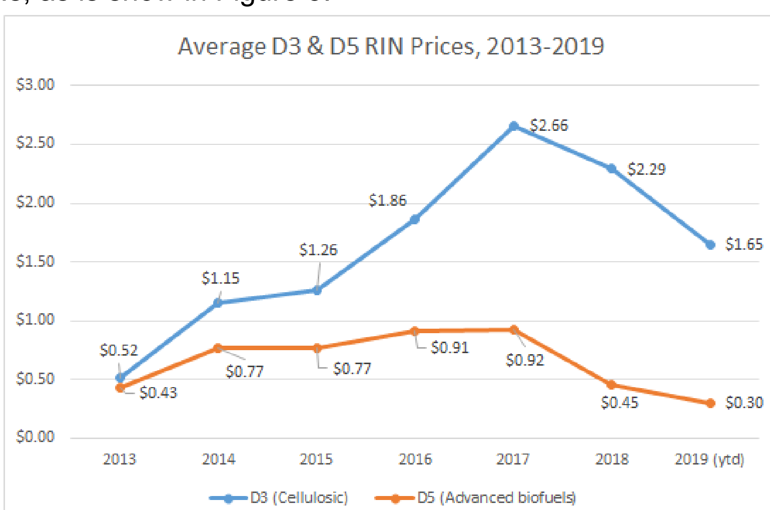

Figure 5. D3 and D5 RIN Historical Values

Figure 5 also highlights the volatility associated with RIN credit prices. In 2019, RIN credit values have experienced downward price pressure due to RIN surpluses and uncertainty surrounding the EPA's RFS reset process this year. However, despite recent negative downwards price pressure, industry analysts, traders and other market experts anticipate a 15-20% rebound in average RIN pricing over 2019 prices, meaning that the RIN revenue potential for NWWRP is anticipated to remain significant into the future.

Unlike the RFS fuel feedstock classification system, LCFS credits are solely based off CO2e emission reductions, which allows credit revenues to scale with the increase in biogas generated when co-digesting unlike RIN revenues under the RFS. It is important to highlight, however, that LCFS credits are calculated based off a constantly declining fuel index, depicted in Figure 6 below.

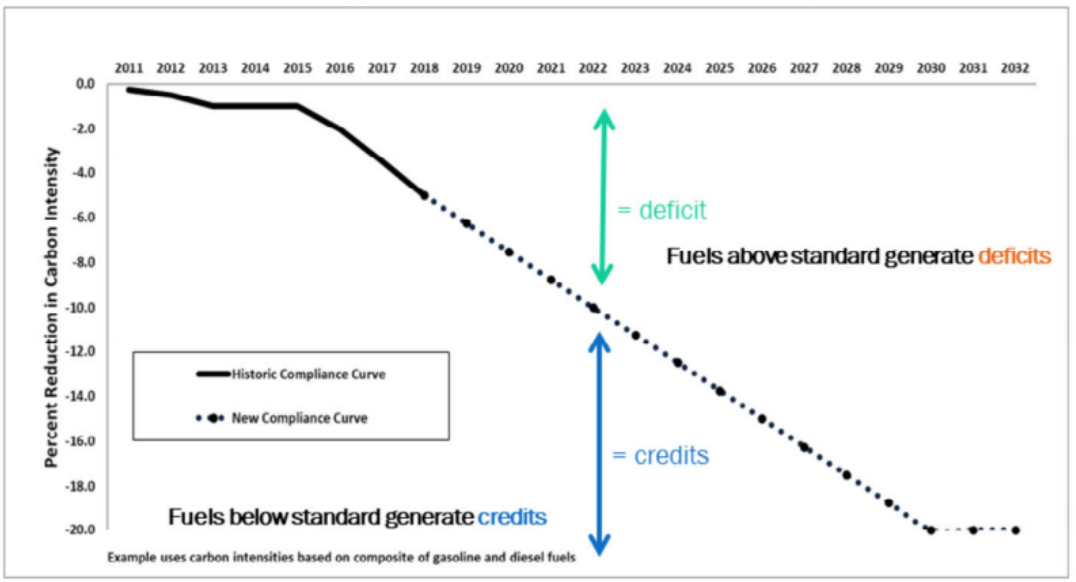

Figure 6. LCFS Declining Carbon Intensity Index

Because of this, the value of LCFS credits NWWRP would generate would slightly decline year over year even without a decline in LCFS credit values. Nonetheless, since NWWRP can qualify for both RIN and LCFS credits simultaneously, the LCFS program provides the potential for incremental renewable fuel credit revenue for NWWRP.

Arcadis analyzed the economic, operational and environmental benefits of co-digestion, RNG production and power generation under 24 distinct scenarios to determine the optimal configuration at NWWRP. The results of the analysis indicate that collecting either D3 or D5 RIN credits for RNG is more valuable than using biogas in the CHP system to generate power. However, due to the significant peak and shoulder peak power costs during summer months, operating the CHP system on NG during these periods increases savings at NWWRP. The most financially lucrative of the scenarios evaluated is to generate RNG without co-digesting to maximize D3 RIN credit revenues and to operate the CHP system on NG during peak and shoulder peak periods during Summer months. In addition to D3 RIN revenues, NWWRP could participate in the LCFS program to yield additional incremental value, assuming that the proposed pipeline interconnection provides a theoretical physical pathway to California.

For RNG generation, Arcadis evaluated both a membrane upgrading system and PSA upgrading system and found the PSA system, shown in Figure 7, to be more economically favorable due to its lower capital cost and reduced operating expenses. A thermal oxidizer was determined to be the best method for treating tail gas from this process. A concept design and general plant layout for implementing RNG at the NWWRP was developed as shown in Figure 8.

Figure 7. PSA RNG Upgrading Skid and Thermal Oxidizer

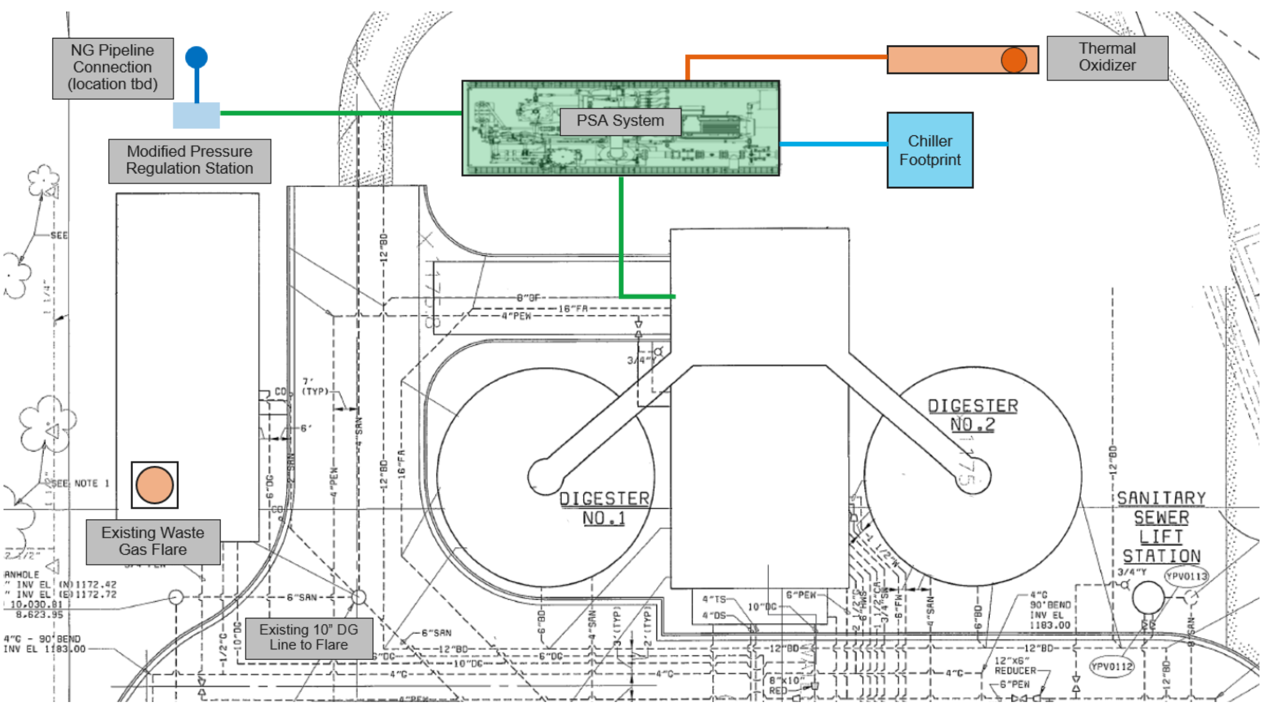

Figure 8. Proposed RNG System Layout at NWWRP

The general PSA system and thermal oxidizer costs and performance metrics are summarized in Table 6 below.

Table 6. PSA RNG Upgrading and Thermal Oxidizer Design Parameters

Parameter	Value	Unit
	PSA Skid	
Capital Cost	$2,679,000[1]	$
Annual Maintenance Cost	$30,000	$/year
Rated Capacity	400	scfm
Power Draw at Rated Capacity	171	kW
CH_4 Capture	92%	%
Gas Pre-treatment Cost	$0	$/mcf Biogas fed
Availability	95%	%
	Thermal Oxidizer	
Capital Cost	$489,000[1]	$
Annual Maintenance Cost	$15,000	$/year
Power Draw	22	kW

1. Only includes direct construction costs. For total project cost inclusive if engineering and construction management services, please refer to Appendix F.

Due to the significant capital cost associated with an OSW pre-processing station, when co-digesting and generating RNG solely for D5 RIN credits, the NPV is negative. However, operating a City owned HSW Pre-Processing Facility affords the City of Mesa insulation from rising tipping fees and promotes sustainability goals by both diverting OSW from landfills and providing renewable fuel for the City's CNG fleet. Before the City can proceed with the food waste collection and pre-processing program, the City must consider the timeline for site remediation and construction of the pre-processing facility at Center Street Yard that will be required in order to begin co-digesting at NWWRP.

Financial Feasibility Evaluation

In collaboration with Arcadis, Raftelis Financial Consultants, Inc. completed an economic evaluation to support the City of Mesa's co-digestion feasibility assessment. An economic evaluation was conducted for seven of the twenty-four configurations analyzed by Arcadis as part of the digestion capabilities analysis. The economic evaluation includes the estimation of life-cycle costs associated with the capital improvements, potential savings or cost avoidance, and incremental costs associated with each scenario. The analyses performed evaluate direct construction costs and do not consider engineering or construction management costs. In addition, the economic evaluation includes an estimate of the 20-year net present value ("NPV"), payback period (if applicable), equivalent annual annuity. The equivalent annual annuity calculation annualizes the cost or net savings of each scenario. A sensitivity analysis was completed by adjusting several key estimates and assumptions to present a range of potential economic outcomes associated with each scenario.

The results of the economic evaluation indicate that two scenarios are expected to have a net present value savings:

Scenario #1: The 'Enhanced Baseline' Scenario assumes current operations. Therefore, under this scenario, there is no high-strength waste collected and delivered to the NWWRP. This scenario assumes that City uses biogas to run the City's existing engine generator system to generate electricity on-site and peak-shave ('Winter On-peak' seasonal period). The biogas is used as it is generated and supplemented with biogas stored in the existing storage tank to operate the engine at approx. 87.5% capacity. Natural gas is fed to the engine when biogas in not available (while the storage tank is being filled). It is assumed that the engine has a 90% annual availability.

Scenario #7: The 'No HSW – all D3 RNG + NG Peak CHP' Scenario assumes that the City will not collect, process, or inject any HSW at NWWRP. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is not added to either digester, this scenario generates only D3 RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the City uses natural gas to run the City's existing engine generator system to generate electricity on-site and peak-shave ('Mild Summer Shoulder-peak' seasonal period). Natural gas fed to the engine to operate at 100% capacity. It is assumed that the engine has a 90% annual availability.

Scenario #1 requires no capital investment and results in the lower NPV of savings of the two scenarios. Scenario 7 requires capital investment and has an expected payback period of approximately 4.3 years assuming D3 RIN prices of $1.85 with 2.5% price increases each year, however, this scenario does not achieve the City's goal of diverting food waste from landfills.

A sensitivity analysis demonstrated that the results of the economic evaluation are highly sensitive to several key variables, including the assumed solid waste tipping fee, vehicle fuel price, and the D3 and D5 RIN credit prices. The graph shown in Figure 9 below illustrates how RIN credit values and OSW disposal costs have significant impacts on the project economics while the influence of vehicle fuel cost offsets and discount rates are less influential.

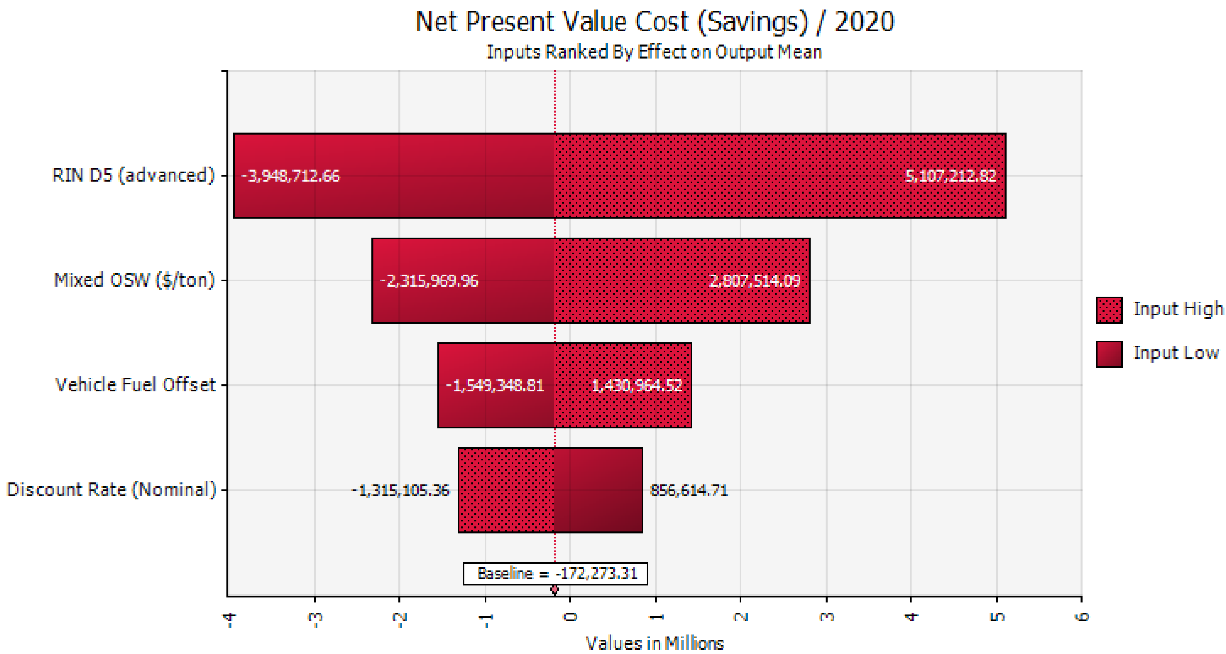

Figure 9. Project Variable Sensitivity Analysis

Given the potential range of possible input values associated with these variables, the NPV of certain scenarios can yield either a net cost or net savings. For instance, Scenario 7 produces the highest projected NPV savings under the most favorable sensitivity assumptions and Scenario 5 produces the highest projected NPV cost under the least favorable sensitivity assumptions. For further details on the impact of parameters on scenario financials, see Appendix D.

It is worth noting that the economic evaluation was based on the projection of direct costs and cost savings/avoidance associated with each scenario but did not consider or quantify other potential externalities associated with each scenario (e.g. environmental benefits or costs, indirect or induced economic impacts of job creation, favorable public perception / publicity, etc.). As such, the City may find non-financial benefits to moving forward with one or more of the scenarios even if economic savings are not projected for the scenario.

3 RECOMMENDATIONS

From the Feasibility Study, the following items were identified as beneficial and recommended for further development by Northwest Water Reclamation Plant (NWWRP):

Short-Term Recommendation:

- Integration of a biogas to renewable natural gas (RNG) system at NWWRP biogas utilization and pipeline interconnection options.
- Register for the U.S. Renewable Fuel Standard (RFS) Program.
- Feed natural gas to existing engine generator at NWWRP to peak-shave electricity prices.

Long-Term Recommendation:

- Investigate subsurface site characteristics at Center Street Yard, regarding potential remediation of buried trash in locations of permanent buildings and traffic thruways.
- Construct HSW preprocessing Facility at Center Street Yard.
- Retrofit Solids Handling Building at NWWRP to accommodate the equalization and injection of mixed HSW slurry injection into the existing thickened sludge stream.
- Execute co-digestion ramp up in a single digester at NWWRP to inform potential full-scale implementation at the Plant; continually scale co-digestion program until 100% target loading rates are achieved.

The following sections include further descriptions of the recommended scenarios. Appendices with the task level technical memorandums have additional detail on conceptual design information, conceptual capital cost estimates and discussion on implementation methods for each recommended option.

Short-Term Recommended Scenario

It is recommended that the City proceed with implementing biogas to RNG systems at NWWRP by installing a 400 scfm PSA RNG upgrading unit from Guild. The PSA skid can accommodate turndown to 20% of its rated capacity, meaning that the unit is appropriate to handle biogas generation rates both before and during co-digestion. This approach provides NWWRP with the flexibility to convert to co-digestion at a later date and have sufficient capacity to continue converting all biogas to RNG. Additionally, a thermal oxidizer is required to treat the energy lean RNG tail gas composed of the rejected contaminants in the biogas feed stream in order to meet air quality permit limits. A 200 scfm thermal oxidizer from Perennial Energy is recommended; this thermal oxidizer unit will also be capable of handling tail gas flow rates prior to and after implementing co-digestion. Once the RNG upgrading system has been installed, NWWRP can produce RNG and feed it to the City owned refuse truck fleet for RIN generation. In this initial phase the project should qualify for more lucrative D3 RIN credits because HSW acceptance will not yet be initiated. The existing CHP system should be maintained and be fueled on NG during summer peak periods, which will not only have a net savings on electric costs but will also extend the life of the engine equipment and simplify operations and maintenance. This configuration represents the most economically favorable scenario analyzed in this study.

In order to qualify for RIN credits, a pipeline interconnection is required to satisfy the theoretical physical connection to the vehicle end user as required under the RFS. The Riverview natural gas distribution system was identified as the logical transmission connection point as this system is directly adjacent to the NWWRP plant site and also is currently planned for pipeline reconfiguration work near the plant.

The Riverview system demand capacity was analyzed, and it was determined does not have sufficient demand to offtake the projected RNG production rates with the maximum load of food waste being accepted at NWWTP. For the long-term offtake of RNG, the 45 psi Riverview system and the larger 25 psi Mesa system would need to be connected. A modified pressure regulation station would be required between the 45 psi and 25 psi system. Alternatively, the Riverview system pressure could be dropped to 25 psi which would allow the two systems to be connected via a simple pipe and one-way valve connection. Further communications with the gas utility are required to determine which option will be possible and how to proceed with the NG transmission pipeline interconnection.

Either the GRS93 and/or GRS56 stations feeding between the Riverview 45 PSI and Mesa 25 PSI systems would have to be a modified design to allow for one-way directional flow. The City of Mesa Gas Engineering Division estimated that each modified pressure regulation station would cost approximately $50,000. The locations of the potential interconnection points are shown in Figure 10 below.

Figure 10. Riverview Gas System Interconnection Plan

It is also important to highlight that, assuming this pipeline connection provides a theoretical physical pathway to a California end user, NWWRP could also participate in the LCFS program to increase renewable vehicle fuel credit revenues and annual savings. If this interconnection does not provide a theoretical physical pathway to a California end user, an alternative interconnection would be required to allow NWWRP to participate in the LCFS program. Further communications with the gas utility will be required to determine whether this theoretical physical pathway exists.

Table 7. Short-Term Recommended Scenario Capital Expenses

Component	Cost[1]
PSA Upgrading Skid	$2,679,000
Thermal Oxidizer	$489,000
Pipeline Interconnection	$150,000
Total	**$3,318,000**

1. Only includes direct construction costs. For total project cost inclusive if engineering and construction management services, please refer to Appendix F.

Long-Term Recommended Scenario

It is recommended that the City proceed with constructing the HSW Pre-processing Facility and integrating co-digestion at Northwest Water Reclamation Plant (NWWRP). This portion of the project currently shows a negative NPV, however it does achieve a wide range of other benefits to the City of Mesa. One benefit is insulation against future rises in landfill tipping fees. Mesa currently pays relatively low tipping fees for landfill disposal of its MSW, but changes in landfill availability and future regulations restricting organics disposals in landfills could change this relatively cost-effective outlet in the future. Another benefit is that the diversion of organics from landfills to digestion with energy recovery is a significantly positive sustainability endeavor, with the potential to reduce the City of Mesa's GHG footprint by almost 5,000 metric tons of CO_2 equivalents per year. The estimated diesel gallon equivalents to be produced with organic diversion is approximately 1,700 gallons of diesel per day, enough to fuel 15-20 refuse trucks.

A third item of consideration is the potential change in RFS policy that currently penalizes projects like Mesa's for accepting food waste into digesters, by reclassifying the biogas eligibility from D3 to D5 RINs. This policy is in direct conflict with other EPA policies aimed at diverting organics from landfills and change to this policy is currently the subject of significant lobbying efforts by biogas advocacy groups. While there is no imminent policy change on the horizon, it should be noted that an eventual change seems logical and likely. If such a change was implemented, the projected NPV from accepting food waste would become positive and this option would become the most beneficial scenario. Given that the HSW component of the project is recommended for longer term implementation, this may lend time for more sensible policy around D3 and D5 RINs to become enacted as well.

Appendix A: Waste Pre-Processing Facility Concept Memorandum evaluates Center Street Yard site characteristic, preliminary conceptual details, and preliminary cost estimates. It is recommended that the City of Mesa proceed with the necessary site remediation prior to the construction. The recommended depackaging system is the Ecoverse's Tiger HS 55 which has advantages of smaller footprint, lower power draw and likelihood that fewer grit/glass contaminates will be present in the organic stream. The Enviro-Care Beast is the recommended pre-processing system to screens incoming FOG the high degree of contamination observed in the ASU Bench Study.

Additional construction at NWWRP shall include retrofitting the existing Primary sludge (PS) wet well for sludge equalization and an injection system into the existing thickened sludge wet well. Further details are available in Appendix B: Anaerobic Digestion Capabilities Concept Memorandum.

Table 8. Long-Term Recommended Scenario Capital Expenses

Component	Cost[1]
Pre-Processing Facility	$9,225,300
Pre-Processing Equipment	$1,194,500
Organic Waste Receiving at NWWRP	$476,000
Total	**$10,895,800**

1. Only includes direct construction costs. For total project cost inclusive if engineering and construction management services, please refer to Appendix F.

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APPENDIX A

High Strenth Waste Feedstock Analysis

High Strength Waste Feedstock Analysis

Executive Summary

The City of Mesa conducted an analysis of the existing food waste sources within the City to determine the feasibility of collecting 44 tons (the excess anaerobic digestion capacity at the Northwest Water Reclamation Plant) of food waste per day, five days a week. The analysis was conducted using data and information from the collection of food waste samples, waste audits, the Environmental Protection Agency (EPA), the Maricopa Association of Governments (MAG) Employer Database, and D &B Hoover's. For the purposes of the feasibility study, the City limited collection to commercial establishments that generate food waste as part of their normal business practices. The analysis was limited to commercial establishments due to contamination concerns resulting from residential collection. The quality of the food waste collected was prioritized over the quantity collected to minimize grit and other operational complications at the Northwest Water Reclamation Plant.

According to data sources, the City of Mesa has 966 commercial establishments that generate a combined total of approximately 37 tons of food waste per day. In order for enough food waste to be collected to fill the excess anaerobic digestion capacity at the Northwest Water Reclamation Plant, nearly all food waste-generating businesses within the city limits would need to subscribe to the City's food waste collection service. The requirement to have such a large percentage of commercial establishments led the City to examine alternative sources outside the City to fill the excess capacity. Currently several small food waste collection services are offered in the Phoenix-metropolitan area. Services are typically delivered to businesses with a sustainability or zero waste initiatives and food waste is either composted or used as animal feed. The City would have to develop partnerships with other waste haulers and surrounding communities in order to collect enough food waste to realistically completely fill the excess capacity at the Northwest Water Reclamation Plant.

The service delivery model developed focused on determining the most cost-effective manner to collect food waste. The City chose to prioritize offering a service that would result in lower disposal costs to customers in order to incentivize participation. There are currently no mandates to divert organic materials from landfills in Arizona, therefore in order to increase program participation the City chose to pursue a service delivery model that offered customers lower disposal costs. The City does recognize that some businesses would opt for higher disposal costs in order to meet corporate sustainability or zero waste goals. During the project the City was contacted by two large companies interested in subscribing to food waste collection services. However, in order to collect the amount of food waste needed the City would have to develop a service that was attractive to businesses without sustainability or zero waste goals. After all costs are accounted for the City is unable to charge a rate for food waste collection that is lower than solid waste collection rates. To incentivize participation with a lower rate a majority of the collection cost must be covered by other sources of revenue or avoided costs. The City will continue to examine opportunities to source food waste regionally.

Collection of Food Waste Samples

The City partnered with food waste generators to collect samples once per week in order to gain a greater understanding of the type of material they dispose of. Each partner was selected to represent a different type of food waste generator, for example the City had restaurants, grocery stores, food banks, and schools represented. The City partnered and collected food waste samples from:

- Arizona State University Memorial Union back of house
- Bashas'
- East Valley Institute of Technology (EVIT) Culinary School
- East Valley Institute of Technology (EVIT) Bistro Restaurant
- United Food Bank
- Sheraton Wrigleyville West
- Mesa Public Schools Carson Junior High School

Weekly samples in 35-gallon barrels were collected from each location from December of 2018 to the end of September 2019. Collection of samples from the Sheraton at Wrigleyville began collection in June of 2019 to supplement materials lost due to the decreased summer quantities from ASU.

Figure 1: 35-gallon collection barrel

Figure 2: Acceptable items barrel sticker

Partner organizations were asked to throw only food waste in their 35-gallon barrels and were not allowed to dispose of eggshells, bones, or glass. These materials are not easily broken down in the digestors and contribute to the buildup of grit in the digestors. Food waste was allowed to be in its original packaging because the assumption was made that at full scale the City would utilize de-packaging equipment that separates organic materials from plastics, cans, and other containers. The ability to dispose of food waste in its packaging is also a benefit to the food waste generator because no additional labor or prep is needed to provide high strength waste to the City. In fact, food waste generators cited in initial conversations that the ability to throw food waste away without any additional requirements was a large selling point that increased their interest in adoption of the program. The fact that minimal training would be needed, and no additional time would be spent disposing of food waste make this portion of the service delivery model very attractive to potential customers.

Collected samples were transported to the City of Mesa Household Hazardous Materials Facility and processed into a slurry. Prior to processing, information was gathered as to the type and quantity of food waste collected from each source as well as the types of packaging and contamination in each barrel. The food waste was then lifted onto a stainless-steel table and processed through an InSinkerator and pumped to a collection barrel.

Figure 3: Food waste processing table and InSinkerator

Figure 4: Peristaltic pump

Figure 5: Food waste processing

Throughout the duration of the feasibility study the City collected 26,924 pounds of food waste. Almost half of the food waste collected was produce, a little over a quarter was grains, and the remainder consisted of meat and dairy. There was very little contamination during the collection period. If contamination was identified in a collection barrel, the food waste generator responsible for the contamination was notified immediately.

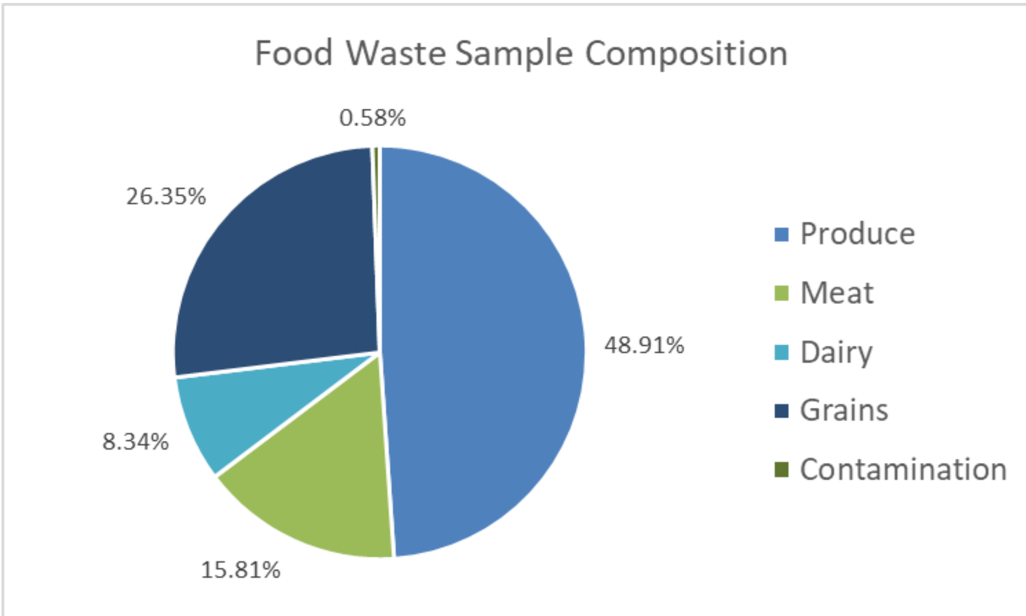

Figure 6: Food waste composition

Researchers at Arizona State University analyzed food waste samples and found that in the aggregate food waste samples were made up of 41% carbohydrates, 12% proteins, and 12% lipids. Once food waste was processed a sample was collected by ASU researchers for introduction into bench-scale digestors.

Food Waste Audits

The City of Mesa also conducted waste audits to gain a better understanding of the quantities of food waste generated by different types of commercial establishments. The City was also interested in understanding the amount of food waste disposed of relative to the amount of solid waste disposed of for each businesses. Understanding the amount of food waste disposed of relative to solid waste may lead to opportunities to offer food waste collection services and a reduction in solid waste services resulting in lower disposal costs to customers. The City of Mesa audited trash bins from:

- Filiberto's
- Whole Grain Bread Co.
- Organ Stop Pizza
- United Food Bank
- Trader Joe's
- Safeway

The City of Mesa collected bins on the customer's regularly scheduled collection day and hand-sorted the material into three categories, trash, recyclables, and food. The total weight of all material was comprised of 34% of materials were trash, 13% of materials were recyclable, and 53% of material were food waste. These results are higher than literature values, which found food waste makes up between 30 to 40% of solid waste, due to the large percent of food waste generated by the United Food Bank. Their food waste percentage was 83.5% and its weight was double the next highest weight from other locations. Removing the United Food Bank from the sample results in a food waste percentage of 45.6%.

The City further sorted the food waste portion of the solid waste stream into categories of produce, meat, grain, mixed;/prepared food, and dairy. When total weights of material categories are totaled for all locations 50% of food waste were produce, 5.1% were meat, 21.3% were grains, 23.1% were mixed/prepared food, and 0.5% were dairy.

The City provided samples to ASU that were representative of the food composition to determine the total percent solids from each location.

Location	**Percent Total Solids**
Trader Joes	27.8%
Safeway	32.5%
Filiberto's	33.6%
Whole Grain Bread Co.	57.9%
Organ Stop Pizza	
United Food Bank	

Table 1: Percent solids of food waste audit samples

Based on these results the City, ASU, and Arcadis agreed to assume in models that the high strength waste feedstock would contain 30% total solids.

Service Delivery Model

The City developed hypothetical routes and associated costs to those routes in order to generate cost estimates for food waste collection. Food waste operational costs were assumed to be similar to the current commercial front load program. Potential customers and their location were identified through the EPA Excess Food Opportunities Map and the MAG Employer Database. The quantity of food waste each location generated was determined through formulas developed by the EPA to estimate the amount of food waste generated.

- Food Manufacturers and Processors - ($ Annual Revenue) × (0.053 lbs. per $ Annual Revenue) ÷ (2,000 lbs. per ton)
- Supermarkets and other grocers - (# of employees) × (3,000 lbs. per employee per year) ÷ (2,000 lbs. per ton)
- Other Wholesalers and Distributors - ($ Annual Revenue) × (0.01 lbs. per $ Annual Revenue) ÷ (2,000 lbs. per ton)
- Elementary, Middle, High Schools - (# of students) × (0.5 lbs. per student per week) × (40 week per year) ÷ (2,000 lbs. per ton)
- Colleges and Universities - (# of students) × (1.13 lbs. /student)/week × 31 weeks/ year ÷2,000 lbs. /ton

- Hospitality Industry - (# of employees) × (1,984 lbs. per employee per year) ÷ (2,000 lbs. per ton)
- Correctional Facilities - (# of employees) × (3.75 inmates/employee) × (1.0 lbs. per inmate/day) × (365 days/year) ÷ (2,000 lbs./ton)
- Healthcare Facilities - (Revenue ($ million)) × (0.269 beds per Revenue ($ million)) × (1.5 lbs. per bed per day) × (365 days per year) ÷ (2,000 lbs. per ton)
- Food Services Sector - ($ Revenue) × (0.033 lbs. per $ Revenue) ÷ (2,000 lbs. per ton)

The number of employees for each location was included in the MAG Employer Database, revenue estimates were obtained from D & B Hoover's, and student counts were received directly from universities and school districts. Below is a map of the location of food waste generating commercial establishments and the distribution of the amount of food waste generated per location.

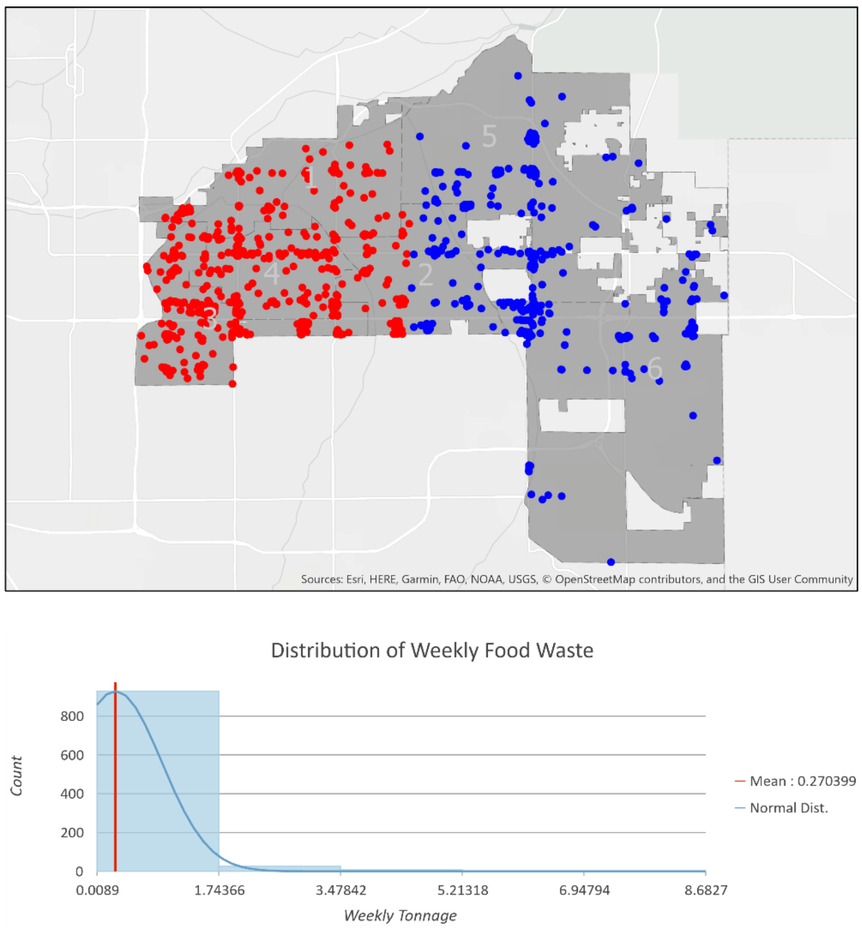

Figure 7: Producer locations and tonnage histogram, red representing the west city zone and blue representing the east city zone

The population (n=966) of food waste generators is best described as a propensity of small waste producers with a handful of larger waste producers dispersed around the city. As evident in Figure 7, the locations cluster around <~1.75 tons per week number, and the mean weekly tonnage for all producers is 0.27 tons. Spatially, food producers populate within two dense poles (West Mesa, East-Central Mesa) with a strong relationship to US-60 as depicted in Figure 8.

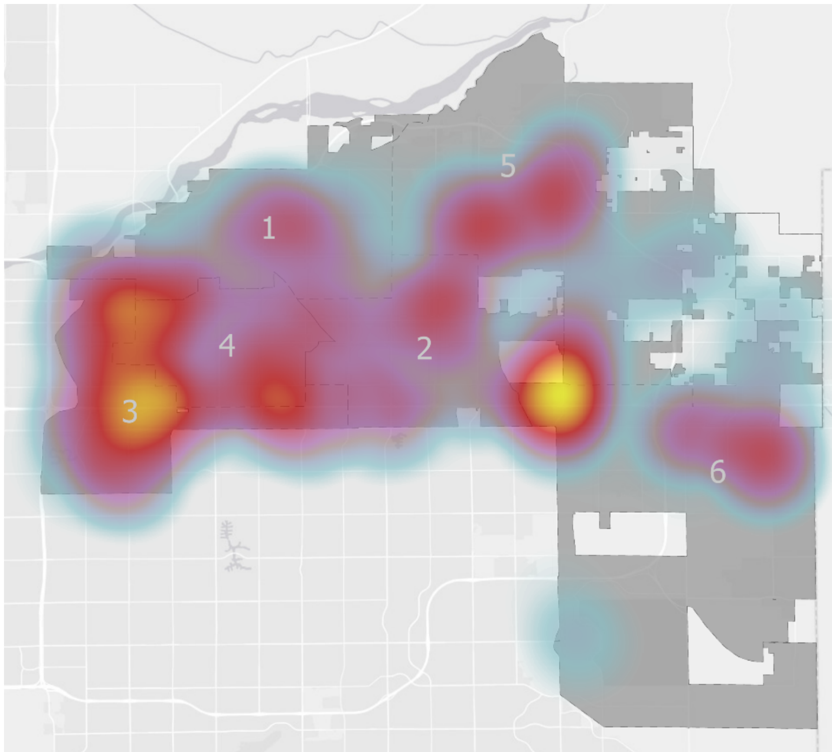

Figure 8: Density map of food locations, weighted by weekly tonnage estimates

With an understanding of the distribution, the city was halved along Val Vista, with the goal of creating two zones for modelled routes, both of which included six large food producers. The intent of the setup was to use the large producers as 3x-a-week waste suppliers and to allow the model's algorithms to find the best locations that clustered around the large food waste producers (Figure 9). Large food waste producers have greater than 3 tons-a-week of food and was primarily represented by grocery stores.

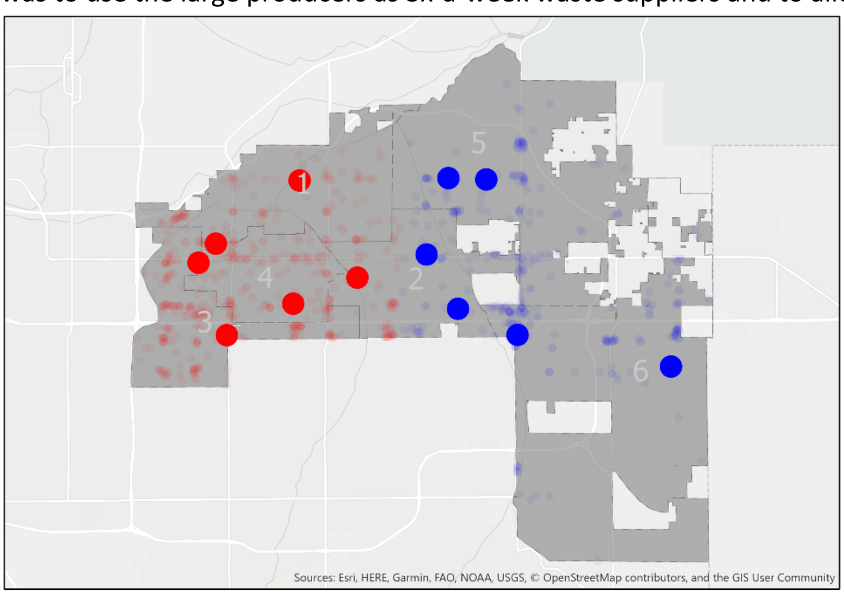

Figure 9: Large producers in relation to smaller food waste producers

The backbone of the analysis is ESRI's Network Analyst Tool and the Vehicle Routing Problem (VRP) Solution. The VRP is a variant of the Traveling-Salesman problem and, as a combinatorial math problem, seeks to balance with an optimized solution versus an exact answer. The solution is flexible in handling varying load sizes, multiple trucks and routes, renewal locations (disposals) and operational constraints like breaks, maximum allowable time worked, and service times. Additionally, cost accumulators are generated if the solutions are provided operating costs. For the purposes of these analyses operational costs were considered for labor ($55.80 per hour) and equipment ($6.58 per mile). While the algorithm seeks to maintain the least costly paths, it does so in combination with logically servicing orders. The City also assumed that once trucks had reached their weight limits, the collected food waste would be delivered to the Center St. yard for pre-processing.

Six separate analyses were run and simulated a two route/ two truck approach (Figure 10). Analyses 1 – 3 represented a Monday-Wednesday-Friday (MWF) schedule which serviced the large food waste producers 3x per week and then serviced a different cluster of locations per each day. Analyses 4 – 6 represented off days of Tuesday-Thursday-Saturday (THS) where the trucks would service small food waste producers not serviced in the MWF routes. Of note, the Thursday route includes collection only in the western zone due to an imbalance in the number of locations between the two zones.

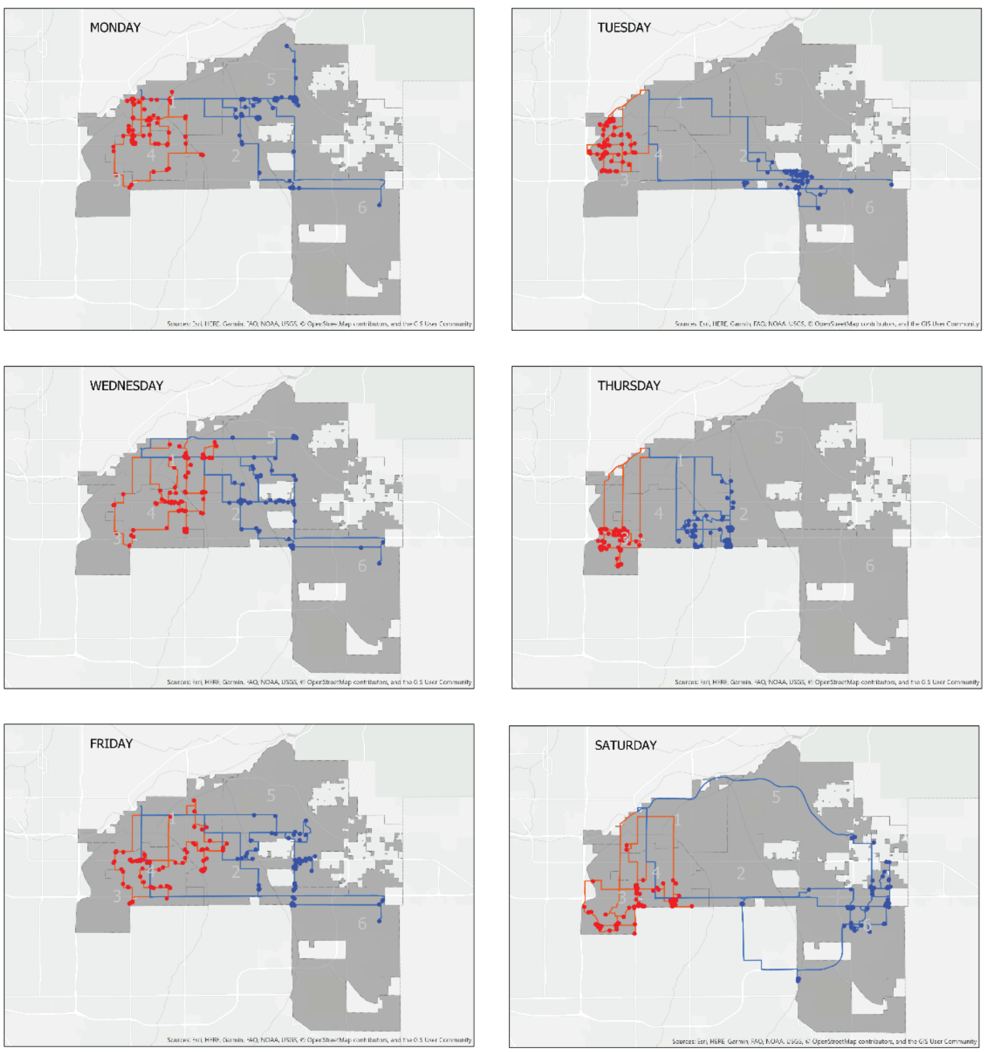

Figure 10: Vehicle Routing Problem results per day

Name	Stops	Total Cost	Day	Tonnage	1 x per week cost
West Route	83	$811.37	Monday	19.33	$9.78
East Route	72	$1,070.37	Monday	20.26	$14.87
West Route	91	$797.29	Tuesday	15.99	$8.76
East Route	75	$1,094.17	Tuesday	15.99	$14.59
West Route	73	$913.23	Wednesday	25.44	$12.51
East Route	72	$1,075.59	Wednesday	21.80	$14.94
West Route	81	$851.09	Thursday	19.50	$10.51
East Route	81	$867.19	Thursday	15.99	$10.71
West Route	79	$890.43	Friday	20.09	$11.27
East Route	63	$1,128.49	Friday	17.15	$17.91
West Route	84	$876.71	Saturday	15.75	$10.44
East Route	74	$1,185.37	Saturday	15.69	$16.02

Table 2: Cost, customers, tonnage per route zones

The results of the VRP Analysis produced operational costs and accumulated tonnage for each day and each zone as shown in detail in Table 2. All 928 customers in total can be serviced at a cost of $11,561.30, an average of $12.46 for 1x per week collection, or $49.84 per month. Large food waste producing customers costs are triple the rate at $149.52 per month to accommodate for the additional pick up days during the week.

The analysis shows that the City of Mesa is able to collect 222.98 tons of food waste per week, which meets the anticipated 220 tons per week capacity at the Northwest Water Reclamation Plant. If the City were not to co-digest fats, oils, and grease the plant would be able to accept 55 tons of food waste per day five days a week, or 275 tons per week. The 222.98 tons can be collected at a lower rate the equivalent solid waste volume. However, in order to collect the 222.98 tons would require 96% of the food waste generating businesses in Mesa subscribe to food waste collection services. The City of Mesa competes with private haulers for commercial business, the expectation that almost all food waste generating businesses would become City of Mesa customers is not realistic.

For the City to realistically collect the needed 220 tons per week food waste would have to be collected from outside sources. Currently, there are limited alternative disposal options for commercial businesses in the Phoenix-metropolitan area interested in diverting food waste from the landfill. The City of Phoenix and the City of Tempe currently operate compost programs that utilize green waste and some food waste to produce compost. Both facilities are at capacity and do not require additional food waste causing private haulers to limit food waste collection service. Several commercial establishments provide food waste as a source of animal feed, but these examples are limited to mostly large food waste generators such as grocery stores. Further investigation is needed to determine the amount of food waste available regionally and to determine the feasibility of collecting food waste outside of City limits.

Collection Equipment

Food waste poses unique challenges for collection. The material is very wet and dense, requiring special collection equipment. The City plans to utilize plastic bins and barrels for collection of food waste. Plastic materials offer several advantages over metal when it comes to food waste collection including prevention of rust, reduced odors, and lighter container weights. Once food waste has been placed in its collection container, the City plans to provide service to customers with a front load truck equipped with a Curotto Can.

Figure 11: Currato Can attachment

The Currato Can allows the truck to service both bins and barrels reducing the capital needs for additional trucks. The ability to service both bins and barrels with one truck is advantageous for food waste collection in Mesa due to the high number of businesses generating low amounts of food waste. 96% of food waste generating businesses in Mesa would require 2.54 yards of service or less once per week. The mean amount of food waste generated per location in Mesa is 540.8 pound per week. According to the EPA one yard of food waste weighs 1,368 pounds. The amount of volume needed for an average Mesa business would be 0.3953 yards or a little less than 80 gallons per week. The City of Mesa would be able to service most of the food waste generating businesses with multiple 64-gallon barrels. The small amount of businesses that would require more than once per week service generate larger quantities and would be serviced with a 2 or 3-yard plastic bins.

Container Type	Number of Customers
64-gallon barrel	754
Two 64-gallon barrels	114
Three 64-gallon barrels	26
2-yard bin	22
3-yard bin	50

Table 3: Number of customers by container type

To offer a food waste collection service the City would need two additional front load trucks equipped with Currato Cans as well as new bins and barrels to provide to customers. The total estimated cost for all equipment if the City of Mesa were to collect the majority of food waste is $ 1,020,000, which includes tax and shipping for equipment.

Item	Estimated Cost	Quantity	Total
Front load truck	$375,000	2	$750,000
Currato Can	$15,000	2	$30,000
64-gallon barrel	$152.04	1,060	$161,162.40
Plastic 2-yard bin	$439.11	22	$9,660.42
Plastic 3-yard bin	$864.80	50	$43,240
Grand Total			**$ 1,020,000**

Table 4: Food waste collection capital cost estimates

Collection Costs and Estimated Rates

The annual cost for capital over a twenty-year period at 3% would equal an estimated annual payment of approximately $70,000. Annual operational costs are estimated to be $605,000 and indirect costs are estimated to be $190,000 putting the total cost of the program at $865,000. These costs result in a rate of $77.67 per customer per collection in order to cover all collection costs. The rate for commercial businesses for solid waste collection is currently $75 per month for a 2-yard bin, $82 per month for a 3-yard bin, and $89 per month for a 4-yard bin collected once per week.

The rate charged to customers to recover all collection costs is not low enough to incentivize participation and would result in higher rates because in addition to food waste customers would still require solid waste service. However, there may be opportunities for the City to offer reduced rates by passing on savings from the reduction in solid waste tipping fee expenses due to the diversion of food waste. The City could also choose to view the service not as material collection and disposal, but feedstock supply and associate a value to the food waste. Since the food waste would increase biogas production there is a value to having a steady supply of feedstock. Revenues from the sale of Renewable Identification Numbers (RINs) or avoided solid waste tipping fees can be used to cover portions of the collection cost, resulting in attractive food waste collection rates. Avoided tipping fee costs are projected to be $350,000 According to projections the food to energy program at full scale producing only D5 Renewable Identification Numbers (RINs) would generate an average operating profit of $480,000 per year.

Data and Analysis Discussion

While conducting the analysis the City of Mesa recognized that there are certain limitations to the data available, impacting assumptions made when developing the food waste collection model. The City of Mesa used the best data available in order to estimate collection costs and build a model that as accurately as possible represents the quantities of food waste generated by local businesses. The food waste estimates used are derived from the EPA Excess Food Opportunities Map, which reviewed existing studies conducted by state environmental agencies, published articles, and other sources, such as the Food Waste Reduction Alliance (FWRA). The estimates used are meant to apply nationally to different business types and do not take regional or local factors into consideration.

The estimates used by the EPA do not distinguish between edible and inedible food, rather the weekly estimates include both food fit for human consumption and food not fit for human consumption. It is the City's desire to only utilize inedible food as feedstock for the production of Renewable Natural Gas and to work with potential customers to find alternative outlets for edible food.

Food waste estimates also do not take seasonality into consideration and assume the same amount of food waste will be generated every week. The City recognizes this is not the case and experiences a decrease in solid waste tons during summer months. During the feasibility study several partner organizations struggled to deliver food waste samples during the summer months. For example, ASU, EVIT, and Carson Junior High School decreased or stopped collection while classes were no longer in session. The City expects quantities to fluctuate throughout the year based upon the mix of customers that subscribe to a food waste collection service.

Collection cost estimates were generated through the production of hypothetical routes. These costs may vary from those estimated depending on several factors. The mix of customers is unknown, through examination of potential customers the City does not have very many commercial establishments that generate large quantities of food waste. This causes the City to service many smaller producers of food waste and depending on which of these smaller producers subscribes to a food waste collection service can alter route density. Typically, more dense routes are more cost efficient to operate.

Conclusions

The City of Mesa contains a diverse mix of food waste generating businesses, however expecting that City would be able to collect almost all of the wasted food in the City is not realistic. In order to come close to meeting excess capacity the City would have to recruit and retain 96% of food waste generating commercial businesses. The City of Mesa will continue to find sources of food waste from outside city limits. Currently there is limited demand for food waste collection, which is mostly driven by large businesses with a commitment to sustainability.

The City's desire to incentivize participation through lower rates is not feasible if rates are the sole revenue used to cover the operating and capital costs associated with food waste collection. The City may be able to offer reduced food waste collection rates so that food waste collection service and solid waste service would not be greater than current solid waste service rates. The City would rely on Renewable Identification Number (RIN) revenue, Compressed Natural Gas (CNG) savings, and landfill tipping fee avoided costs to cover portions of collection costs. If rates were reduced by about half to $40 per month per pick-up the City would have to use 87% of the anticipated average operating profits to cover collection costs.

The City will continue to examine partnerships with private haulers and neighboring municipalities to establish demand for food waste collection. An option for the City that will be further explored will be to charge a tipping fee to other haulers to dispose of food waste at the City operated pre-processing facility. This option allows the City to obtain food waste from beyond City borders and may result in a more diverse mix of food waste generators.

APPENDIX B

Waste Pre-Processing Facility Concept Memorandum

Design & Consultancy for natural and built assets

Registered Professional Engineer (Civil)
CERTIFICATE NO.
39480
BRIAN J.
BUBELA
Date Signed 9-18-2019
ARIZONA, U.S.A.

City of Mesa, Arizona

FOOD TO ENERGY CO-DIGESTION FEASIBILITY STUDY

Pre-Processing Facility Concept Memorandum

FINAL

September 2019

CONTENTS

FIGURES

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ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway Transportation Officials
ACM	asbestos containing materials
ACP	asbestos cement pipe
ADCCM	Anaerobic Digestion Capabilities Concept Memorandum
ADEQ	Arizona Department of Environmental Quality
ADMS	Area Drainage Master Study
ADOT	Arizona Department of Transportation
amsl	above mean sea level
ASU	Arizona State University
bgs	below ground surface
BOD	biological oxygen demand
CAN	controller area network
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
City	City of Mesa
COD	chemical oxygen demand
FCDMC	Flood Control District of Maricopa County
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FO	fiber optic
FOG	fats, oils, and grease
gpd	gallons per day
gpm	gallons per minute
GUI	graphical user interface
HHMF	Household Hazardous Materials Facility
HMI	human machine interface
HSW	high strength waste
mm	millimetre
MS4	Municipal Separate Storm Sewer System
NWWRP	Northwest Water Reclamation Plant

ACRONYMS AND ABBREVIATIONS (CONTINUED)

PLC	programmable logic controller
ppmv	parts per million by volume
RIN	renewable identification number
RSL	regional screening level
SGHHSL	soil gas human health screening level
SRPMIC	Salt River Pima Maricopa Indian Community
SSO	source separated organics
St.	street
TGC	Tempe Grease Cooperative
TPD	tons per day
TPH	tons per hour
TS	total solids
$\mu g/m^3$	micrograms per cubic meter
UPS	uninterruptable power supply
USEPA	United States Environmental Protection Agency
VA	volatile acids
VCP	vitrified clay pipe
VI	vapor intrusion
VOC	volatile organic compound
VS	volatile solids

1 BACKGROUND

The City of Mesa (City) currently operates a natural gas utility, wastewater utility, and provides solid waste collection services. These areas of operation are partnering together on a food waste to energy program that may provide financial, environmental, and economic benefits to the City. Conceptually the program would utilize solid waste collection trucks to gather food waste, termed High Strength Waste (HSW), and deliver it to a future facility located at the City-owned Center St. Yard. The HSW would undergo pre-processing to meet requirements for anaerobic digestion in the existing digesters at the Northwest Water Reclamation Plant (NWWRP). Anaerobic digestion of the HSW would occur along with digestion of municipal wastewater sludge (co-digestion), or potentially used as the sole feedstock in one digester dedicated for HSW. Either digestion method will increase current biogas production.

The NWWRP was selected as the location for digestion of HSW due to the plant's:

- Proximity to the proposed pre-processing facility at Center St. Yard and,
- Excess digester organic solids loading capacity which is not anticipated to be used long-term for municipal wastewater sludge.

The biogas has a number of potential uses, all of which are beneficial to the City. These alternatives will be studied and evaluated as part of the overall Feasibility Study to be presented in a subsequent report. This Memorandum will focus on the conceptual siting, layout and configuration of the Pre-Processing Facility located at the Center St. Yard.

1.1 Selection of Center St. Yard Location

Center St. Yard was selected as the location for the HSW Pre-Processing Facility based on the following:

- City ownership of the parcel
- Central location that is also convenient to the NWWRP
- Sufficient distance from adjacent residences and businesses
- Available space to accommodate the building and HSW hauling ingress / egress
- Existing Solid Waste Department operations onsite

1.2 Property Description

The Center St. Yard is located at 2412 North Center Street, Mesa, Arizona and is listed by the Maricopa County Assessor as Parcel Number 136-16-001A. The Parcel is somewhat square in shape and encompasses an area of approximately 1.58 million square feet. The Parcel and is bounded on the north and west by the Salt River Pima Maricopa Indian Community (SRPMIC) and to the east and south by Center Street and West Lehi Road respectively (see also paragraph 1.4).

The Parcel is comprised of generally flat terrain at an average elevation of around 1225± feet above mean sea level (amsl) with a gentle slope from southeast to northwest towards the Salt River. The northeast corner of the Parcel appears to have been filled with the exception of the northwest corner outside of the perimeter fence which is lower and partially filled.

1.3 Zoning and General Plan Designation

The City Zoning Ordinance designates the zoning of the parcel to be Public and Semi-Public. The Mesa 2040 General Plan assigns the property a Community Character type of "Specialty District". The Specialty District character type is typically assigned to large areas greater than 20 acres having a single use, as in this case municipal use. Specialty Districts by definition have impact to surrounding developments due to traffic generated and noise associated with onsite activities. The definition for Specialty Districts carries an expectation of high-quality building design and materials. Therefore, locating a Pre-Processing Facility at the Center St. Yard is consistent with current zoning and the 2040 Mesa General Plan.

1.4 Traffic Planning

The Mesa 2040 Transportation Plan indicates no future improvements are planned along Center Street or West Lehi Road in the vicinity of the Center St. Yard. Center Street in this area is designated as a 2-lane "collector". Collectors are defined as having low to moderate traffic volume intended to collect traffic from local properties and distribute it to the major through roads termed arterials or to freeways. East Lehi Road, which intersects Center St. south of Loop 202, is also designated as a collector. West Lehi Road on the south border of Center St. Yard is undesignated in the 2040 Plan.

These planning indications and street designations favor the hauling activities associated with a Pre-Processing Facility. Low traffic volumes in the vicinity of the Center St. Yard provides ease of site ingress/egress and decreases local noise concerns.

However, Center Street south of McKellips is planned for improvements under the "Complete Streets" program which accommodates all categories of transportation users (bicycles, pedestrians, mass transit, etc.). The Complete Streets categorization beginning south of McKellips indicates this may be a corridor to avoid and should be considered in determining the HSW haul route(s) to the NWWRP.

2 CURRENT SITE USES AND FUTURE DEVELOPMENT

2.1 Uses of Adjacent Property

Uses of properties adjacent to the Center St. Yard are shown in Table 2-1. Other property uses along West Lehi Road include materials yards, a Department of Public Service office, a Community Service Center, and various tire, trucking and vehicle repair locations.

Table 2-1 Center St. Yard – Adjacent Property Use

Adjacency	Owner	Adjacent Property Use
North	SRPMIC	Salt River, floodway and floodplain
South	ADOT	Right-of-way for West Lehi Rd. & Loop 202
East	Contractors Landfill & Mark's Valley Grading 2425 N. Center St. Contractors Landfill & Recycling 2555 N. Center St.	Business office & large vehicle maintenance shop Truck rental Accept & recycle demolished concrete & asphalt Sell various soil, rock & recycled fill materials
West	SRPMIC Bureau of Reclamation ADOT	Salt River Regulatory Floodway High risk flood Zone AE (100-year event floodplain) Mesa Road Maintenance

2.2 Center St. Yard

2.2.1 Current Uses

The Center St. Yard is currently a shared-use municipal facility. The northern portion of the site is used by the Mesa Police and Fire Departments for training and also includes the Police Firing Range as well as a vehicle impound yard. The southern portion of the site is used by multiple City departments for material storage and is the location of the City's new Household Hazardous Materials Facility (HHMF). General areas of the current site uses are shown on Figure 2-1.

Site uses in the northern areas of Center St. Yard are not expected to change and are not considered as potential areas for locating the Pre-Processing Facility. Southern site areas currently used for miscellaneous storage are flexible for change of use and are available for development.

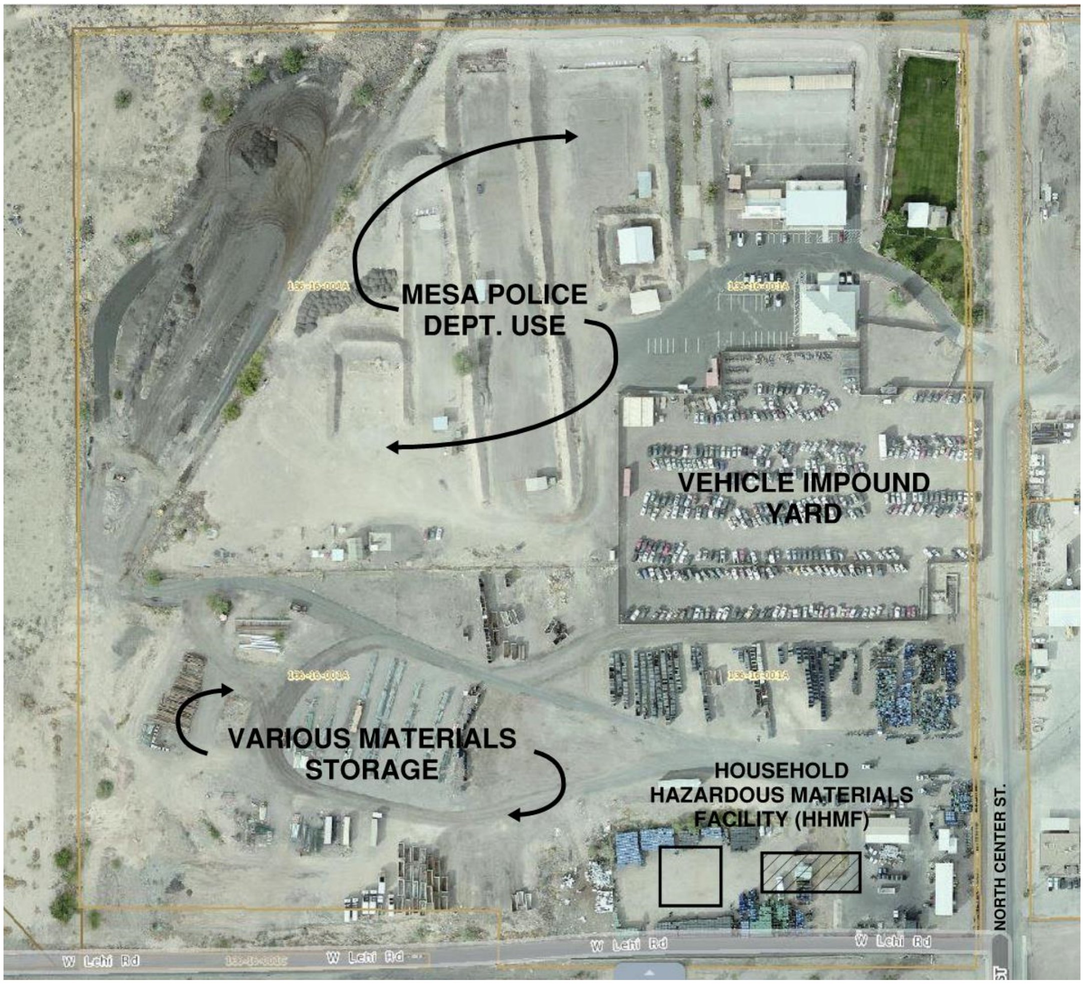


Figure 2-1. Center St. Yard - Current Uses

2.2.2 Future Planned Uses

The City's Solid Waste Division would like to add a Solid Waste Transfer Station to the Center St. Yard in addition to the food waste Pre-Processing Facility. Additionally, the City's Police Department has proposed locating an evidence storage facility in the area of the existing impound yard. In anticipation of these future uses at the site, the City has retained professional services of an architectural firm to develop a master plan for the Center St. Yard. Master plan site layout alternatives, shared with the City on March 6, 2019, were provided to Arcadis for review. In these alternative layouts, the Police evidence storage was shown to be directly east of the vehicle impound yard. Current and planned future uses of the southern site area were shown in the alternatives to be as follow.

- Storage areas for roll offs, dumpsters and trash cans
- Storage and training areas for the City's Transportation Department
- Solid waste Transfer Station
- Food waste Pre-Processing Facility

3 SITE CHARACTERISTICS

3.1 Geotechnical

The geotechnical characteristics of the Center St. Yard have been evaluated in the following two prior reports.

- Site Investigation Report, Center Street Landfill, City of Mesa, by SCS Engineers, June 2008 (SCS Report).
- Report on Geotechnical Investigation, City of Mesa – Household Hazardous Waste Center, by Speedie and Associates, October 2016 (Speedie Report). Several additional tests were performed through report addenda including:
    - Agronomic soils analysis, November 2016
    - Percolation testing, February 2017
    - Offsite pavement design (Center St.), February 2017
    - Corrosion testing, June 2017

Native soils at the site generally consist of sandy lean clay and clayey sand with subordinate amounts of gravel and cobble as would be expected in areas bordering the Salt River. In these studies, groundwater was not encountered determined not to be a factor for design of shallow foundations.

However, geotechnical challenges to the Center St. Yard identified through these studies are described in the following paragraphs.

3.1.1 SCS Report

This 2008 report investigated and evaluated the southern portion of the Center St. Yard, generally south of the police operations impound lot. This study was conducted in advance of proposed site redevelopment as a recreational baseball facility. The evaluation included a geophysical survey, excavation of soil test pits and advancing soil borings/soil vapor probe sampling to determine the location, depth, thickness and general nature of the landfilled materials. The following summarizes the findings and conclusions.

- Historic aerial photographs show that the Center St. Yard was an area previously used for agriculture, and more importantly, as a landfill. Landfill use began in the late 1940s and continued into the 1960s. The site is underlain by depths of waste varying from less than 2 feet to more than 20 feet. Soil cover over the top of the waste is also highly variable in depth ranging from 2 to over 15 feet in thickness. Wastes encountered included paper (newspaper), municipal solid waste or household trash, plastic bags and yard waste. Some carpet, glass, metal, concrete and brick were also encountered. While not specifically the focus of this investigation, no mention of asbestos containing material (ACM) or hazardous material identification or testing occurred.

- Soil vapor samples were collected at depths of 10 feet, 20 feet and 30 feet below ground surface (bgs) in three soil borings (B2/P1, B3/P2, and B5/P3) drilled during the site investigation program as shown on Figure 3-1 in Appendix A, taken from the SCS Report. Methane from decomposition of buried wastes was also identified during the site investigation program. Methane concentrations up to 30% were identified in the northwest portion of the site, which is consistent with the geophysical survey, test pitting and soil boring results as the area where the most significant volume of landfill waste was identified. At all locations monitored, the methane concentrations were reportedly higher in the shallower soils. Report recommendations were that enclosed structures where landfill gas could migrate and collect should be protected. Passive measures such as impermeable membranes and gas venting systems were stated as “probably adequate” given the low concentrations of methane at relatively low pressures. Sealing of electrical conduits and vented light poles were also suggested as mitigation measures.

Other aspects included in this report specific to site development on buried waste included the following:

- Experience at other landfills indicates a total average settlement of 6 to 24-inches.
- Differential settlement is likely based on variable waste thicknesses and distribution.
- Possible drainage issues and any increase in moisture content from irrigation, etc. can exacerbate settlement.
- Underground utilities may penetrate waste materials.

3.1.2 Speedie Report

This report investigated the specific area of the Center St. Yard identified for the City’s Household Hazardous Materials Facility and provided geotechnical building design guidance and parameters. Of important note is that this specific area of the Center St. Yard was identified in the SCS Report as being undisturbed native land. Although the Speedie Report revealed aerial photos showing previous agricultural activity, this area was outside the extent of historic waste disposal. Therefore, the investigation findings and conclusions summarized below are considered to more accurately represent characteristics of native site materials.

- Field and laboratory testing indicate that the upper soils are of low density and capable of post-construction settlement. Accordingly, recommendations were made to over-excavate and re-compact a limited depth of the bearing soils to increase density and reduce the potential for collapse.
- Wetting of fine portions of upper clayey soils could result in swell. Recommendations to reduce - not eliminate - swell potential included placing 12-inches non-expansive material under building slabs and contiguous structures such as sidewalks.
- Positive drainage was recommended to keep water away at least 10 feet from the building to avoid wetting foundation soils. A list of recommendations was also included for keeping water from underlying soils from sources such as planters, roof drains, etc.
- For pavement, recommendations were made for subgrade preparation, frequent jointing and joint sealing to reduce - but not eliminate - the potential for slab movements (thus cracking) on the expansive native soils.

3.1.3 Arcadis Observations

Based on review of these geotechnical reports, Arcadis offers the following comments regarding geotechnical challenges at the Center St. Yard.

3.1.3.1 Geotechnical Considerations

The following are specific issues related to foundations for future structures and pavement.

- The low density of native soils is not ideal noting that the allowable soil bearing capacities recommended for design of the HHMF are relatively low even with over-excavation and re-compaction.
- Keeping water away from subsurface materials was emphasized in the 2016 Speedie Geotechnical Investigation and is a concern due to the presence of expansive clayey soils from 5 to 11 feet below grade. Surface water infiltration into soils is also of particular concern considering the proximity of buried waste materials. However, Arcadis noted that an unlined retention basin for the HHMF was sited west of the building towards potential areas of prior landfill.
- The prior areas of landfill are the greatest issue for site development. Additional investigation will need to be conducted for the specific site locations selected for the Pre-Processing Facility as well as for other planned site uses. Investigations should include additional subsurface investigations regarding potential remediation of buried trash in locations of permanent buildings as well as traffic areas under dynamic loads from frequent large vehicle traffic.

3.1.3.2 Landfill Gas

The United States Environmental Protection Agency (USEPA) together with the Arizona Department of Environmental Quality (ADEQ) have adopted the use of calculated soil gas human health screening levels (SGHHSLs) to evaluate the potential for vapor intrusion (VI) at sites within Arizona regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund). The VI evaluations are based on land use for residential or commercial/industrial exposure scenarios, respectively (USEPA Soil Gas Human Health Screening Levels [SGHHSLs] for Arizona Superfund Sites 2014). The calculated SGHHSLs are exposure-based soil vapor contaminant concentrations which may be left in place in the subsurface and still be protective of a resident or commercial/industrial user. The SGHHSLs are derived using the most recent (November 2018) USEPA regional screening level (RSL) lookup tables for indoor air exposures (both residential and commercial/industrial scenarios) divided by attenuation factors for the transfer of subsurface contaminants from soil vapor into indoor air space.

The soil vapor data from Table 2 of the 2008 SGS Engineers report were converted from parts per million by volume (ppmv) to micrograms per cubic meter ($\mu g/m^3$) for comparison to the USEPA indoor air RSLs and derivation of the SGHHSLs. Table 1 attached in Appendix A (revised with the SGHHSLs for the constituents) identifies that residual concentrations of five of the volatile organic compounds (VOCs) reported from the soil vapor laboratory analyses exceeded the residential use SGHHSLs (benzene, ethylbenzene, 1,4-dichlorobenzene, trichloroethene, and vinyl chloride) at one or more depths in each of the three soil boring/soil vapor probe locations. The commercial/industrial use SGHHSLs were exceeded at locations shown on Figure 3-1 attached in Appendix A for the VOCs ethylbenzene at location B2/P1 at 20 feet bgs and 1,4-dichlorobenzene at location B2/P1 at 20 feet bgs and at B3/P2 at 10 feet bgs.

Based on the comparison of the soil vapor data with the USEPA SGHHSLs and the age of the data, it is unlikely that the residual soil vapor concentrations would prevent redevelopment of the site for the City's needs. However, because the commercial/industrial SGHHSL for 1,4-dichlorobenzene was exceeded at a depth of 10 feet bgs in soil boring/vapor probe location B3/P2, development of structures at that location (north central portion of the site) should be avoided unless the buried waste is successfully remediated. Based on the detection of methane and VOCs in subsurface soil vapor, it is recommended that additional soil vapor testing be completed to determine if the soil vapor concentrations have since attenuated or if other locations where development may occur contain elevated soil vapor constituents as a result of the historical landfilling operations. This testing, together with ACM and hazardous material screening, could be completed in conjunction with additional geotechnical testing to support new facility design efforts. ***This additional testing is recommended to better define limits and character of buried refuse and the extent of remedial work necessary for satisfactory implementation of the City's planned facilities***.

3.2 Flood Control and Stormwater Management

The Flood Control District of Maricopa County (FCDMC) is responsible for floodplain management and regulation for the City of Mesa. FCDMC is currently conducting the North Mesa Area Drainage Master Study (ADMS) which is a regional drainage study being conducted in the Mesa area north of US 60. The study encompasses the Center St. Yard within the northern boundary of the study at the Salt River.

The purpose of this study is to investigate and assess existing flooding problems including a comprehensive inventory of known flooding problems impacting the study area based on past flooding information provided by the City of Mesa as well as a review of previous drainage studies. A comprehensive hydrologic analysis will be conducted and will include current rainfall parameters and current land use conditions. This study will also review the status of previously recommended stormwater facilities, determine what has been built, and prioritize any facilities that may still be needed. FCDMC has broken the ADMS into geographical areas, or sub-watersheds, for focused analysis; however, the Center St. Yard is outside the northern limit of this detailed examination.

In 2014, the City of Mesa completed a Storm Water Management Plan that included all City owned and operated facilities in compliance with the 2010 MS4 permit. None of the City-owned facilities were determined to present a "high risk" to cause a substantial pollutant load to the City's storm sewer system or to waters of the United States.

A review of Federal Emergency Management Agency (FEMA) materials yielded the following aspects specific to the Center St. Yard.

- The parcel's north and west boundaries abut the FEMA high risk flood Zone AE (100-year event floodplain). The Zone AE designation is a result of the Salt River Regulatory Floodway as shown in Figure 3-2 below.

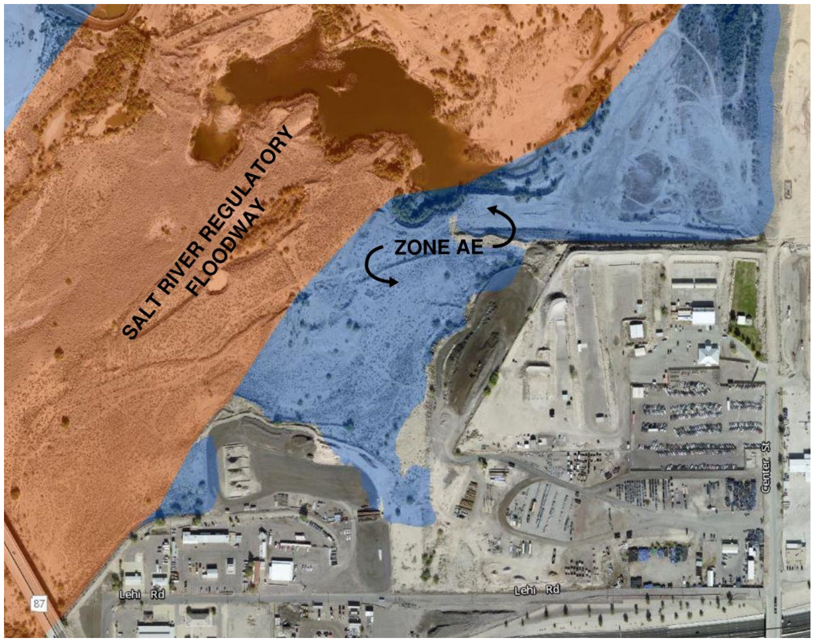


Figure 3-2. Flood Zone AE at Center St. Yard

- All but the northwest corner of the Center St. Yard parcel is designated Zone X on the FEMA Flood Insurance Rate Map (FIRM), attached as Appendix B. Zone X areas are protected by levees from 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile.
- The FIRM indicates the flood elevation in Zone AE at the location of the Center St. Yard is 1213.01 feet for a 100-year storm event. This flood elevation is 12 feet lower than the average elevation across Center St. Yard and is 5+ feet lower than the fill area on the northwest corner.

Although FEMA information currently indicates the Center St. Yard as having a low flood risk, subsurface moisture from a long duration event could impact buried waste materials on the western areas of the site.

Onsite stormwater is currently uncontrolled with the exception of the unlined stormwater retention basin on the west side of the HHMF. Depending on the location of new site development, the siting of this retention basin should be reviewed regarding subsurface moisture impacts to potential adjacent development or unidentified buried waste nearby.

Based on the recommendations from the previous geotechnical reports, any new site development should include infrastructure to quickly capture stormwater runoff and convey it to an isolated retention. All onsite stormwater facilities should follow the Uniform Drainage Policies and Standards for Maricopa County as published by the FCDMC as modified by the City of Mesa Engineering and Design Standards.

3.3 Environmental Considerations

3.3.1 Noise

The Mesa City Code has a noise ordinance that addresses offensive, excessive and prohibited noises. Although the “activities or operations of governmental units or agencies” are exempted by in this ordinance, overall good neighbor policy should be followed for a Pre-Processing Facility at the Center St. Yard. Approaches for noise control can include favorable orientation of the building, locating offloading activities in a building or similarly enclosed area, use of exterior security barriers to also serve as sound walls.

Center St. Yard is considered sufficiently distant from surrounding neighborhoods and commercial properties for noise to become a primary concern. Loop 202 also provides a barrier for noise from areas to the south. However, Pre-Processing facility layout and design should still consider the other site uses at the Center St. Yard including classroom and training activities by Police and Fire Departments. Truck ingress/egress, loading and unloading, and pre-processing activities should be located and configured for noise abatement.

3.3.2 Odor

Handling and processing of HSW will create offensive odors. Odors may be characteristic to the particular types of food waste being delivered and processed. As some odors tend to travel, positioning the building on the site and locating building access openings will be oriented to consider prevailing wind direction (See Section 5).

Systems for controlling odors from and within the building will be required in the Pre-Processing facility design. Multiple systems will be required for mitigating fugitive odors associated with delivery and HSW hauling operations as well as for controlling odors in the workspace. Odor control systems to be employed will be a combination of the following based on building area.

- Ventilation systems sized for multiple air changes per hour.
- Odor abatement system (scrubber, biofilter, etc.).
- Air curtains.
- Polyvinylchloride (PVC) strip curtains.

In addition, the process and HSW materials will be isolated as much as possible with covers and enclosed in piping and storage tanks.

3.3.3 Vector control

Facilities like the Pre-Processing Facility can attract vectors including insects, birds, rodents, etc. Therefore, the majority of facility components will be located in the building interior. Vents will be provided with mesh screens. Washdown systems will be provided including potable water supply, hose bib connections, trench drains, etc. to provide convenient means of clean up. System capacity will consider frequent wash down. Wash down water collected will also be processed as needed for particulates and oil/grease.

3.4 Site Ingress / Egress

Proposed uses of the Center St. Yard as well as uses of adjacent properties require careful consideration of ingress / egress due to the variety of traffic types, vehicle limitations and safety considerations as described below.

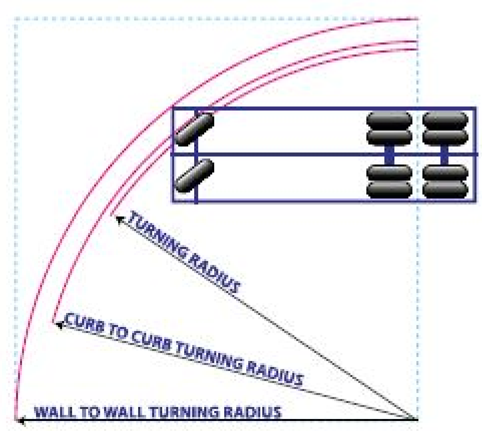
3.4.1 Traffic Types

Traffic types accessing the various activities at Center St. Yard as well as the private businesses directly to the east result in a mix of private and commercial vehicles accessing Center Street north of the 202 Loop. Traffic will consist of personal automobiles and trucks, impounded vehicle hauling, light and heavy-duty commercial vehicles (including solid waste fleet vehicles) and tractor trailer commercial haulers. Many of the vehicles are related to Police and Fire Department activities at Center St. Yard and aerial photos indicate that as many as 200 to 300 vehicles may be in the impound yard at a given time. There will also be personal vehicle traffic associated with the City's HHMF. HHMF staff indicate that as many as 60-70 vehicles per day access the HHMF for drop off. The wide variety of traffic types will dictate that improvements need to be made to N. Center Street as well as W. Lehi Road as required for ingress / egress to the Pre-Processing Facility for traffic flow and safety considerations.

3.4.2 Solid Waste Fleet Vehicles

The City indicates HSW source materials will be collected with existing solid waste fleet vehicles. Based on planned future uses, any of the solid waste fleet vehicles may come to Center St. Yard. Current solid waste fleet vehicles include automated side loaders, front loaders, roll-off trucks, and rear loaders. Important ingress / egress aspects for these vehicle types are detailed as follow.

- Turning radius: Access roads, drives and entries must allow for a geometrically large enough path in which the vehicle can comfortably navigate a turn, called the turning radius requirement. A typical turning radius for a front loader truck for a 90-degree turn is approximately 47 feet for the outside wheel, while a roll-off truck requires 65 feet.



- Unloading / Loading: Backing up solid waste vehicles is difficult and dangerous. There are many driver blind spots and areas of poor visibility. Configuring unloading and loading such that trucks can move forward rather than backwards is preferable. If backing is required, 50 feet should be allowed and should be a straight line.
- Queuing: Weighing, unloading and loading activities require adequate time to be executed safely. Therefore, space should be provided for queuing vehicles once on site. Queuing space requirements can be determined based on haul routes and times.

- Weight: Solid waste vehicles are heavy and heavier when loaded. Concrete pads should be designed to withstand single axle loadings of 20,000 pounds. Access roads should be designed to accommodate

3.4.3 Safety

As discussed above, North Center Street will have a variety of traffic and may be heavy at certain times based on activities of Police and Fire. Truck traffic from the adjacent commercial businesses and other planned solid waste uses for Center St. Yard will increase large truck traffic. For traffic safety, the posted speed limit north of Loop 202 is suitable as 25 miles per hour. Other considerations for traffic safety may include:

- Truck traffic caution signage on Center Street and Lehi Road.
- Additional speed limit signs.
- Permanent speed limit and cross-traffic warning signs on Lehi Road. (currently Lehi Road has no posted speed limit since it is not classified as a public roadway.)
- Turning lanes for Center St. Yard ingress / egress (Center Street right-of-way is 40-feet each side of centerline).

Since Center Street south of McKellips is planned for improvements under the “Complete Streets” program, “Local Traffic Only” signage could be considered for the north side of McKellips.

Site safety considerations should include:

- Onsite speed limit signage.
- Clear directional signage and designated parking areas.
- Wide access roadways and large paved areas for operations.
- Bollards and other protective barriers for building components and utilities.
- Effective stormwater control.
- Fire protection systems.

Personnel safety and operating requirements will be consistent with City of Mesa Solid Waste Department requirements for solid waste operations staff.

3.5 Utilities

The existing main utility lines serving Center St. Yard are located in Center Street as follow.

- Water. An existing 6-inch asbestos cement pipe (ACP) waterline is in Center Street but is skewed to the roadway centerline. At the Center St. Yard entry drive, record drawings for the HHMF show it 11.2-feet west of centerline. Connections to this line were made for a 2-inch service to the HHMF just north of West Lehi Road and for an 8-inch service into the site south of the entry drive. This 8-inch line was then tapped for the 6-inch HHMF fire line.

- Sewer. An 8-inch vitrified clay pipe (VCP) gravity sanitary sewer is located 23-ft west of the Center Street centerline. A 4-inch service from this line to the HHMF was installed at the Center St. Yard entry drive to the back of the HHMF building.
- Power. Overhead power is located along the south side of West Lehi Road 20.6-ft from the Center St. Yard property line and on the east side of Center Street, 34.2-ft from centerline. Power is provided by Salt River Project. The City of Mesa provides gas service to the vicinity with a 2-inch gas line just east of Center Street centerline.
- Communications. Two fiber optic (FO) communications lines are located on the west side of Center Street. A Century Link FO line is located 36.3-ft west of centerline and a City of Mesa FO line is 29-ft west. The Century Line FO also runs along the south side of West Lehi Road about 36.8-ft south of the Center St. Yard property line.

There is also an abandoned water line just west of the eastern Center St. Yard property line, as well as an 8-inch abandoned sewer on the west side of Center Street that may have been the site service prior to construction of Loop 202.

3.6 Setbacks

With a 2040 General Plan Community Character designation as a Specialty District, property line setbacks for the Pre-Processing Facility will not likely be a controlling factor. In addition, adequate clearances for safe vehicle operation and clear sight distances will likely be the aspects controlling the building location and position on the site relative to the property line and other functional areas. For example, vehicle egress from the site will require that buildings and building appurtenances are positioned far enough back from the property line to allow clear driver sight distance in both directions.

4 HIGH STRENGTH WASTE DELIVERY

4.1 Waste Characteristics

4.1.1 Food Waste

Food waste characteristic guidelines are being established for the generators by the City in the collection contracts. The City has also documenting what is received and providing feedback to generators to minimize contamination. Contamination reminders are also posted on the front of the collection containers at each generator location.

Currently, food waste is being collected in 35-gallon containers and transported to the Pre-Processing Facility with existing solid waste fleet vehicles. Pickups are currently scheduled at twice per week. Based on current operating experience with the City's pilot processing apparatus, food waste throughput in the process has the following characteristics as analyzed by ASU.

- Food waste collected: Content includes dairy, meat, bakery, and deli waste; mixed fruits and vegetables; canned goods; and cafeteria waste. Mix of waste is likely 30% total solids.
- Food waste after processing: Slurried to 15% solids.
- Pilot reactor loading and expectation for slurry for digester loading: 12% solids.

For full scale operation, the City would like to keep the collection hauling and slurry transport as dry as possible. Addition of dilution water is expected to occur at the NWWRP using waste activated sludge or reclaimed plant water. Dilution of food waste may be accomplished to some extent using fats, oils and grease (FOG), depending on the volume and characteristics of FOG available.

4.1.2 FOG

FOG will be sourced from the City of Tempe's Grease Cooperative (TGC), the partnership between Tempe and restaurants to better manage this waste material. FOG is collected by grease trap pumpers picking up grease traps and yellow grease under contract to Tempe. Based on current analysis by ASU, FOG has a moisture content of 83% and particle size in the 1-2 millimeter (mm) range. Septage or mixed loads of FOG and septage should be precluded from delivery as a contractual requirement.

4.2 Transport to the Pre-Processing Facility

As indicated above, collected food waste will be transported to the Pre-Processing Facility with the City's existing solid waste vehicles. Although currently collected in 35-gallon containers, as the Food Waste to Energy program advances, food waste will be collected similar to household refuse in solid waste vehicles or in roll off dumpsters. However, food waste may also be collected and transported in:

- milk crates for expired liquid wastes, and
- totes from food preparation generators (i.e. 64-gallon barrels, 2 and 3-yard plastic bins)

Therefore, the Pre-Processing Facility must be configured for deliveries from a potential variety of transport container types. Transport is anticipated to be primarily with side loader or front load trucks, so food waste will be dumped from the rear of the truck. Roll off transports will also need to be accommodated.

FOG may be transported to the site directly by the Tempe grease trap pumpers as a contractual requirement. Therefore, grease trap pumping trucks will also be managed on site.

4.3 Unloading

Basic component areas to be included in the Pre-Processing Facility for unloading operations include the following.

4.3.1 Site Access

Site ingress and egress for food waste transport is proposed to be from North Center Street. Although egress onto West Lehi Road would be favorable for direction of traffic flow, the travel direction and volume of traffic associated with the HHMF could present safety concerns if solid waste vehicles were exiting the site in the same traffic lane. Onsite ingress and egress will be paved and designed for American Association of State Highway Transportation Officials (AASHTO) H20 loading consisting of an axle loading of 32,000 pounds.

4.3.2 Queuing

Although high volume traffic for food waste is not expected, arrival times of trucks for unloading may vary. Additionally, Tempe grease trap pumpers will be arriving to unload as well as other occasional arrivals from third-party transport. Once through the gate, transport vehicles will enter a queuing area to await weigh-in. The queuing area will provide:

- distribution of trucks into lanes for holding up to 20% of the average volume of truck traffic on site,
- control of trucks prior to weigh-in and/or unloading, and
- a temporary place to park for driver’s use of restroom facilities.

Since the City is also planning a solid waste transfer station at the Center St. Yard, this queuing area can be configured to serve both facilities.

4.3.3 Truck Scales

Truck scales will be provided to establish the weight of food waste delivered. Truck scales will be a pitless type with shallow setting depth which is gained through ramping pavement to and from the scales as shown on Figure 4-1. Trucks will drive on the scale before entering the Pre-Processing facility for unloading and then weigh again prior to exiting the site. As with the queuing area, the scale system can also support the proposed future solid waste transfer station. Scale systems come with data management software and the digital logging system will tabulate load weight as indicated in Section 7.

Figure 4-1 Pitless Truck Scale

4.3.4 Unloading

Following weigh-in, trucks will proceed to for unloading at the Pre-Processing Facility. A detailed discussion of the unloading area and the Pre-Processing Facility appears in Section 5. Unloading capabilities at the Pre-Processing Facility will include the following.

- Truck bays for rear dump vehicles.
- An outside area for offloading materials with a forklift.
- An area for offloading FOG from septage trucks.
- Area for problem or rejected materials.
- Area for cleaning out trucks.

4.3.5 Storage

Various types / areas of storage are necessary to provide the process interface between the cyclical unloading operation and the HSW processing as follows.

- Feedstock storage. Facility floor space will be needed for materials that may be delivered in transport other than normal collection means. Industry experience indicates that materials may be received (or collected) in containers such as crates or totes that are offloaded by forklift and need to be stored temporarily prior to processing. Roll off dumpsters may also be stored prior to emptying.
- Reject materials storage. Facility floor space will be needed for temporary storage of reject materials prior to haul off. In addition, space may be needed for an occasional reject load if unacceptable contamination is encountered.
- FOG deliveries. The HSW processing concept is to have FOG delivered to the Pre-Processing Facility for use in dilution of food waste to produce a slurry of around 15% solids content. This strategy allows septage drivers to transport to location designed for accessibility and offloading. This also allows the City to accept Mesa FOG in the future.

- Water Storage. Standby dilution water will be needed for instances where FOG is not available or in insufficient volume for processing to the desired solids content. More discussion of storage appears in Sections 5 and 6.

4.4 Loading

Once processing is complete, tank trunks will be loaded with the HSW for transport to the NWWRP. The Pre-Processing Facility will include a loading area where the transport vehicles will pull up and load the HSW. This area will include HSW holding tanks and transfer pumps.

4.5 Transport to NWWRP

Tank trucks will transport the HSW to the NWWRP where it will be offloaded for feeding into the digesters. Options for offloading at the plant are described in the Anaerobic Digestion Capabilities Concept Memorandum. Tank trucks will likely be between 2,500 and 5,000 gallons capacity, typical of septage hauling trucks, and equipped with appurtenances for frequent cleanout.

5 PRE-PROCESSING FACILITY OVERVIEW

General requirements and conceptual Pre-Processing Facility and ancillary facilities to be located at Center St. Yard are described in the following paragraphs and are illustrated in a concept layout on Figure 5-1 attached in Appendix E.

5.1 General

5.1.1 Governing Codes and Standards

The Pre-Processing Facility and supporting systems will be governed by 2018 International Code Council (ICC) "family" of codes and the 2017 National Electric Code produced by the National Fire Protection Association. The 2018 Codes will be in effect February 10, 2019. Specific codes governing the Pre-Processing Facility include the following as amended by City of Mesa.

- 2018 International Building Code (IBC)
- 2018 International Energy Conservation Code (IECC)
- 2018 International Fire Code (IFC)
- 2018 International Mechanical Code (IMC)
- 2018 International Plumbing Code (IPC)
- 2017 National Electrical Code (NEC)

Additional standards that apply to facility and supporting infrastructure design include:

- 2018 Life Safety Code, National Fire Protection Association (NFPA) 101
- 2018 Standard for Electrical Safety in the Workplace NFPA 70E
- Maricopa Association of Governments (MAG) Standard Specifications for Public Works Construction
- 2017 Mesa Amendments to MAG Standard Specifications
- 2017 Mesa Standard Details
- 2017 City of Mesa Engineering & Design Standards

5.1.2 Initial Requirements and Future Expansion

Pre-Processing Facility layout and equipment will consider the initial target of collecting and processing 20 tons of HSW feedstock per day and considering processing up to 50 tons per day. However, processing equipment selected may accommodate a greater daily volume than initially required since equipment manufacturers offer a limited size range for these types of machines. Details of equipment selection and sizing is covered in Section 6.

Because processing of HSW feedstock is based on collection frequency, the volume to be processed is more directly related to processing equipment size rather than building size. Accommodating future processing needs is best accomplished by providing adequate space for future equipment upsizing or duplicating. Future needs are being evaluated based on available digester capacity under a separate memorandum. The recommendation is to provide adequate space for future processing upsizing and related additional equipment.

5.2 Architecture

As noted in Section 1, the Center St. Yard has been assigned a Community Character type of “Specialty District” by the Mesa 2040 General Plan. The definition for Specialty Districts carries an expectation of high-quality building design and materials. Although the Pre-Processing Facility will be an industrial use, it will be the first facility of this type in Arizona, so public interest and visitation are likely. Therefore, the architectural concept and character will be similar to the HHMF and meet the expectation set forth in the 2040 General Plan.

The building superstructure is anticipated to be either a pre-engineered rigid frame type metal building anchored on concrete foundation walls or a combination of masonry block and steel construction similar to the HHMF. Wall and roof panel coatings and colors can be selected to match or compliment the HHMF, depending on how the Pre-Processing Facility is positioned on the site. The operating areas of the building interior will be unfinished but will be insulated. Finished areas will include operator offices, break room, laboratory, locker and restroom facilities. Storage and loading areas will be covered, but not enclosed by permanent walls.

Unloading, loading and food waste processing areas will be robust cast-in-place concrete components designed for heavy vehicles and equipment and the impact loads associated with unloading and processing activities.

5.3 Site Orientation

As illustrated in Figure 5-1, the Pre-Processing Facility will be oriented on site to:

- Avoid areas that are the most compromised by historic landfill activities.
- Work in combination with the City’s planned Solid Waste Transfer Station regarding layout and traffic management.
- Avoid crossing traffic patterns.
- Allow a minimum truck turning radius 5 feet greater than the published minimum radius for the solid waste fleet vehicle.
- Have vehicle backing only occur inside the buildings for unloading.
- Minimize the impact of the prevailing east - west wind directions to manage odor travel.

5.4 Configuration

The Pre-Processing Facility building will consist of a single-level with a stepped lower area for food waste receiving and processing. Other building area separations will be based on operating function. Separating building areas based on function will benefit facility safety, minimizing conflicts between moving vehicles and operations staff. The building will consist of five areas as described below and shown on Figure 5-2 attached in Appendix E.

- Unloading area. The unloading area receives the solid waste vehicles and provides unrestricted space for backing up and unloading.
- Processing area. The processing area function includes food waste receiving and pre-processing waste for transport and further dilution prior to loading into the NWWRP digesters. This area provides space for receiving the dumped food waste and provides unrestricted space for managing and loading the pre-processing equipment with a front-end loader. The processing space will be sized to accommodate operation and maintenance of pre-processing equipment, storage and removal of de-packaging refuse material, and will allow for future expansion.
- Operations area. The operations area will be adjacent to the pre-processing area and include an operations office, slurry product analysis operations laboratory, staff breakroom, staff locker rooms, and restroom facilities.
- HSW loading area. The HSW loading area includes tankage for storing processed HSW and infrastructure for connection and pumping to the HSW transport truck. This area will be sized to accommodate operation and maintenance of the HSW transport activities.
- Storage area. The storage area will provide space for temporarily storing materials dropped off in vehicles other than the usual solid waste transports, as well as additional temporary storage for de-packaging refuse. This area will also accommodate the FOG receiving and storage infrastructure and dilution water tank with unloading station.

5.5 Dimensions

The building superstructure is estimated to have the following conceptual dimensions. These dimensions may change based on preferred process equipment layout and vendor input. The dimensions shown below include the HSW loading storage areas which will be covered but proposed as otherwise open.

Overall width	150’-0”
Overall length	150’-0”
Eave height	35’-0”

The building foundation walls are recommended to extend minimum 4-feet above grade, monolithic with the below grade foundation walls for protection of the superstructure from truck traffic and for housekeeping washdown considerations.

Approximate conceptual dimensions for the building areas under roof are estimated to be as follow.

Unloading area	90’-0” x 70’-0”
Processing area	130’-0” x 40’-0”
Operations area	40’-0” x 70’-0”
HSW loading area	130’-0” x 20’-0”

Storage area	130’-0” x 40’-0”

5.6 Features

The following features will be incorporated into the Pre-Processing building design. Materials of for the purposes of this Concept Memorandum are assumed to be cast-in-place concrete floor and stem walls covered by a steel building superstructure. Materials of construction for equipment appear in Section 6.

5.6.1 Unloading Area

The building entry and unloading area will accept the solid waste fleet vehicles intended to be used for food waste pickup including front loaders, side and rear loaders which are envisioned to be the typical transport vehicles. Roll-off vehicles may potentially be accepted on the unloading floor. The ceiling clearance will accommodate the maximum tipping height of 36 feet and unloading floor should be designed to accommodate the Federal Bridge Law gross weight limit of 80,000 pounds. Signalization and cameras will be placed at the facility access points to control truck entry into the unloading floor.

The unloading area will have concrete stem walls for protecting the superstructure from impact in addition to bollards. Concrete stem walls also provide stray materials containment and aid washdown.

The unloading area will be configured for trucks to back in and unload into a lowered floor bunker area on the processing floor. This configuration keeps the food waste off of the unloading floor and out of truck traffic where it can be tracked around, complicating clean-up and attracting vectors.

Building doors will be arranged to minimize or eliminate cross traffic. A low barrier concrete wall will serve as a wheel block to keep trucks from backing into the waste receiving area. Additional features will be signals for directing truck entry / exit and rolling doors for securing the facility when not in use. With the rolling doors open, air curtains will be used for isolating the building volume from outer atmosphere.

5.6.2 Processing Area

The processing area will accept food waste dumped from the solid waste vehicles in a lower floor bunker area approximately 4’-0” to 5’-0” below the tipping floor. An articulating wheel loader will be used to manage the dumped materials and load it from the dump area into the first component of the process equipment which is the de-packaging machine. Like the unloading area, the processing area will have concrete stem walls and floor to accommodate materials loading as well as an exterior door for the articulating wheel loader, processing equipment access, and processing waste collection and disposal.

The processing area will house the following components for pre-processing of food waste for storage, loading and transport to the NWWRP. A food waste pre-processing flow diagram is presented in Figure 6-1 in Section 6.

- De-packaging machine
- Secondary Screen
- Product transfer tank and pumping systems

Features of the processing area will include dumpster areas for collection of pre-processing packaging waste and other processing contaminants configured adjacent to the pre-processing equipment.

Odor control and mitigation of vehicle exhausts for the processing area will be achieved with ventilation system(s) providing at least 12 air changes per hour, conceptually discharging through a biofilter for odor treatment. Exterior access to this area may be closed during operations and equipped with an air dam when open.

Other features of the processing area will include service water and trench drains to expedite washdown of unloading bunker, floor and equipment. Pre-processing equipment will be mounted on concrete equipment pads for anchoring and housekeeping considerations. Other than local control panels, power service and supervisory control systems will be located in the operations area. Storage for processed HSW will be located in the loading area.

5.6.3 Operations Area

The operations area will be on the level of the loading floor and above the processing area. As previously indicated, this area will include the operations office, slurry product analysis operations laboratory, staff breakroom, staff locker room, and restroom facilities. The laboratory will be equipped to perform slurry product analysis for the following:

- COD (daily)
- BOD (daily)
- %TS (daily)
- VS (daily)
- pH (weekly)
- Alkalinity (4/week) – ideal VA/Alkalinity ratio of less than 0.4 ensures correct conditions for proper digester operation
- Volatile Acids (2/week)

The operations office will have windows around the room's perimeter to view the pre-processing equipment as well as the unloading area. The elevated aspect over the processing area provides enhanced operator visibility of the pre-processing equipment, as well as a location for electrical room and control systems away from the areas of frequent washdown at the unloading bunker and in the processing area. This area will be climate controlled and will provide overall facility control including:

- Pre-Processing Facility traffic control
- Building lights and alarms
- Truck scale monitoring and reporting
- Remote pre-processing equipment monitoring, control and alarms
- Storage tank level sensing and alarms
- Valve position indicators and controls
- Rolling doors
- HVAC
- Odor control

5.6.4 HSW Loading Area

The HSW loading area will be on a covered and shaded location on the building exterior. Sun screening and area cooling may also be provided for use in the summer to mitigate fermentation during storage, depending on elapsed time between production and hauling. This area will feature the HSW holding tank(s) and containment and the pumping system and controls for loading the HSW transport truck. The holding tank(s) will have external level indication visible for truck loading. This area will include a truck loading pad, with capabilities for spill control and washdown. Ancillary control features for site traffic safety will be included since HSW transport truck egress may intersect with solid waste vehicle egress.

5.6.5 Storage Area

The storage area will a covered and shaded location on the building exterior. Features will include a concrete deck for forklift operation and adequate area for:

- Holding bulk contaminants removed from the pre-processing operation prior to pick up.
- Space for temporarily holding food waste materials that may be dropped off in bulk from vehicles other than solid waste collection trucks or in roll off dumpsters.
- Tank, auxiliary heating system, spill containment, and pumping equipment for FOG receiving and injection in HSW processing. The size of the FOG tank will be determined based on projected available volume of suitable quality material. This tank and the conveyance into the HSW process may be heat traced as required to avoid congealing and reduce viscosity for conveying FOG into the process.
- Tank and pumping system for unloading and storing pre-processing dilution water. This water can also be used for washing process machines and floor washdown. Based on anticipated water use, the dilution water tank is anticipated require a volume of around 30,000 gallons.

An additional feature of the storage area will be a climate-controlled restroom for truck drivers easily accessible from the truck queuing area. This location will discourage facility use during weigh-in or unloading activities or use of operator’s facilities.

5.7 Ancillary Facilities

5.7.1 Reject Load Disposal

Should a food waste load be received that must be rejected due to discovery of significant contamination with undesirable materials (i.e. glass, construction waste, etc.) space will be provided to temporarily hold the rejected load in the storage area. This reject area will be located on the concrete area pad, accessible by front end loader or roll-off container and truck.

5.7.2 Washdown and Runoff Control

Gutters and drains will be provided for capture and control of area washdown water. Certain drains maybe connected to the facility sanitary sewer. Other washdown which may contain oils or disinfectants may need to be collected and treated prior to release.

6 PRE-PROCESSING FACILITY EQUIPMENT

This section presents the pre-processing treatment train following the handling path of the food waste from initial delivery to the Pre-Processing Facility through production of the HSW product for transport to NWWRP. Descriptions of equipment, sizing requirements and recommendations of specific pre-processing equipment are provided herein.

6.1 Equipment Sizing

Sizing of food waste processing equipment is based on several factors as described below. Of important note is that equipment size offerings in the industry is currently very broad. For example, one vendor's de-packaging machines only come in the three sizes of small, medium and large. Consequently, system-specific processing requirements are developed first, followed by comparisons of these requirements to vendor equipment size offerings. The following factors were used to identify the specific processing requirements for the City's proposed concept.

6.1.1 Digester Capability

The two anaerobic digesters at NWWRP have excess organic solids loading capacity and therefore system-specific equipment sizing can be identified by working backward from the excess digester capacity available. A separate Anaerobic Digestion Capabilities Concept Memorandum (ADCCM) developed by Arcadis examined potential limiting factors to the amount of HSW that can be loaded to the NWWRP digesters. This analysis identified the following factors that influence the choice of processing equipment sizes.

6.1.1.1 Maximum Organic Loading

From the ADCCM, the maximum mass fraction of total organic load to the digesters that can be comprised of HSW as compared to the mass of sludge processed at the NWWRP is a limiting factor to avoid digester overloading. For the NWWRP, the maximum mass fraction of HSW is 35% (reference ADCCM). This is considered a safe and conservative organic load target for minimal disruption to normal digester operations. Although this limit is identified for the NWWRP, there is industry evidence that the HSW loading to the digesters could possibly be increased because there are known installations operating with greater than 50% mass fraction from imported HSW. Therefore, prudent sizing of the food waste processing equipment should recognize this potential maximum capacity to avoid limiting the food waste to energy system. This does not mean that NWWRP needs to accept the maximum amount of food waste, but it is recommended that the food waste processing system be sized to provide the greater amount of HSW if desired in the future.

6.1.1.2 Digester Operations

Another factor in selecting processing equipment size is whether one or both digesters will be receiving HSW loads. While the economic viability of this decision is highly dependent on projected future renewable identification number (RIN) pricing structures, it is considered prudent to design for the condition that both digesters will receive HSW to provide for maximum flexibility.

6.1.1.3 Material Total Solids

Another parameter governing size of the food waste processing equipment is the solids and water content of the material delivered to the Pre-Processing Facility. For equipment sizing, a value of 30% TS for incoming bulk food waste is assumed to yield a conservative machine sizing for this conceptual project stage. This assumption has been borne out by the City's food waste audits and is considered to be a conservative estimate. If material arrives at a higher %TS than the design parameter of 30%, then less tons per day (TPD) would need to be processed to meet the same organic loading targets. The food waste processing would then yield a target %TS between 12 and 15% for transport to the NWWRP.

6.1.1.4 Processing Operations

Sizing of equipment also depends greatly on the anticipated processing operations. For example, to produce a specific organic loading target, the processing throughput rate differs widely if processing is conducted over 1 or 2 work shifts or 3 days versus 5 days. For this Concept Memorandum, food waste processing is assumed to be accomplished in one 8-hour work shift, 5 days per week.

6.1.2 Recommended Food Waste Processing Equipment Sizing

Although the projected food waste loading rate is expected to be less, *the smallest viable equipment sizes available from the vendors have a much larger throughput capacity than projected for the NWWRP*. These smaller size machine offerings still allow for processing of up to 160 tons per day. This equipment size will easily accommodate the sizing criteria described above and shown in Table 6-1 below. With an assumed 8-hour workday, this translates to a nominal processing rate of 20 tons per hour.

Table 6-1 Maximized Digestion Capabilities Limitation for Pre-Processing Equipment Sizing

Parameter	Limit
Food Waste Mass Fraction of Digester VS loading	50%[1,2]
Number of Digesters Receiving Food Waste	2
Food Waste Incoming Total Solids (TS)	15%
TPD of throughput capacity for food waste processing	160 TPD[3]

1. *Theoretical maximum loading limit, initial operational limit of 35% recommended*
2. *7 days/week loading basis*
3. *5 days/week operating basis; 8 hour work shift*

6.1.3 Recommended FOG System Sizing

Although FOG has a higher biogas yield potential than food waste, it is also more dilute and does not offset landfill tipping fees. Therefore, the maximum volume of FOG estimated to be delivered to the Pre-Processing Facility is based on providing dilution for food waste to generate a slurry of approximately

12%-15% TS. This volume is estimated to be 10,000 gpd and the FOG system would be sized accordingly. If a more specific %TS of food waste arriving at the facility is determined from the bench testing, the FOG receiving sizing may be adjusted.

6.2 Process Flow Diagram

Process components were selected based on anticipated food waste quality in accordance with the City's disposal requirements. The recommended process train shall have the capability to remove common contaminants such as glass, plastics, metals, and film plastics such as garbage bags. Figure 6-1 below illustrates the conceptual process flow for the Pre-Processing Facility. For food waste, the process train is anticipated to consist of de-packaging, secondary grit removal and storage. For FOG, the process is anticipated to consist of screening and storage.

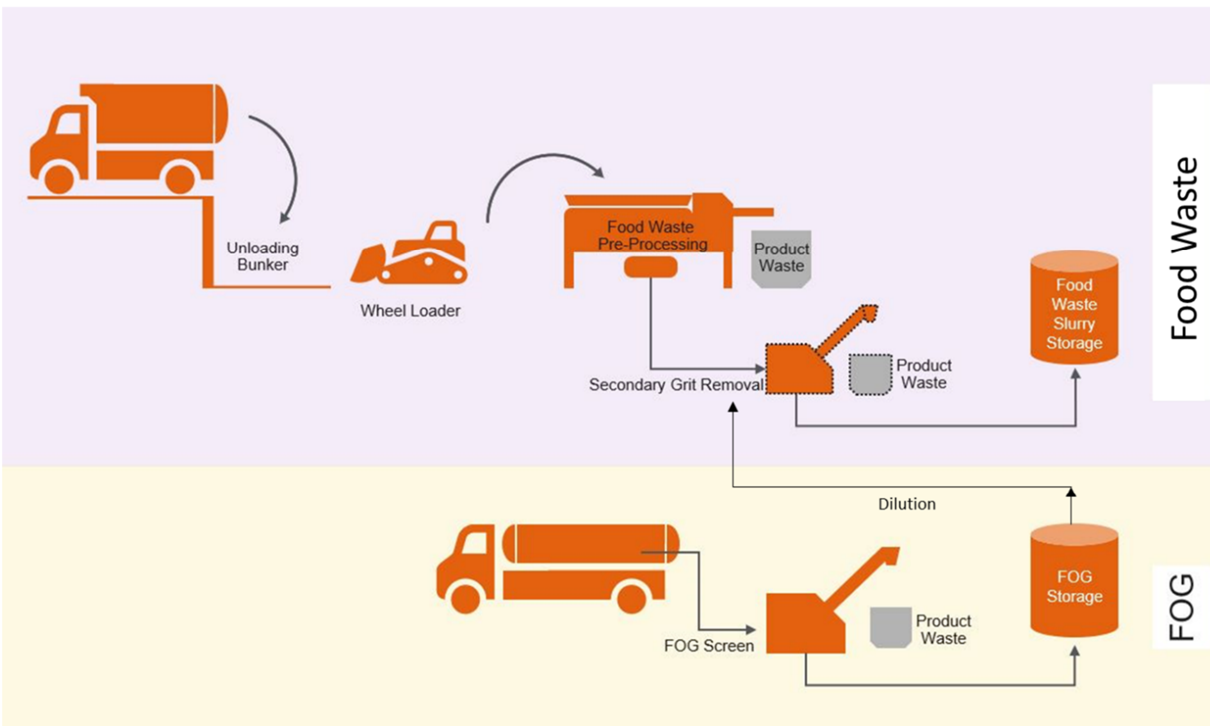


Figure 6-1 Food Waste and FOG Process Flow Diagram

6.3 Food Waste Transfer

Managing and transferring the food waste from the unloading bunker into the first piece of processing equipment is anticipated to require a wheel loader. This type of machine is comprised of a pivoted frame with the engine mounted over the rear wheels. A cab or canopy rests over the frame, and an enclosed climate-controlled cab is recommended. The machine's pivot arrangement gives the wheel loader the ability to work in small turning circles for navigating in the limited footprint of the Processing Area.

Materials of construction typical of wheel loaders in the construction industry are acceptable for this application. Loading bucket size should be coordinated with the width of receiving bay and throughput capability of the de-packaging machine described in following paragraphs.

For transferring materials delivered in bulk by vehicles other than the solid waste collection fleet, a forklift should be available to move these materials to the unloading bunker, or directly into the de-packaging machine if equipped with a rotator attachment.

6.4 Food Waste Pre-Processing

This section provides technical information and unit selection for pre-processing equipment. Equipment descriptions summarize function, approximate dimensions, materials of construction and applicable design criteria. Although several manufacturers provide similar equipment components, performance characteristics can vary depending on throughput speed and types of contamination expected.

Evaluations were conducted on the basis of providing one unit, since maintenance to the unit can be completed outside of the 8-hour daily service period. The equipment reviews also examined estimated electric usage, operational modes, and estimated contamination removal.

Equipment selected for evaluation is provided by known industry leaders for de-packaging, separating, and screening organic solid waste for anaerobic digestion. Each unit consists of the following components:

- Feed Hopper – collection and storage
- Auger – de-packaging and compacting
- Mill – food waste and product waste separation and screening
- Packaging Screw – product waste removal
- Slurry Pump – food waste slurry removal

The processing equipment alternatives are presented in the following paragraphs. Product data for this equipment is attached in Appendix C.

6.4.1 Scott Equipment THOR Separator

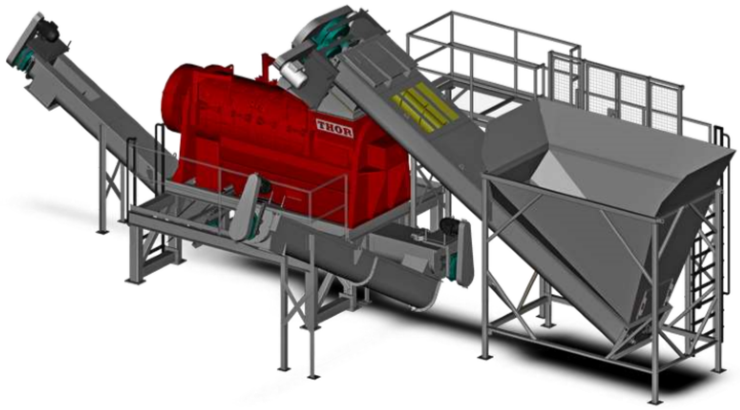


Figure 6-2 Thor Turbo Separator

The THOR Turbo Separator is manufactured and distributed by Scott Equipment company. The Turbo Separator equipment line has been in production since 1996 and over 300 systems have been furnished.

The THOR separator system consists of a hopper with a double screw auger that tears apart packaging, such as bags, boxes, aluminium cans, etc, to release as much food waste as possible prior to conveying the waste into a swing hammer mill. A swing hammer and screen mill is a high speed mechanical impact mill. Swing hammers rotate and fragment the waste. The size reduction provided by the swing hammers allows for further separation of the packaging and other contaminants from the organic waste stream. The organic waste then discharges through 1 ¼” or ¾“ screens, while the contaminant product waste travels horizontally through the mill to a disposal container.

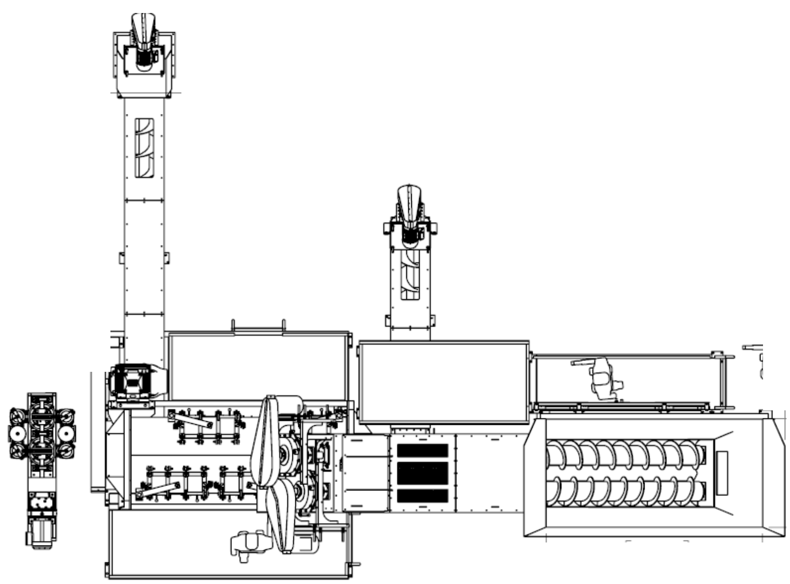


Figure 6-3 Thor Turbo Separator Plan View

The THOR unit is intended to process pre-consumer packaged, post-consumer, mixed commercial, and residential source separated organics (SSO). Swing hammer mills are highly efficient at particle size reduction. Therefore, the collected food waste from generators should not contain any contamination that may splinter or shatter. The system is not intended for glass, lumber, and polypropylene capable of fracturing, such as mop buckets or coolers. The hammer mill may cause glass to shatter into particulates smaller than the 1 ¼" to ¾ "screens used, resulting in any glass fed into the THOR entering the organics stream. This waste should be removed from the food waste feed prior to processing via the THOR.

The THOR system can process food waste at any incoming moisture content, however, dilution will still likely be necessary at the organic slurry outlet in order to reach the target %TS required for pumping. Design data for the Thor unit is presented in Table 6-2.

Table 6-2 Thor Turbo Separator Design Data

Parameter	Value
Dimensions	384" L x 314" W x 180" H
Materials of Construction	316 SS (shell)
Hopper Capacity	8 yds^3
Processing Rate	0-20 TPH
Rotational speed	1,800 RPM
% Contaminants in Organic Stream	<1%
Power Consumption	110 kW
Quoted Capital Cost	$ 432,105

6.4.2 Ecoverse Tiger HS 55

Figure 6-4 Tiger HS 55

The Tiger HS 55 is manufactured and distributed by Ecoverse. The Tiger HS 55 offers a 'plug and play' type installation with a relatively small footprint. The Tiger employs a dual screw auger to de-package the food waste. An auxiliary screw works simultaneously with the feed screw to convey the waste into a vertical separation mill. In comparison to a swing hammer mill, the Tiger separation mill utilizes gravity to separate the contamination from the organic slurry, requiring a lower power draw. The high-speed vertical paddles in the mill spin to break apart and elevate the product waste towards the product screw. The organic waste is screened through ¾" to ½" perforations. The vertical mill configuration yields rapid separation and does not aggressively fragment the packaging, reducing the risk of grit particles. Ecoverse advertises only a 0.2% contamination in the wet organic slurry.

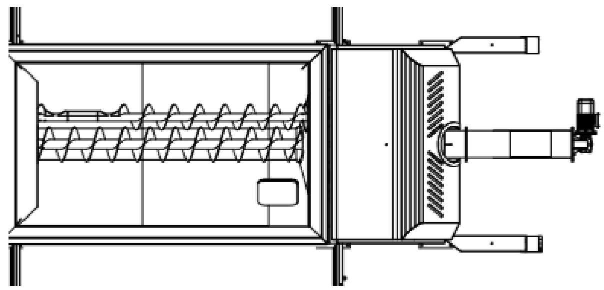


Figure 6-5 Tiger HS 55 Plan View

The Tiger system can process food waste at any incoming moisture content, however, dilution water will likely be needed for the organic slurry outlet in order to reach the target %TS required for pumping. Tiger system design data is presented in Table 6-3.

Table 6-3 Tiger HS 55 Design Data

Parameter	Value
Dimensions	291" L x 98" W x 162" H
Materials of Construction	SS hopper; ST 37 body
Hopper Capacity	7 yds^3
Processing Rate	0-20 TPH
Rotational speed	1,000 RPM
% Contaminants in Organic Stream	0.5%
Power Consumption	65 kW
Quoted Capital Cost	$ 547,700

6.4.3 Doda Bio-Separator

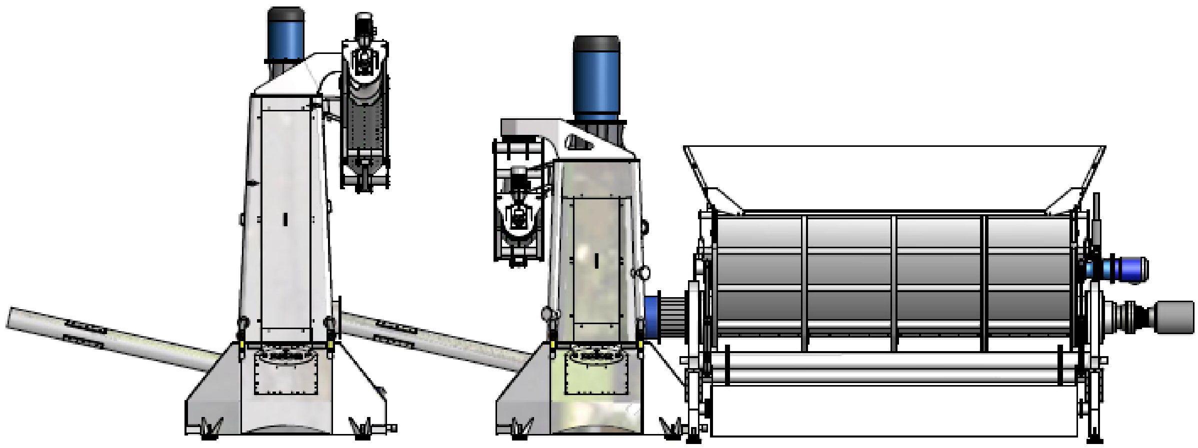


Figure 6-6 Doda Bio-Separator

The Bio-separator is manufactured and distributed by Doda Organic Waste Solutions. Doda USA primarily focuses on the agriculture and industrial organics, but also provides products capable of producing food waste slurry. Various models are manufactured with throughput rates ranging from 2 to 20 tons per hour of commingled organic and non-organic waste.

The Doda Bio-separator system has a triple screw auger feed system which de-packages the waste into small pieces before entering a hammer mill. The hammer mill macerates the organic waste and fragments and granulates contaminants in de-packaged food waste stream, similar to the Thor system. However, the Bio-Separator employs a vertical hammer mill separator which uses gravity to separate the contamination from the organic slurry. The vertical unit is equipped with cylindrical screens with 3/8" or 5/8" perforations.

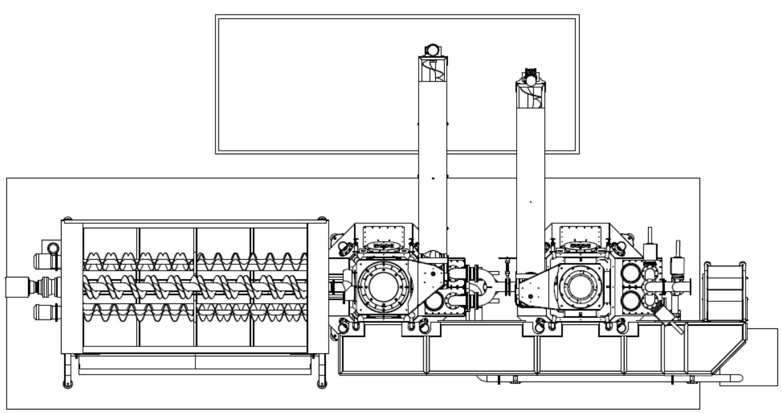


Figure 6-7 Doda Bio-Separator Plan View

The Bio-separator system can process food waste at any incoming moisture content, however, dilution water will likely be needed for the organic slurry outlet in order to reach the target %TS required for pumping. Bio-Separator design data is presented in Table 6-4.

Table 6-4 Doda Bio-Separator Design Data

Parameter	Value
Dimensions	384" L x 314" W x 140" H
Materials of Construction	304 SS; Hardox steel hammer mill; hot galvanized screen
Hopper Capacity	10 yds^3
Processing Rate	0-20 TPH
Rotational speed	1,200 RPM
% Contaminants in Organic Stream	1%
Power Consumption	207 kW
Quoted Capital Cost	$ 300,000

6.4.4 Recommendations

Each comparative unit has a processing rate of 0-20 TPH and similar contaminant removal capabilities. Although any of the three systems appear to be capable of processing the food wastes which have been identified in the City's bench testing, differences in the following parameters are important to note.

- Footprint. All systems require about the same vertical clearances, however, the Scott and Doda systems require significantly more floor space than the Ecoverse Tiger. The more compact footprint of the Tiger system, and particularly the narrower width, yields a smaller floor space requirement and more flexibility in orienting this system in the Processing Area.
- Power consumption. The Scott and Doda hammer mill machines require more power and higher rotating speed for processing than the Tiger system. The Tiger system's auger-based processing approach results in 40 to 50% lower power consumption as calculated in Appendix C.
- Grit contaminants. Glass and other small grit particulates can impact operation and maintenance of anaerobic digesters and increase wear in dewatering centrifuges. This is particularly true for glass contamination which industry experience identifies as a major contamination concern. As the name implies, hammer mills are expected pulverize the materials, so are likely to generate more small particulates in the organics stream. The Tiger dual screw auger de-packaging technique is intended to separate and screen contaminants without the pulverizing action and therefore is expected to remove glass contaminants in larger pieces.

Follow up discussions were conducted with the vendors regarding contaminants and contaminant removal. Vendor discussions all assured a contaminant capture rate of 99% or better, but there were contrasting statements specifically concerning glass contaminants. Ecoverse suggested that glass does not present a major issue for the Tiger system and glass should be limited by the waste generator. Ecoverse confirmed that action in the vertical mill screen of the Tiger with no secondary grit removal has proven in existing installations to be adequate for anaerobic digestion. In contrast, the published contaminant capture for the Thor system is only possible when no glass is present in the food waste feed stream. Doda was not forthcoming about glass, but industry experience indicates glass is also an issue for their system.

Based on the system comparisons discussed above as well as the expected characteristics of the City's incoming food waste, the Ecoverse Tiger HS 55 is the recommended de-packaging system. While the Tiger system has the highest capital cost, the advantages of smaller footprint, lower power draw and likelihood that fewer grit/glass contaminates will be present in the organic stream should offset the additional capex long-term.

6.5 Fine Particulate Screening

As previously noted, grit and glass in the food waste slurry can impact digester and digested sludge dewatering. These materials increase abrasion, reduce capacity and increase cleaning requirements. Inevitably the HSW stream may contain a small percentage of retained glass and grit. Although indications are that the Tiger system has fewer issues with glass, additional screening is included in the pre-processing strategy for the purpose of this Pre-Processing Facility Concept Memorandum. This final screen would be positioned following dilution of the HSW just prior to HSW storage. An overview of one potential final screen type is discussed below.

The final screening device and sizing will be selected based on the total solids content determined for HSW storage and transport to the NWWRP. As with the de-packaging system, the Pre-Processing Facility would be equipped with one unit since maintenance can be completed outside of the 8-hour daily service period.

A paddle finisher is initially recommended for application in the Pre-Processing Facility. Depending on the way the machine is set up, paddle finishers can provide various functions such as breaking up feedstock or separating and screening to produce a high solids puree of uniform consistency. For the City's application, the paddle finisher would provide final screening of the diluted food waste/FOG slurry to remove remaining damaging particulates, such as glass, seeds, eggshells, etc. These machines are readily adaptable for screening applications depending on final product needs with screen hole sizing that can be anywhere from 0.375 inches to 0.010 inches. Paddle finishers are typically 'plug and play' setups with a horizontal paddle arm which presses the organic material through the screen. These systems are also equipped with built-in clean-in-place systems for internal clean up.

Figure 6-8 Brown International Paddle Finisher

As identified in the LIFT See It Trip, Central Marin Organic Waste Receiving Facility in Marin, California, operates a Brown Model 202 paddle finisher for mixed slurry screening. As HSW dilution and solids content parameters become more closely defined as the bench study advances, other fine particulate removal technologies may also be considered.

6.6 FOG Receiving

FOG receiving will be designed to process 10,000 gpd of FOG based on the initial market evaluations. FOG will be received from a FOG hauler through a screen and then pumped to a holding/recirculation tank. From the holding/recirculation tank, FOG will be pumped at a steady rate to the food waste processing flow stream for dilution of the HSW to a target solids content. When FOG is not available for dilution, stored dilution water will be available. Dilution water may also be necessary as a supplement to the FOG to achieve a target HSW solids content.

FOG receiving will consist of the following components:

- Rock Trap
- Receiving Screen
- Screened FOG Pumps
- Holding/Recirculation Tank
- Recirculation Pumps
- Transfer Pumps
- FOG System Heating

The key component of FOG receiving will be the Receiving Screen. Screening is recommended due to the potential contaminants that can be present in the grease traps where FOG is collected. Screening systems typically come with an integral component that serves as a rock trap. Alternative screening systems are presented in the following paragraphs. As with the other processing components, only one unit would be provided, since maintenance can be completed outside of the 8-hour daily service period. Product data for FOG Receiving equipment is attached in Appendix D.

6.6.1 Enviro-Care Beast

Figure 6-9 Enviro-Care Beast

Enviro-Care Company supplies pre-treatment screens and solids/grit management equipment for water and wastewater applications. Their system for septage-FOG-sludge screening, called the Beast, is designed to remove inorganic material from FOG. This system also conveys, washes, and dewaters screenings prior to discharge. The system consists of the following components:

- Motorized inlet valve
- Beast
    - Inlet tank
    - Rotary Screen
    - Screw auger

The FOG will be conveyed through the motorized inlet valve, then to the Beast inlet tank. The FOG is then conveyed through the inlet tank and rotary screen. Any debris captured in the screen is conveyed out of the Beast by the screw auger and into an endless bagger system prior to being deposited into a dumpster.

The tank component is designed to handle up to 600 gpm of FOG which allows fast unloading times. The 6 mm screen perforations provide a high contaminant capture.

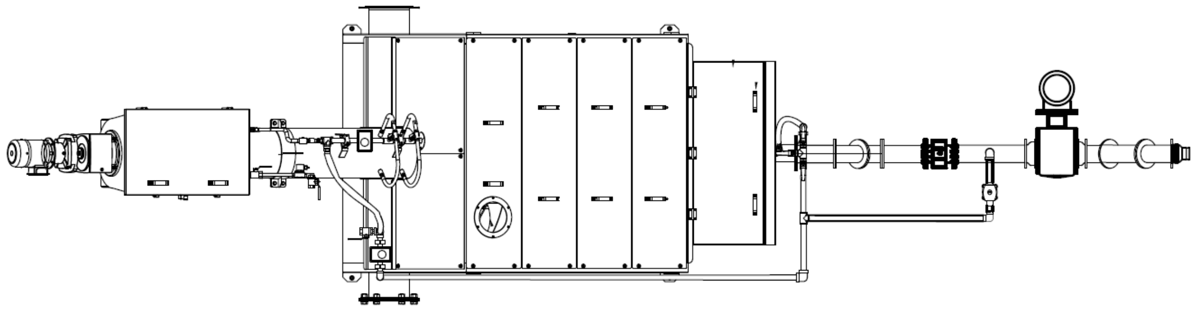


Figure 6-10 Enviro-Care Beast Plan View

A hauler access station and Flo-Logic® software management system are options also available with the Beast. These options can provide security, data logging and reporting/invoicing capabilities. With these options, permitted haulers can have unsupervised access by using simple login procedures and a key card. The software system monitors, collects and tabulates data on flow and load volumes. Design data for the Enviro-Care Beast are presented in Table 6-5.

Table 6-5 Enviro-Care Beast Design Data

Parameter	Value
Beast Dimensions	195” L x 67” W x 107” H
Main Control Panel Enclosure	36” W x 8” W x 42” H
Hauler Access Station	24” L x 14” W x 24” H
Materials of Construction	304 SS (316 SS optional)
Processing Rate	400-600 gpm
Screen Perforation Size	6 mm
% Solids Captured	99.5%
Power Consumption	65 kW
Quoted Capital Cost	$305,500

6.6.2 JWC Environmental Honey Monster

Figure 6-11 JWC Environmental Honey Monster

The Honey Monster, manufactured by JWC Environmental, is also a receiving system for screening septage, FOG or sludge from haul trucks. As with the Beast, this system is capable of providing automated (unsupervised) FOG acceptance. The Honey Monster includes the following components:

- Inlet Valve
- Rock Trap
- Grinder
- Honey Monster
  - Perforated Screenings Trough
  - Screw Auger

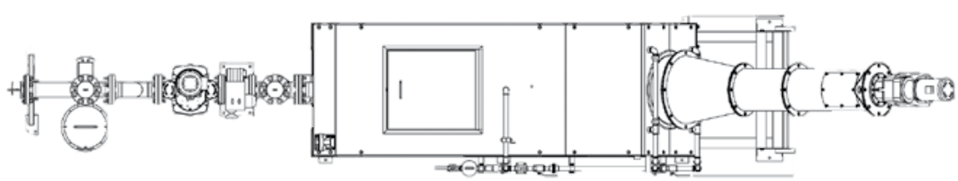


Figure 6-12 JWC Environmental Honey Monster Plan View

The FOG is conveyed through the motorized inlet valve, then to a rock trap and tank. The FOG is then conveyed through the tank and passes through a 40K series Muffin Monster grinder. Any debris captured in the tank is dewatered and conveyed out of the Honey Monster by a screw auger into an auto bagger system for dumpster deposit. Any materials passing the tank are macerated in the grinder.

The Honey Monster is designed to handle up to 400 gpm of FOG which allows fast unloading times. System automation also provides data capture and instrumentation is available for pH sensing. Design data for the JWC Environmental Honey Monster are presented in Table 6-6.

Table 6-6 JWC Environmental Honey Monster Design Data

Parameter	Value
Honey Monster	142" L x 48" W x 132" H
Materials of Construction	304 SS Pipe & Tank (316 SS optional); 304 SS casings & trough
Processing Rate	400-600 gpm
Screen Perforation Size	12 - 25 mm
% Solids Captured	99.5%
Power Consumption	5.2 kW
Quoted Capital Cost	$200,000

6.6.3 Recommendations

Typically, FOG collected from grease traps is anticipated to have contamination such as rocks, bones, and other debris washed down sinks and drains. Comparison of the two FOG screening systems reveals that physical screening of the FOG is only provided by the Enviro-Care Beast system. The Honey Monster unit relies on a larger bar screen for separating rocks and heavy debris while screening of FOG throughput is provided by grinding. Therefore, any contaminants or stringy materials that make it through the grinder (i.e. non-dispersibles) remain in the HSW. In addition, the Honey Monster requires an external cleaning system (provided by others) while the Beast comes with an integral clean-in-place system.

Therefore, the Enviro-Care Beast is the recommended pre-processing system. Although the contamination seen thus far in the bench study does not indicate a high degree of contamination in the collected FOG, the Enviro-Care Beast that screens to 6 mm is anticipated to provide the desired separation of contaminants. This system assumes that a rock trap is not required based on the screening technology, but a rock trap may be included if additional protection is determined to be needed.

7 SUPPORT SYSTEM REQUIREMENTS

This section provides basic information regarding ancillary systems required to support the Pre-Processing Facility operations. Conceptually, utility infrastructure is available to serve the facility. However, considering other future site uses, water and wastewater services may require upsizing. Requirements would need to be reviewed through use of the City's water and wastewater models.

7.1 Water and Wastewater

7.1.1 Water

Potable water supply is required for the operations area and the driver's restroom facilities. Fire protection requirements need to be identified with City's fire code official. Future site uses may require upsizing the 6-inch water main in Center Street or providing onsite storage for supply to all onsite facilities.

Much of the service water required for HSW dilution can be supplied by reclaimed water brought to Center Street Yard from the NWWRP. Once the HSW is unloaded from the transport truck, the truck can be washed out and then refilled with reclaimed water for the return trip to the Pre-Processing Facility. As indicated in Section 5, a storage tank for this dilution water will be provided in the storage area and used to supplement FOG as required to reach the target product solids content.

7.1.2 Wastewater

The existing infrastructure appears to be satisfactory to provide adequate wastewater service to the Pre-Processing Facility. Washdown water will need to be treated to acceptable industrial discharge standards in compliance with the City's industrial pretreatment program.

7.2 Power

The Pre-Processing Facility will require 480 volts, three phase power supply for motors and processing equipment. Other areas of the facility will require 120 volt and 240-volt power. Power supply will be provided through local transformers and local panels located in an electrical room in the operations area.

In addition to the above-mentioned power sources, an uninterruptible power supply (UPS) will be provided. The UPS will be located in the control room and furnish power to control systems, alarms and lighting.

7.2.1 Area Classification

Hazardous area classifications will apply to locating and designing electrical systems for the Pre-Processing Facility. As previously indicated in Section 3, ventilation for multiple air changes per hour will be required for controlling offensive odors created by handling and processing of food waste. Up to 12 air changes per hour during facility operations may be required to effectively control odors. This ventilation rate may reduce the area classification, but not declassify building areas due to the significantly large spaces / volumes in the building. Building areas will ultimately be classified by and in accordance with the requirements of the City's fire code official.

7.3 Instrumentation, Controls and Communications

The food waste processing equipment is expected to come with vendor-supplied instrumentation and controls that are local to the machine. Master system control and monitoring will be provided in accordance with City of Mesa standards consisting of a programmable logic controller (PLC) and human machine interface (HMI) system presenting operations information in graphical format (Graphical User Interface or GUI). The HMI will be located in the Pre-Processing Facility operations area along with uninterruptible power supply (UPS) and with communications infrastructure.

The master control system will interface with the vendor-supplied control panels. Vendor panels are typically designed to directly monitor and control the equipment and are often custom designed to suit owner requirements. Some vendor systems are supplied with a controller area network (CAN bus) that allows microcontrollers and devices to communicate with each other without a host computer, but the master system control may still be configured for interface with a CAN bus system.

In addition to interface with HSW processing, the master system control will collect and tabulate weigh data from the scale system. This data will be used to estimate delivery volumes and HSW processing throughput.

Traffic control monitoring will also be provided through the master control system. As previously indicated in Section 5, signalization and cameras will be placed at the facility access points to control truck entry into the unloading floor. Depending on food waste transport patterns (time of day and frequency of unloading operations) the system can be automated for appropriate intervals between incoming loads to allow for managing the materials in the processing area.

Communications to offsite locations (fire alarms, etc.) will likely be provided via the City's FO communication line on the west side of Center Street.

7.4 Emergency Systems

Fire alarms and fire protection systems will be installed throughout the Pre-Processing Facility. Specific requirements will need to be identified with the local fire code official. Supporting infrastructure for fire protection systems is expected to be similar to that installed for the HHMF.

Although not expected for this facility type, combustible gas detection may also be required in accordance with requirements of the City's fire code official.

8 OPINION OF PROBABLE CONSTRUCTION COST

An opinion of probable construction cost was developed for the recommended Pre-Processing Facility concept and recommended equipment alternatives described in this Concept Memorandum. The majority of the capital costs are based on vendor furnished equipment costs and manufacturer input on installation of similar size projects and equipment. The anticipated construction cost was calculated based on March 2019 dollars. Table 8-1 and Appendix F summarizes the capital costs associated with the Pre-Processing Facility concept, ***excluding site preparation costs to be determined based on findings and recommendations of additional geotechnical investigation as indicated in Section 3*****.**

Table 8-1 Opinion of Probable Construction Cost

Component	Total Cost[1]	Total Cost -30%	Total Cost +50%
Sitework[2]	$624,000	$436,800	$936,000
Pre-Processing Facility Building	$4,582,500	$3,207,800	$6,873,800
Depackaging System	$766,800	$536,800	$1,150,200
Grit Screening	$49,000	$34,300	$73,500
FOG Receiving	$427,700	$299,400	$641,600
Storage, Pumping Systems & Piping (FOG, HSW, etc.)	$250,000	$175,000	$375,000
Subtotal	**$6,700,000**	**$4,690,100**	**$10,050,100**
Indirect Costs			
General Conditions (8%)	$536,000	$375,200	$804,000
Overhead, Mob/Demob, Bond, Insurance (12%)	$804,000	$562,800	$1,206,000
Total Indirect Costs	**$1,340,000**	**$938,000**	**$2,010,000**
Other Costs			
Profit (8%)	$643,200	$450,200	$964,800
Total Other Costs	**$643,200**	**$450,200**	**$964,800**
Subtotal	**$8,683,200**	**$6,078,300**	**$13,024,900**
Contingency (20%)	$1,736,600	$1,215,600	$2,604,900
Total Estimated Probable Construction Cost	**$10,419,800**	**$7,293,900**	**$15,629,800**

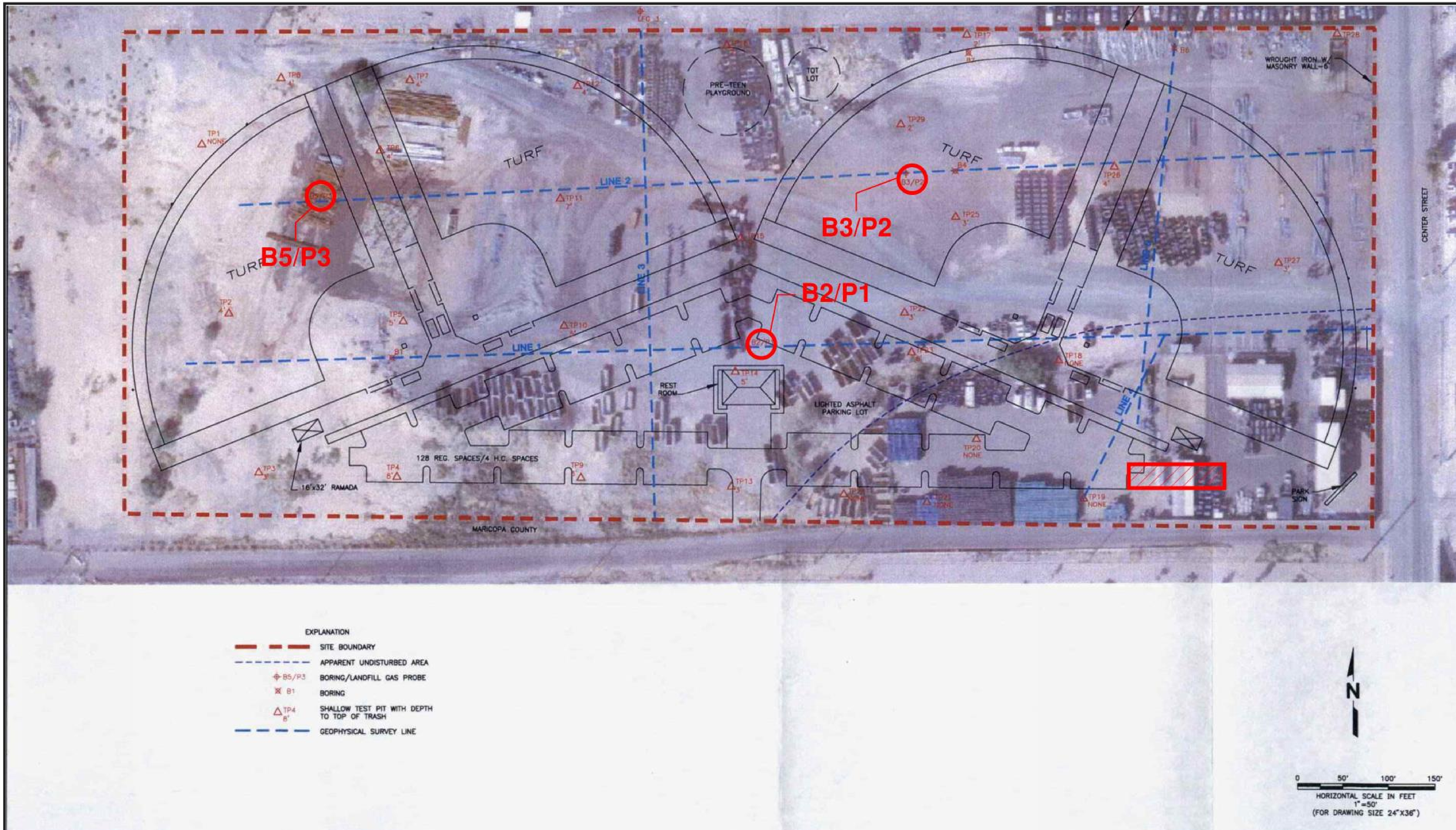
[1]The following items are excluded from the Opinion of Probable Construction Cost:

- Geotechnical Investigation & Site Remediation
- Design and Permit Fees
- Rolling Equipment, Dumpsters, and Misc. Ancillary Items
- Control System Programming

[2]Assumes only sitework for Pre-Processing Facility as stand-alone installation without adjacent similar facilities.

APPENDIX A

Soil Vapor Analysis



ARCADIS Design & Consultancy for natural and built assets

FIGURE
3-1

TABLE 1 - SOIL VAPOR ANALYSIS

	Date	Probe	Depth at bottom of probe (ft)	propene	CFC12	CFC114	vinyl chloride	ethanol	acetone	carbon disulfide	1,1-dichloroethane	2-butanone	cis-1,2 DCE	ethyl acetate	n-hexane	THF	benzene	cyclohexane	trichloroethene	1,4-dioxane
*Calculated SGHHSLs Residential				1,300,000	43,000	NE	74	NE	14,000,000	320,000	780	2,300,000	NE	32,000	320,000	910,000	160	2,700,000	210	240
*Calculated SGHHSLs Industrial				11,000,000	370,000	NE	2,300	NE	120,000,000	2,600,000	6,400	18,000,000	NE	260,000	2,600,000	7,300,000	1,300	22,000,000	2,500	2,100
	5/6/2008	P1	30	1,600	430	531	588	979	261	2,832	49	50	111	50	197	83	51	79	50	50
	5/6/2008	P1	20	2,236	3,806	1,118	792	1,111	1,116	560	222	224	262	223	423	324	249	224	236	223
	5/6/2008	P1	10	16,340	1,730	1,607	843	697	688	240	142	139	475	140	1,937	501	156	258	140	140
	5/6/2008	P2	30	344	6,425	2,096	1,022	358	356	591	89	71	71	72	775	71	73	213	70	72
	5/6/2008	P2	20	2,408	2,619	468	536	128	128	1,214	26	26	26	26	257	26	80	89	26	26
	5/6/2008	P2	10	1,720	642	699	143	264	261	75	53	53	123	54	387	53	169	248	53	54
	5/6/2008	P3	30	757	237	168	87	77	237	1,245	15	77	17	15	24	53	19	15	16	15
	5/6/2008	P3	20	4	4	13	5	60	45	14	4	9	4	4	5	4	4	4	5	6
	5/6/2008	P3	10	2,924	6,919	4,262	1,558	377	380	75	73	74	475	76	669	74	265	320	102	76

	Date	Probe	Depth at bottom of probe (ft)	n-heptane	4-methyl-2-pentanone	toluene	n-octane	tetrachloroethene	chlorobenzene	ethylbenzene	m,p-xylenes	o-xylene	n-nonane	cumene	a-pinene	n-propylbenzene	4-ethyltoluene	1,3,5-trimethylbenzene	1,2,4-trimethylbenzene	1,4 dichlorobenzene	1,2 dichlorobenzene	d-limonene
*Calculated SGHHSLs Residential				180,000	1,300,000	2,300,000	NE	4,800	23,000	480	43,000	43,000	9,100	180,000	NE	430,000	NE	27,000	27,000	110	91,000	NE
*Calculated SGHHSLs Industrial				1,500,000	11,000,000	18,000,000	NE	39,000	180,000	4,100	370,000	370,000	73,000	1,500,000	NE	3,700,000	NE	220,000	220,000	920	730,000	NE
	5/6/2008	P1	30	90	49	49	51	50	51	52	52	52	50	49	50	49	49	49	49	132	50	95
	5/6/2008	P1	20	614	901	8,662	560	224	225	6,076	12,150	4,122	3,039	688	21,717	884	737	1,032	3,144	961	355	11,138
	5/6/2008	P1	10	1,065	139	1,205	1,447	142	267	3,645	1,128	1,866	4,349	388	9,466	786	138	236	182	336	138	2,005
	5/6/2008	P2	30	209	74	72	191	75	97	74	95	74	73	74	111	74	74	74	74	379	72	189
	5/6/2008	P2	20	131	26	49	173	26	78	694	100	74	141	84	139	79	26	26	42	348	78	184
	5/6/2008	P2	10	315	53	53	205	53	69	608	65	65	257	79	111	54	54	54	54	3,124	53	134
	5/6/2008	P3	30	29	15	16	29	16	87	28	56	30	19	15	26	15	15	15	49	60	16	72
	5/6/2008	P3	20	5	5	5	4	4	5	16	15	9	5	5	8	5	5	5	17	14	5	49
	5/6/2008	P3	10	983	74	527	700	95	129	3,211	3,038	3,254	1,939	206	1,225	590	197	152	255	78	72	284

Exceeds Residential SGHHSLs

Exceeds Industrial SGHHSLs

NE Not Established

* Calculated Soil Gas Human Health Screeening Levels (SGHHSLs) for residential and industrial use scenarios were derived using United States Environmental Protection Agency (USEPA) indoor air Regional Screening Levels (RSLs) (November 2018) divided by attenuation factors of 2.30E-03 for residential and 1.20E-03 for industrial. The SGHHSLs are risk-based values describing residual soil vapor contaminant concentrations which may be left in the subsurface and yet still be protective of indoor air for a residential or commercial/industrial use scenario.

APPENDIX B

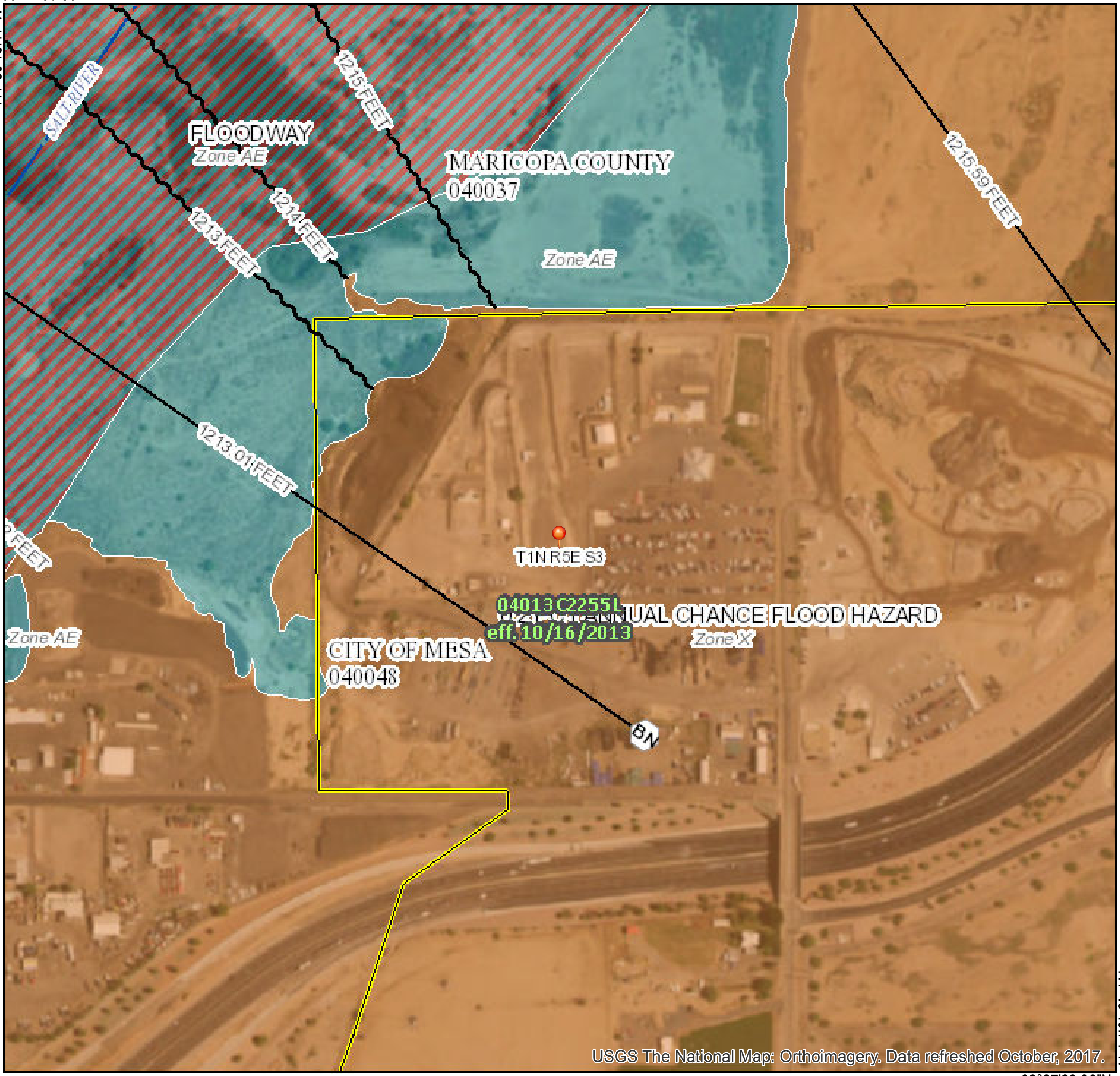
FEMA Flood Insurance Rate Map

National Flood Hazard Layer FIRMette

FEMA

33°27'53.89"N

111°50'18.17"W



111°49'40.71"W

33°27'23.88"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- B 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- 8 Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 1/16/2019 at 7:35:23 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

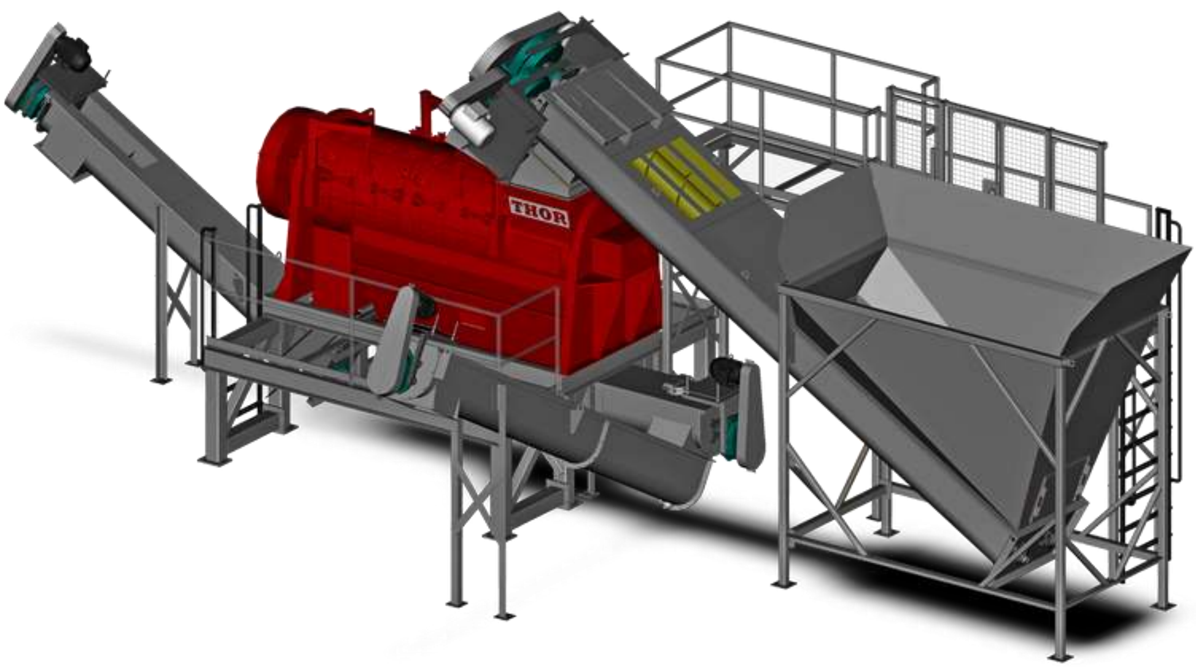
APPENDIX C

Pre-Processing Equipment Product Data

Scott Equipment Company

THOR -Turbo Separator Proposal for:

Shayla Allen
Water Resources Engineer
ARCADIS U.S., Inc.
27-01 Queens Plaza North, Suite 800
Long Island City, NY, 11101



SCOTT EQUIPMENT COMPANY RECYCLING PRODUCTS DIVISION

Notes:

The THOR is intended to process:

- pre-consumer packaged Source Separated Organics (SSO)
- post-consumer, mixed commercial and residential SSO w. contamination

This mixed waste stream may include all forms of typical packaging materials:

- paper fiber- cartons, paper, wrappers, tetrapaks, etc.
- plastics- bags, up to 5 gal. pails, clamshells, etc.
- metal- canned goods
- Not intended for glass-will crush, not separate-glass will go into organics
- Typical grocery and restaurant organics waste streams

The system is not intended for municipal solid waste (MSW):

- No mop buckets, coolers, tires, shoes, rugs, car parts, lumber, etc.
- The system may process some of these items, but may result in damage

Customer is responsible for all <u>mechanical</u> and <u>electrical</u> installation.
Customer is responsible for all <u>gear reducer lubrication</u> required for machine startup.

Customer is responsible for all <u>freight charges</u> from Scott Equipment factory in MN (unless included)

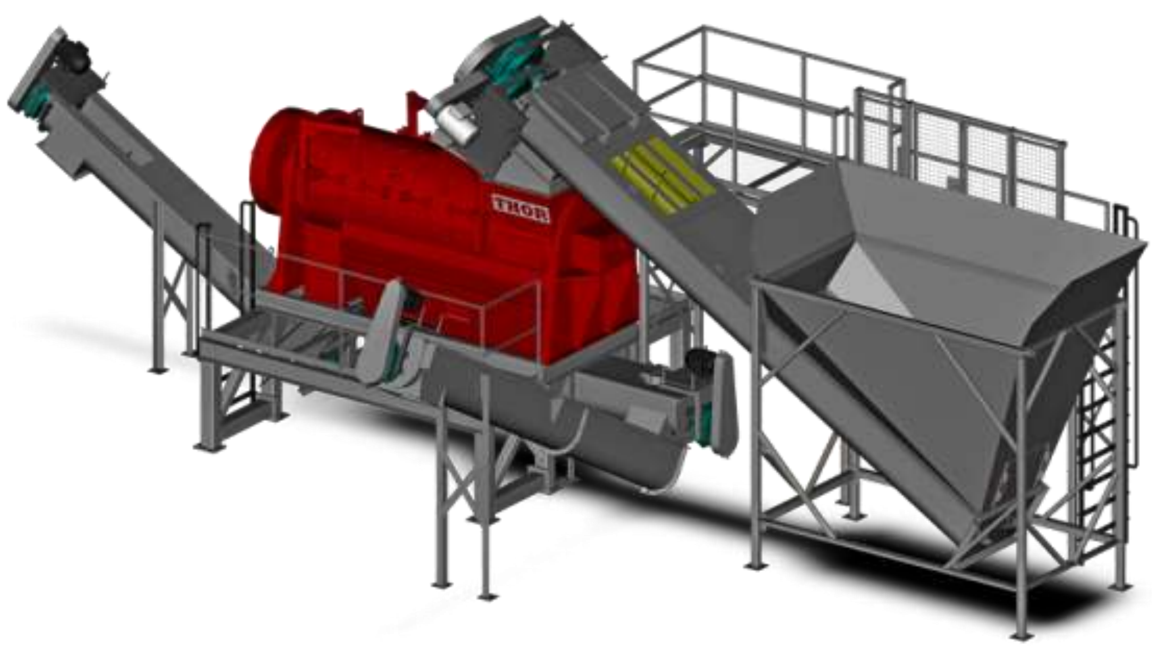
Delivery is 15 to 17 weeks, scheduled after receipt of approved construction drawings.
Approval construction drawing delivery is an additional 1 to 3 weeks from receipt of PO & Down payment from you the customer.

Operation and maintenance manuals will be electronically supplied.
Additional manuals will be billed to the customer at a rate of $65 each.

Model THOR Turbo Separator System Components Detail Listing

THOR Turbo Separator w/ Swing Hammers

1. Construction
    - 42"D X 120"L internal dimension/formed & welded shell
    - 5/8" thick 316 stainless steel/smooth mill finish/THOR red enamel paint-RAL3000
      5/8" thick 316 stainless steel endplates and bearing shelves
    - 4 qty. HD 1" thick, Scott Swing Arm door assemblies with safety slide pins
    - 8 qty. std. removable & replaceable carbon steel screens for Mega THOR
    - 12" HD carbon steel shaft w. 2 qty. Dodge (or similar) protected outbound pillow block bearings
    - 52 qty. Scott Swing Hammers
2. Motor
    - 100HP TEFC 3ph/230/460v/60hz / 1800RPM
    - 1 qty.- Allen Bradley PowerFlex Variable frequency drive (see Control Panel)
3. Liquid Manifold
    - SMARTFLOW brand adjustable, ball valve style with 5 ports for optional liquid addition
4. Collection Hopper, Support Stand, And Work Platforms
    - Industrial gauge carbon steel/stand supports over 8 ton/mill finish/gray enamel paint-RAL7022
    - Slip resistant steel grating work platform with safety handrails & full stairs
    - 7 gauge stainless steel tapered organics collection hopper w/ dual access panels



Twin Screw Infeed Conveyor & Hopper w. Wet/Dry Option

1 Construction

- Twin 16"D X 20'L tubular, carbon steel auger screws
- 3/16" thick 304 stainless steel tub/smooth mill finish/gray enamel paint-RAL7022
- 2 qty. sealed, lower shaft bearings
- 10 gauge top cover with accessibility hatch
- Mating inlet flange assembly for THOR
- Observation and maintenance platform with ship style ladder(s) w. safety gate/switches
- OPTION#1: 304SS upgrade on trough & hopper; Wet Kit w. liquids management w.
    - 1HP Wastecorp MiniMudsucker pump with cart
    - 12"D x 24" Screw Auger with 2" ANSI flange drain line with T- cleanout
    - 1 qty. 2"D X 5'L Flex Hose with camlocks and ball valve shutoff (suction)
    - 1 qty. 2"D X 25'L Flex Hose with camlocks and ball valve shutoff (discharge)
    - 2" ANSI flange connection to T42

2 Motor

- 2 qty. -10HP TEFC 3ph/230/460v/60hz
- OPTION#1: 1 qty. -1HP TEFC 3ph/230/460v/60hz or 1HP TEFC 3ph/575v/60hz
- OPTION#1: 1 qty. -1/2HP TEFC 3ph/230/460v/60hz or 1/2HP TEFC 3ph/575v/60hz
- 2 qty.- Allen Bradley PowerFlex variable frequency drives (see Control Panel)

3 Gear Reducers

- 2 qty. – Heavy duty cycle Dodge (or similar) gear reducer

4 Hopper

- 5'W X 10'L 304L stainless steel construction
- 7 gauge 304 stainless steel/smooth mill finish/gray enamel paint-RAL7022
- One piece construction, 24"H, angled bolt-on flanged backsplash for hopper inlet
- Approximately 8 cu. yard capacity

Waste Packaging Conveyor

1 Construction

- Single 16"D X 16'L tubular, carbon steel auger screw
- 3/16" thick carbon steel/smooth mill finish/gray enamel paint-RAL7022
- 1 qty. sealed, lower shaft bearing
- Mating flange assembly for T42

2 Motor

- 1 qty. - 5HP TEFC 3ph/460v/60hz or 5HP TEFC 3ph/575v/60hz
- 58 RPM kit with expanded discharge and tapered screw flighting
- 1 qty.- integrated motor starter, soft start (see Control Panel)

3 Gear Reducers

- 1 qty. – heavy duty cycle Dodge (or similar) gear reducer

Recovered Organics Single Screw Conveyor-HORIZONTAL

1 Construction
  - Single 16"D X 12'L tubular, 316 stainless steel auger screw
  - 3/16" thick 316 stainless steel/smooth mill finish/gray enamel paint-RAL7022
  - 304SS organics viewing hatch
  - 1 qty. sealed, lower shaft bearing

2 Motor
  - 1 qty. - 5HP TEFC 3ph/460v/60hz or 5HP TEFC 3ph/575v/60hz
  - 1 qty.- integrated motor starter, soft start (see Control Panel)

3 Gear Reducers
  - 1 qty. – heavy duty cycle Dodge (or similar) gear reducer

Recovered Organics Single Screw Conveyor - INCLINED

1 Construction
  - Single 16"D X 12'L tubular, 304 stainless steel auger screw
  - 3/16" thick 304 stainless steel/smooth mill finish/gray enamel paint-RAL7022
  - 1 qty. sealed, lower shaft bearing
  - Mating flange assembly for T42

2 Motor
  - 1 qty. - 5HP TEFC 3ph/460v/60hz or 5HP TEFC 3ph/575v/60hz
  - 1 qty.- integrated motor starter, soft start (see Control Panel)

3 Gear Reducers
  - 1 qty. – heavy duty cycle Dodge (or similar) gear reducer

Engineered Control Panel For Mega THOR Turbo Separator

1 Construction

- All steel cabinet (approx. 72"H x 60"W x 12"D)
- UL listed/ Schematics provided
- Nema 12 for dust protection
- Nema 12 window kit to protect VFD keypads
- OPTION#4: Upgrade all to NEMA4X rating; 304SS enclosure; integrated air conditioning

2 Motor Controls

- 1 qty.-100 HP Allen Bradley PowerFlex Variable frequency drive w. door mount keypad
- 2 qty. -10 HP VFD's with door mount keypad for start-stop and speed control for Twin Screw Infeed Conveyer
- 1 qty.-5 HP across the line starter for Waste Packaging Conveyor with start-stop buttons
- 1 qty.-5 HP across the line starter for Organics Conveyor (HORIZONTAL) with start-stop buttons
- 1 qty.-5 HP across the line starter for Organics Conveyor (INCLINED) with start-stop buttons
- OPTION#1: 1 qty. -1HP across the line starter for Wastecorp Mudsucker pump (hopper)
- OPTION#1: 1 qty. – ½ HP across the line starter for Wet Kit (hopper)
- OPTION#2: 1 qty.- 10 HP across the line starter for PE1142 pump with start-stop buttons
- 24VDC Power Supply

3 Safety Features

- Main disconnect with lockable handle
- Raised, Illuminated E-Stop & relay
- Digital amperage meter for Turbo Separator
- Analog service hour meter
- Light stack with red/green/strobing green indicators
- UL Listed w/ schematics

January 15, 2019
Proposal for: City of Mesa, Arizona
Proposal # HS-19010-A

HS-55 DEPACKAGING SYSTEM

MACHINE SPECIFICATIONS AND STANDARD EQUIPMENT PROPOSAL

PROPOSAL #: HS-19010-A
DATE: January 15, 2019
TO: City of Mesa, Arizona
Address
CSZ
ATTN: Name

TIGER HS-55 DEPACKAGING SYSTEM

Dimensions

- Total length: 24’ 4”
- Total width: 7’ 2”
- Total height: 13’ 5”
- Weight: 26,790 lbs.

Functional details

- Rotational speed of separation shaft: 1000 rpm
- Three AC Motors
- Feed screw motor: 7.5 kW
- Squeezing group motor: 55 kW
- Dry fraction extraction motor: 2.2 kW

Miscellaneous

- Engine compartment: Protected but accessible
- Feed screw drive: Motor reducer
- Squeezing group drive: Direct AC
- Dyeing and paint specially designed to prevent the machine from weather and food waste corrosion

Stationary frame (chassis and single wing doors)

- Legs 4’ (Different sizes can be ordered based on site requirements)
- Anti-Vibrational Silent-block device
- The machine is completely made out of steel, ST 37 steel 6 mm thick plates for the body (3 mm for inspection doors)

Feed Compartment

- Feed hopper in stainless steel with one open side for the feeding.
- Feed screw in black steel (thickness = 10 mm)
- Inspection door
- New removal system of the main feed screw
- 7 cubic yard hopper
- Hopper dimensions: 11' 4" x 6' 5"
- Second auxiliary auger in hopper to prevent bridging

Squeezing Compartment

- ¾” Separation basket made from FE S700 Iron – basket can be changed based on material type
- High speed shaft
- Replaceable wear paddles
- Hardoxed reinforced shaft

Plastic extraction Compartment

- Dry fraction extractor screw, equipped with hoisting hooks and hood

Liquids

- Double water feeding system to accept water from the grid and from other source such as a leachate recovery or rainwater source, and a clean-water line for cleaning the mill
- Solenoid valve to regulate the process water flow

Electric devices and Software

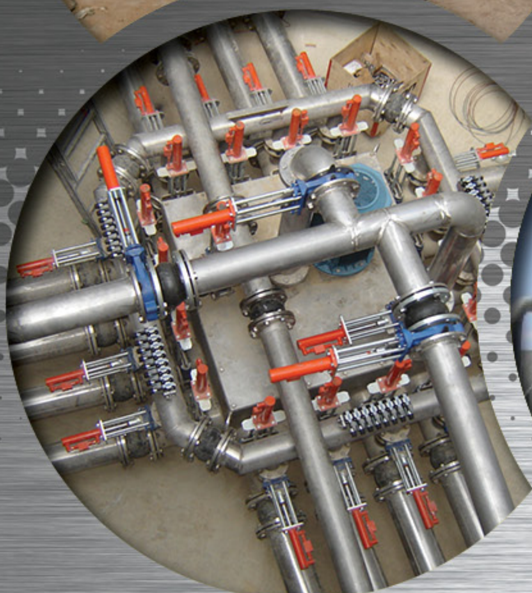
- Control panel with touch screen.
- The control panel can be remote. The choice must be declared at the order.
- The necessary wires length must be declared after the order. The price difference will be charged separately after the order.
- Soft starter for 55kW engine
- Operator panel and Electric panel
- Main Breaker
- Electric cabinet with air-conditioner
- LED light system to signal the rate of process water flow

Safety

- Safety device for the shaft that prevents any possible damages on the engine and on the belts due to accidental contaminants entrance and/or blocking.
- Rotation sensor for the 55kW engine
- Magnetic disconnection system mounted on all main doors to shut down all engines in case of accidental doors opening.
- Stairs to enter to the squeezing compartment and access to all the mechanical elements by means of wide and comfortable doors so that the personnel can enter and/or operate effectively
- Emergency stop buttons
- Safety and warning labels on all machine sides

Miscellaneous

- LED light system with green, yellow and red colors to signal the operating conditions of the machine
- Color RAL 5010 (Gentian Blue)
- Complies with all EC standards



organic waste solutions

USA Inc.

DODA® USA Inc.
ORGANIC WASTE SOLUTIONS

255 16th Street South
St. James, MN 56081
Tel: 507-375-5577●Fax: 507-375-5578
http://www.dodausa.com

Organic and Non-Organic Bio Separators

Decomposition of food and other organic waste in landfills account for 34 percent of all methane emissions. Methane is a Greenhouse gas 21 times more damaging to the environment than carbon dioxide. The United States generate about 35 million tons of food waste annually. Doda offers various sizes of Bio Separators for separating food and other organic waste from the waste stream.

Doda Bio Separator

- Manufacture in AISI 304 Stainless Steel with Hardox steel Hammer Mill and hot galvanized Screen
- Screen sizes of 3/8” or 5/8” are standard
- Various models with throughput ranging from 2-20 ton per hour of comingled organic and non-organic waste
- Hopper sizes of 850 or 2,500 US gallons for Dry systems
- Bag openers and specially designed chopper pumps for mixing and feeding Wet system
- In store hand fed compact units for de-packaging, separation and volume reduction
- Turn Key projects, from design to startup.

Doda Bio-Separator Advantages

- Up to 20 Ton per hour throughput of food waste
- Very Robust, can treat a variety of waste streams without additional setup
- Reinforced Stainless Steel construction with few easy replaceable wear parts
- Up to 99% removal of non-organics from food waste
- Minimal use of fresh water as not to increase overall volume
- Volume reduction for Transport and Tipping fees savings
- Recycled food waste can be used as compost for fertilizer replacement
- Creation of an Anaerobic Digester waste stream with High methane production potential
- Reducing GHG (Methane) emissions from landfills and waste combustion
- Improved sanitation, public safety and health for both your facility and community

255 16th Street South
St. James, MN 56081
Tel: 507-375-5577●Fax: 507-375-5578
http://www.dodausa.com

Equipment List

- Hopper
- Bio-Separator
- USA made and CSA approved Control Panel
- Two 25 HP Transfer pumps
- Two 6" Gate Valves
- Hydraulic unit (for tilting the Hopper, opening and closing of Lid and Gate Valves)

Supporting equipment requirements

- Front Loader for loading the Hopper (not included)
- Storage tank (not included)
- Piping
- Odor control (not included)

Accessories

- Lid for Hopper
- Walk Path
- Piping and Valves
- Hydraulic Unit for Tilting and opening of Lid
- Distribution Box for mixing and loading of Storage tank

APPENDIX D

FOG Receiving Equipment Data

The Beast

Septage-FOG-Sludge Screening System

VFA-DM

SAVI

Patent Pending

Septage Beast Property of Devonshire Island of Bermuda

The BEAST

Enviro-Care
A WAMGROUP® Company

WAMGROUP®

The Beast VFA-DM

SAVI

Septage-FOG-Sludge Screening System

The BEAST

The Next Generation of Septage, FOG & Sludge Screening

FOG Beast Property of Frederick Winchester VA

Screening septage, FOG or sludge comes with a long list of problems. The two biggest complaints are the inability to process heavy solids and long truck unloading times. These problems are the result of not having the proper equipment for the application. The Beast has been engineered specifically for septage and heavy solids loading applications.

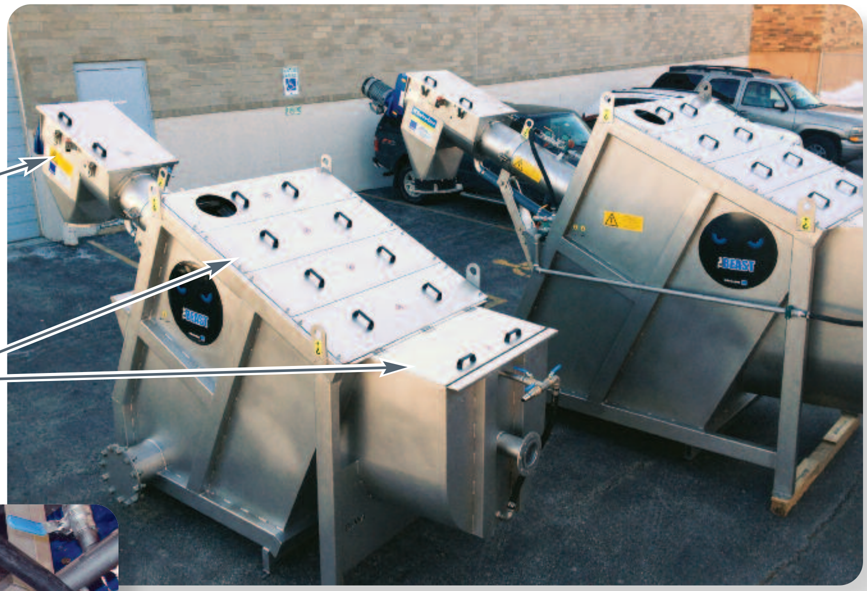
Unique Tank Design. Standard tank designs promote solids sedimentation. The Beast has a two-stage tank with a curved, sloped inlet section that directs the flow into the screen cylinder. The hopper trough extends beyond the cylinder opening which reduces screenings recycle. The screen is supported at the drive end which eliminates the need for support arms and solves the ragging problem.

Dual Drive System. This feature enables the screen basket and auger to operate independently. The speed of the auger is increased to provide faster solids removal while the speed of the screen basket is decreased to improve capture efficiency.

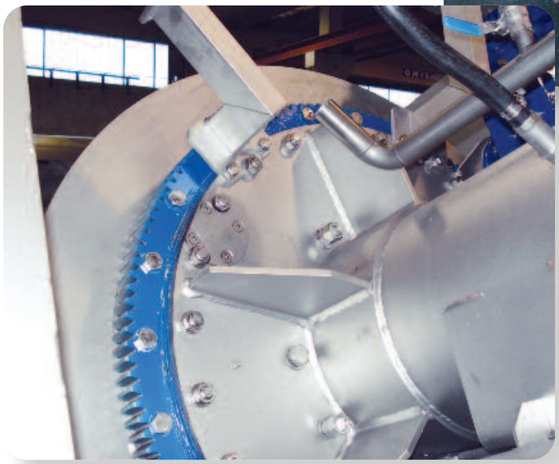
Angle of Inclination. The drum screen component sits at a 25° angle inside the tank to enhance capture even further.

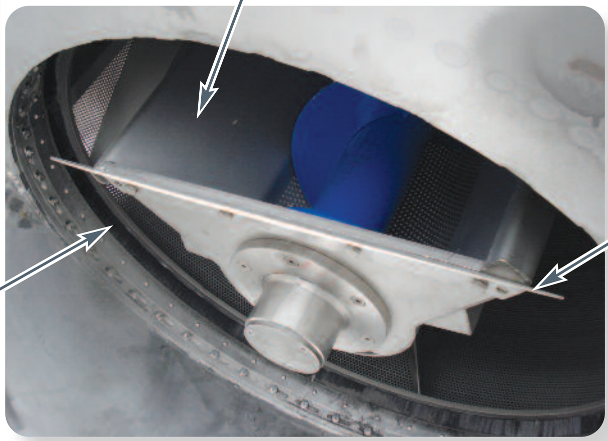
Sequence of Operation. As the pumped flow enters the tank, it is discharged directly into the rotating screen basket. As the screen rotates, solids are captured on flights or scoops that carry the solids around the basket and deposit them into the auger trough.

From the trough, solids are conveyed by the auger into the washing zone and then to dewatering. The percent of dryness achieved is dependent upon the solids concentration and the type of solids in the influent. Solids capture is 65% or greater based on the material in the flow.



Beast 1200 & 1400 side-by-side





Features & Benefits

1 **Engineered for large, heavy solids loading applications requiring fast processing -** Each feature solves a specific problem associated with these applications.

2 **Proven Flo-Drum technology -** Over 300 installations worldwide.

3 **Dual drive system -** Drum and auger are driven independently to optimize solids capture and removal.

4 **Screen is mounted using a large diameter, single row, heavy duty industrial bearing assembly with a built in grease fitting -** Better resistance to axial and radial loading with fewer maintenance points.

5 **Two-stage tank design narrows the inlet -** Solids are fed directly into the screen basket which prevents sedimentation.

6 **The auger is run at a faster speed -** Removes the solid material faster.

7 **The screen cylinder is run at a slower speed -** Produces better solids capture and cleaning of the screen.

8 **Dual seal on the screen cylinder -** Prevents bypass and improves capture of fine material.

9 **Angle of inclination is 25° -** Screen handles more solids and removes them faster.

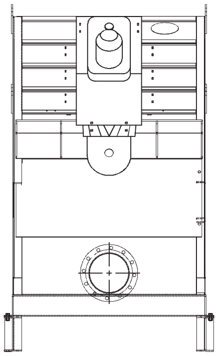
10 **Trough extends beyond the screen opening -** Reduces screenings recycle by preventing solids from dropping out of the front of the screen basket.

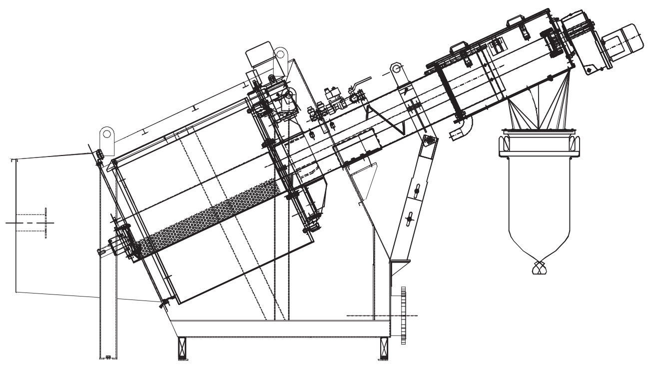
11 **No support arms on the influent side of the screen drum -** Nothing to snag and accumulate long stringy solids.

12 **Eliminates brushes inside the screen basket -** Less extrusion and manipulation of the screenings for better capture and less maintenance.

13 **Additional monitoring options and security access may be added -** Controls can be as basic or as sophisticated as required.

14 **Optional bagger is available -** Maintains a cleaner screenings area.





Specifications

Drum Screen OD	mm	800	1200	1400
		Septage Only	Septage-FOG-Sludge	Septage-FOG-Sludge
Capacity (at 3-4% solids content)	gpm	450	660	875
Screen type		Perforated plate	Perforated plate	Perforated plate
Openings	mm	6	6	6
Angle of inclination		25°	25°	25°
Wash water	gpm/psi	30 @ 60-70	43 @ 60-80	43 @ 60-80
Drive motor - Drum Screen	Hp	1.5	2	2
Drive motor - Shafted Screw	Hp	1.5	2	2
Controls		NEMA 4X or NEMA 7	NEMA 4X or NEMA 7	NEMA 4X or NEMA 7
Voltage	V/P/H	240/480/3/60	240/480/3/60	240/480/3/60

Materials of Construction

Screen media	AISI 304 SS (316 Optional)
Transport tube	AISI 304 SS (316 Optional)
Shafted screw	High Strength Alloy Steel (304/316 SS Optional)
Tank, piping, supports, end plates	AISI 304 SS (316 Optional)
Fasteners	AISI 304 SS (316 Optional)

Enviro-Care™
A WAMGROUP® Company
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ecsales@Enviro-Care.com
www.Enviro-Care.com

JWC Environmental®
Trust Monster Quality™

Muffin Monster®

HONEY MONSTER®

Overview

The automated Honey Monster receiving and screening system quickly tracks and screens septage, grease or sludge to remove unwanted debris. Our model SRS-XE system uses an auger screw and perforated screening basket with 6mm circular openings to remove rocks, rags, plastics, silverware and other trash. It provides complete protection for downstream equipment and the treatment plant.

The unique combination of grinding, solids removal, washing and dewatering allows a typical septage truck to unload in 5 to 15 minutes. The system is completely enclosed to ensure safety, vector control and to capture foul odors.

The optional 'MonsterTrack' metering and control system uses a flow meter to track septage and provide accurate billing data for the facility and a receipt for the hauler.

Features & Benefits

Advanced Screening and Dewatering

- Auger Monster screen with 6mm perforations removes unwanted solids and trash
- Perf screen captures far more than bar screens
- Patented dual compartment compaction zone provides significant additional dewatering

Easy Access, Pivoted Auger

- The auger is mounted to a pivot support for easy inspections and removal
- A forklift or crane can lift and swivel the screening trough and auger out of the tank

Dual-Shafted Grinder

- Muffin Monster® grinder maximizes surface area of solids for better washing and compacting

Triple-manifold Wash Water System

- Washes soft organics off of captured debris
- Ensures optimal throughput while minimizing odors

High Level Ultrasonic Sensor

- Regulates plug valve for optimum performance
- Baffles prevent overflow conditions

Optional 'MonsterTrack' System

- Records driver information and measures flow data
- PIN or card access for security
- Printed transaction receipts
- Data stored on compact flash card
- Ethernet/SCADA connection capable

MonsterTrack

Exclusive Tilt and Swivel Auger

Track Loads with MonsterTrack!

www.jwce.com

Honey Monster®

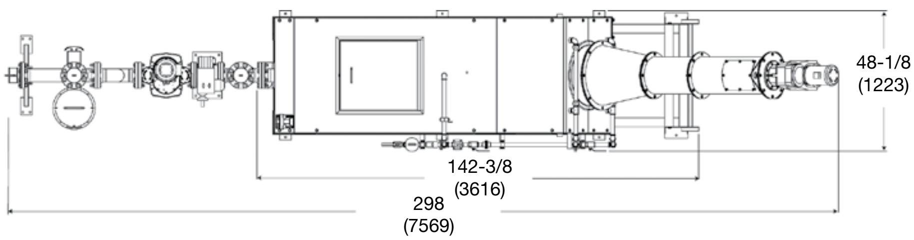
Model: SRS-XE - Septage Receiving with Automated Solids Removal

Materials of Construction

Tank, piping & Support: 304 stainless steel
Auger Assembly: Casings and trough are 304ss; rotor is 480mm Ø alloy steel
Grinder Housing: Ductile iron housings ASTM A536-77
Cutters: Hardened alloy steel
Mechanical Seal Faces: Tungsten carbide

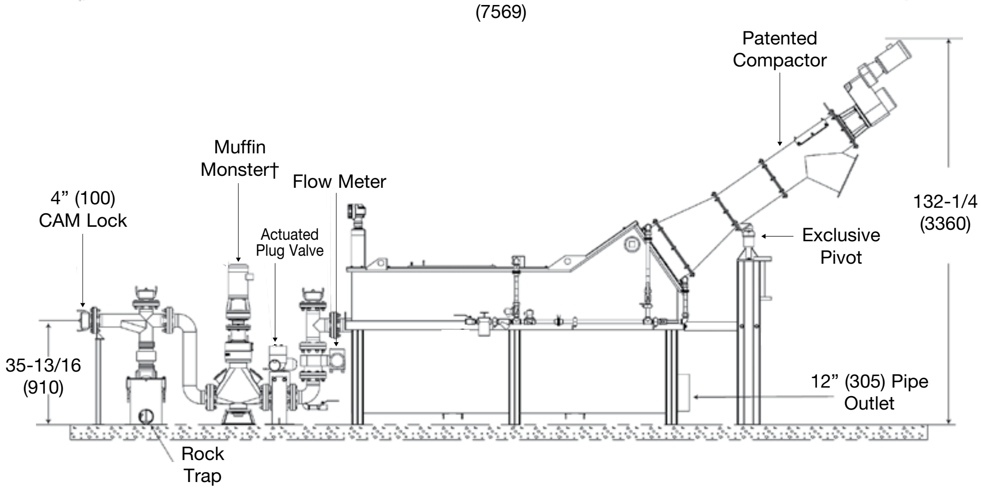
Model	Screen Diameter	Auger Motor	Screenings Capacities	*Typical Septage Flow Capacity
SRS3235-XE	19” (480mm)	2 HP (1.5 kW)	90 ft3/h (2.55 m3/h)	400 gpm (25.2 l/s)

**Up to 63 l/s through tank screen (clean water)* **Recommended max 1 bar*



Configurations

1. Septage Screening
2. Sludge Screening
3. Grease Screening



Options

- 40K Series Muffin Monster grinder for higher-flows
- 6” (150) mm inlet pipeline
- Cold weather protection system
- Discharge bagger
- pH and conductivity sensing loop
- 316 stainless steel pipe and tank
- MonsterTrack billing controller
- Skid mounted system

Rock Trap

Shredded Material Moving Up the Auger Screw for Disposal

Cold Weather Protection and auto bagger

800.331.2277 | jwce.com | jwce@jwce.com

Grease Receiving

Model: GRS - Heavy Object Trap + Muffin Monster

MODEL	Pipe Size - (mm)	Basket Capacity
GRS0103-1804	4 (100mm)	1.1 ft3 (0.03 m3)
GRS0103-2004	4 (100mm)	1.5 ft3 (0.04 m3)
GRS0103-2404	4 (100mm)	*2.2 ft3 (0.06 m3)
GRS0103-1806	6 (150mm)	1.1 ft3 (0.03 m3)
GRS0103-2006	6 (150mm)	1.5 ft3 (0.04 m3)
GRS0103-2406	6 (150mm)	*2.2 ft3 (0.06 m3)

Lifting station recommended to empty basket

Overview

This trap features adjustable bar screens to capture and direct heavy objects into the debris basket. As trucks unload grease, the silverware, rags, knives and other large debris are removed. The Muffin Monster then homogenizes the grease – breaking grease solids into an easy to pump slurry. Optional MonsterTrack billing controller, flow meter and modulating plug valve are also available.

Flow Capacity

- 4" pipe - 400 GPM (25 l/s)
- 6" pipe - 600 GPM (38 l/s)
- Flow Rate - max. 15 psi

Features

- 5HP (3.7) kW Grinder Motor
- Hot Water Wash Down (supplied by others)
- Adjustable bar spacings 1/2" or 1" (12 or 25mm)

Septage Receiving

Model: SRS3000 - Rock Trap + Muffin Monster

MODEL	Pipe Size - (mm)	Basket Capacity
SRS3000-1204	4 (100mm)	**0.18 ft³ (0.005 m³)**
SRS3000-1206	6 (150mm)	**0.24 ft³ (0.007 m³)**

Overview

This small rock trap is a good choice for small sites receiving only a few thousand gallons per day. The perforated screening basket has 1/2" (12mm) circular openings and captures rocks and silverware.

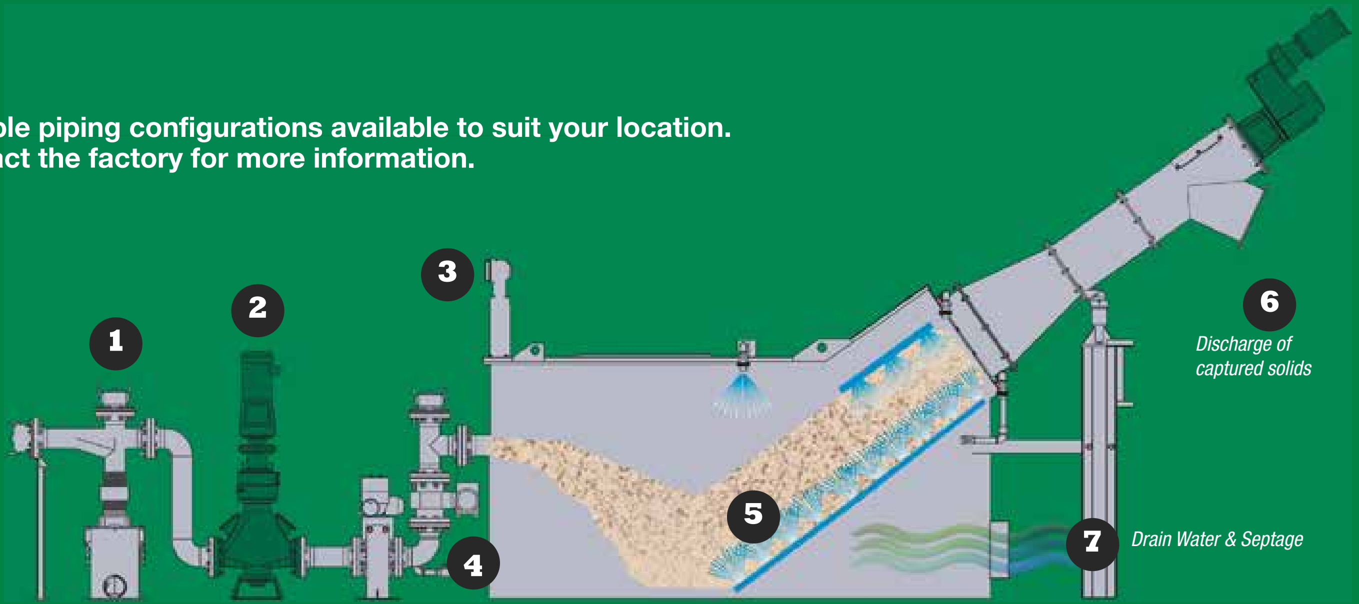
Flow Capacity

- 4" pipe - 400 GPM (25 l/s)
- 6" pipe - 600 GPM (38 l/s)
- Flow Rate - max. 15 psi

Features

- 5 HP (3.7 kW) Grinder Motor

Multiple piping configurations available to suit your location.
Contact the factory for more information.



Operation

1) Haulers connect to the cam lock inlet and start the flow of septage which first passes through the rock trap.
2) Muffin Monster grinds-up solids.
3) Ultrasonic level sensor and modulating plug valve regulate flow.
4) If the 'MonsterTrack' option is installed, the flow meter sends data to the controller.
5) Septage and solids now enter the perf screening trough. Spray wash cleans the solids and keeps the screen clear.
6) The unwanted solids are captured by the inclined auger screen and transported to the compaction zone for additional dewatering before being discharged.
7) The screened septage now safely flows into the wastewater treatment plant.

Skid Mounted System

Muffin Monster®

MonsterTrack™ Billing Controller

Heat Tracing and Blanket

Optional Endless Bagger

JWC Environmental®
Trust Monster Quality™

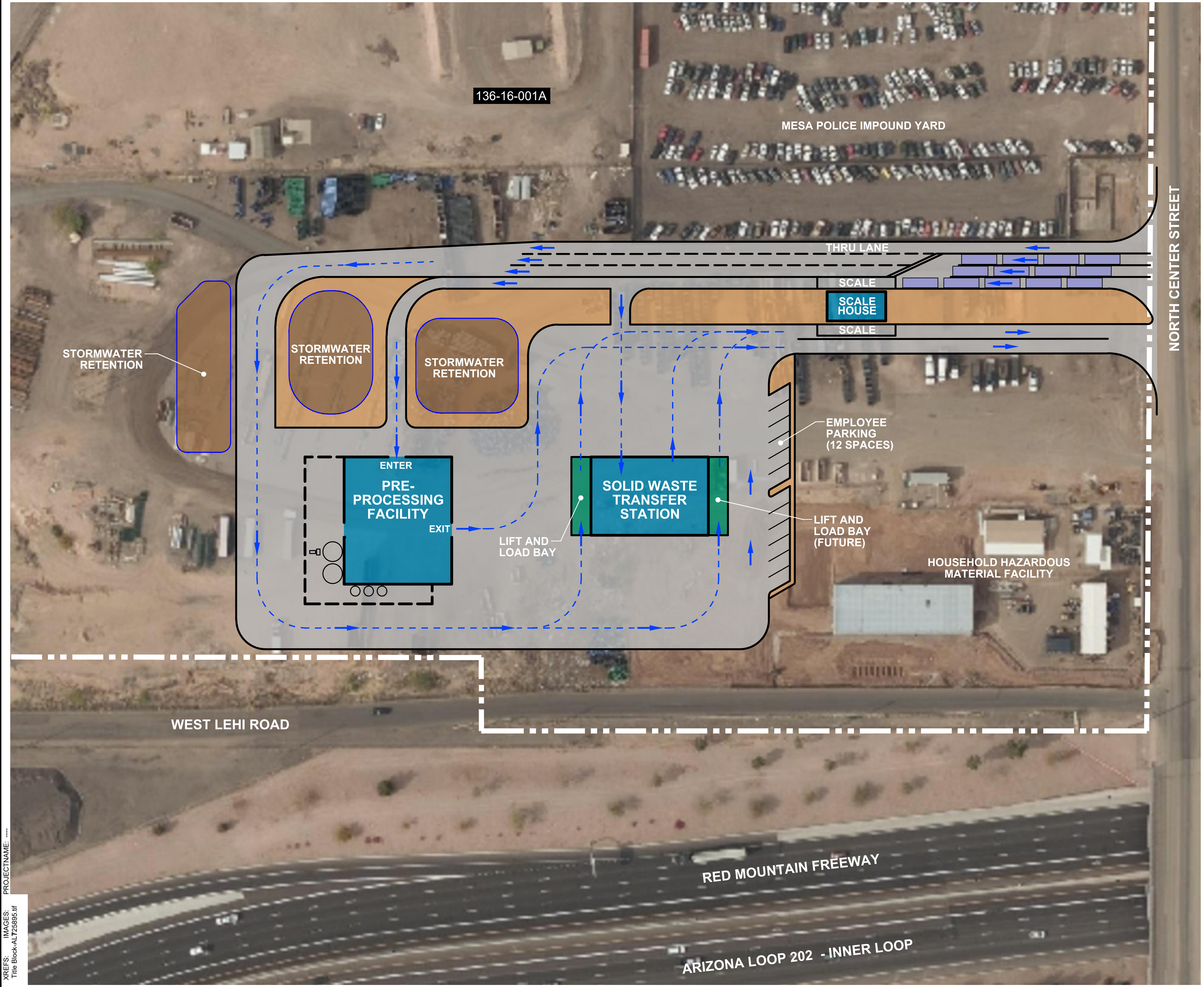
Headquarters
2850 S. Red Hill Ave., Suite 125
Santa Ana, CA 92705 USA
toll free: **800.331.2277**
phone: **949.833.3888**
fax: **949.833.8858**
email: **jwce@jwce.com**

www.jwce.com

(HoneyMonster-NA-JWCE-1216)

APPENDIX E

Site & Facility Layout Figures



LEGEND:

- PROPERTY BOUNDARY (APPROXIMATE)
- TYPICAL TRUCK ROUTE
- PROPOSED ASPHALT
- PROPOSED LANDSCAPE AREA
- PROPOSED STORMWATER RETENTION
- 36' WASTE TRUCK STACK (13)

NOTES:

1. APPROXIMATE PROPERTY BOUNDARY PROVIDED BY THE MARICOPA COUNTY ASSESSOR'S OFFICE (maps.mcassessor.maricopa.gov).
2. AERIAL PHOTOGRAPH PROVIDED BY MICROSOFT CORPORATION 2019 DigitalGlobe.
3. TURNING RADIUS AS SHOWN ACCOMODATE CITY REFUSE TRUCK (17' WHEELBASE) AND STAA-STANDARD (US) CALTRANS 2012 SEMI-TRUCK (40' TRAILER).
4. THIS SITE LAYOUT ASSUMES NO PUBLIC ACCESS.
5. SEE FIGURE 5-2 FOR PRE-PROCESSING FACILITY.
6. SEE FIGURE 5-3 FOR SOLID WASTE TRANSFER STATION.

0 100' 200'

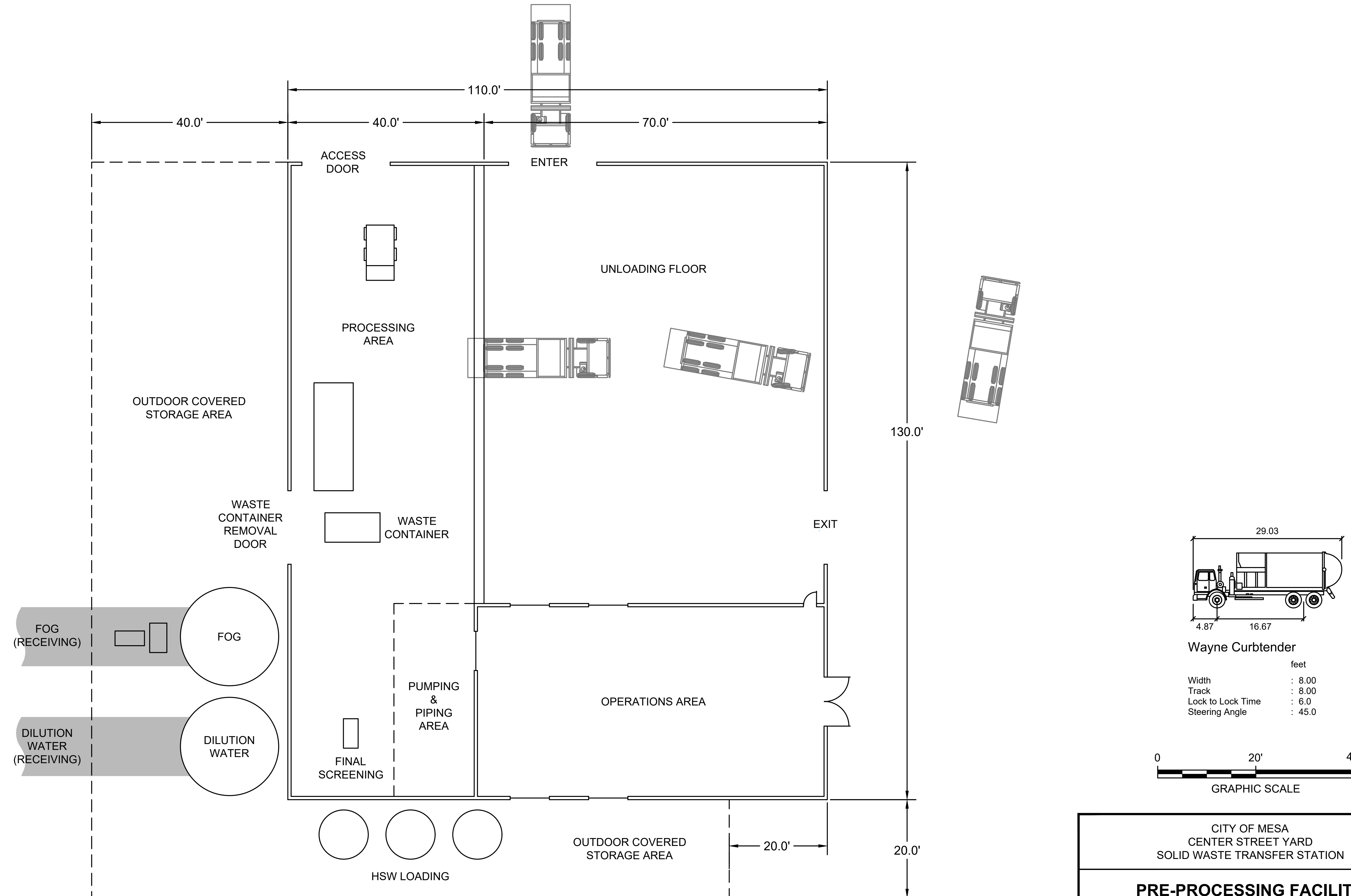
GRAPHIC SCALE

CITY OF MESA
CENTER STREET YARD
SOLID WASTE TRANSFER STATION

CONCEPT SITE LAYOUT

ARCADIS Design & Consultancy for natural and built assets

FIGURE 5-1



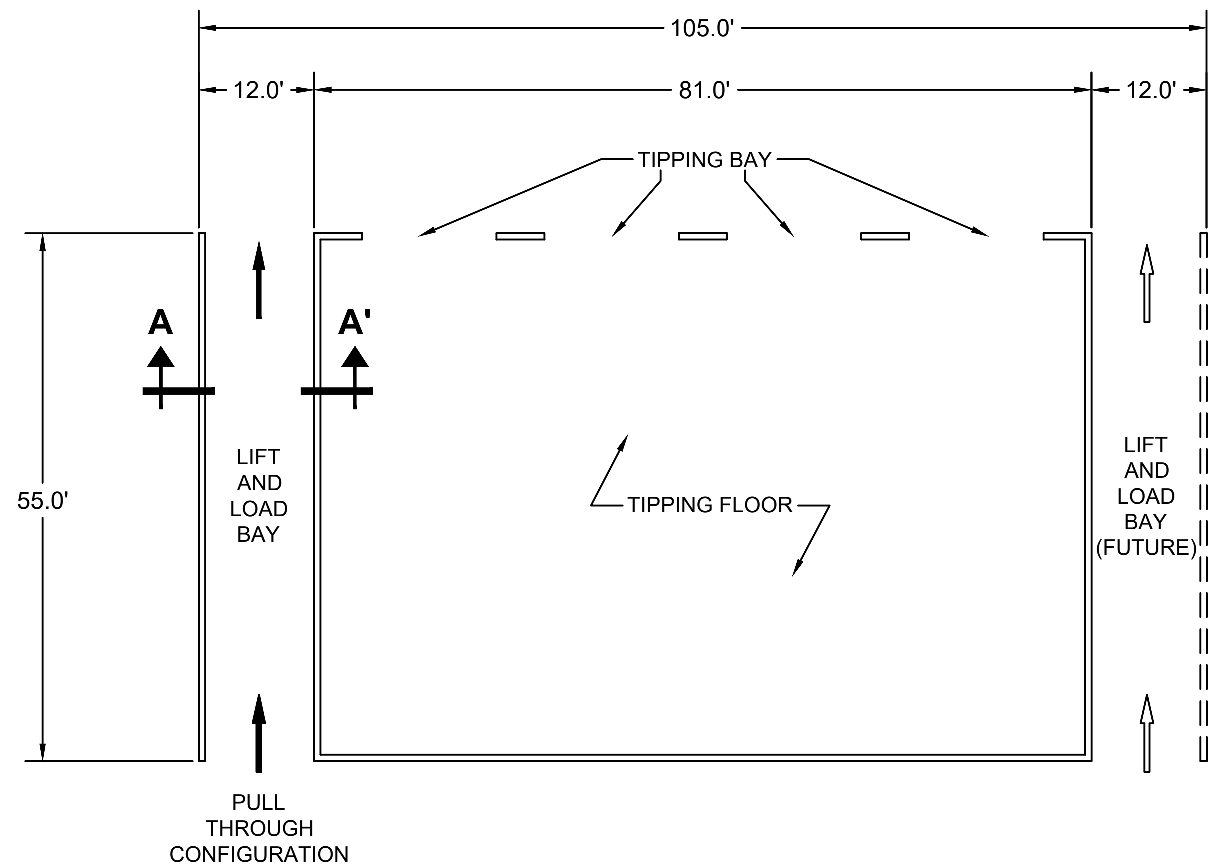
CITY OF MESA
CENTER STREET YARD
SOLID WASTE TRANSFER STATION

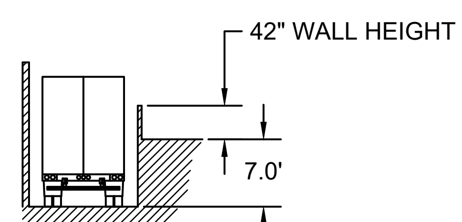
PRE-PROCESSING FACILITY
CONCEPT FLOOR PLAN

ARCADIS Design & Consultancy for natural and built assets

FIGURE
5-2

CITY: SYRACUSE NY DIV/GROUP: ENVCAD DB: E. KRAHMER PIC: PM: TM: TR: LYR:(Opt)ON=*;OFF=*REF*
C:\BIM\OneDrive - ARCADIS\BIM 360 Docs\ANA - CITY OF MESA\NWWRP FOOD TO ENERGY\2019\00678068.0000\01-DWG\0870 Mesa PPF_siteplan_V2.dwg LAYOUT: 5-2 SAVED: 7/12/2019 11:04 AM ACADVER: 23.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 7/12/2019 12:18 PM BY: KRAHMER, ERIC
XREFS: IMAGES: PROJECTNAME: ----
Title Block-ALT Conceptual Floor Plan.jpg





SECTION A-A'

0 20' 40'

GRAPHIC SCALE

CITY OF MESA
CENTER STREET YARD
SOLID WASTE TRANSFER STATION

SOLID WASTE TRANSFER STATION
CONCEPT FLOOR PLAN

ARCADIS Design & Consultancy for natural and built assets

FIGURE
5-3

APPENDIX F

Cost Estimates

Basis of Cost for Pre-Processing Facility Structure

- Area inside the building walls @ $225/sq. ft.

Unloading area	90’-0” x 70’-0”
Processing area	130’-0” x 40’-0”
Operations area	40’-0” x 70’-0”

14,300 x $225 = $3,217,500

- Exterior area covered but not enclosed @ $175/sq. ft.

HSW loading area	130’-0” x 20’-0”
Storage area	130’-0” x 40’-0”

7,800 X $175 = $1,365,000

Total = $4,582,500

Basis of Cost for Pre-Processing Facility Site Work

- From the Center Street Yard Solid Waste Transfer Station civil site work cost estimate, the total cost *without* contingency is $1,845,570.
- The cost of two scales is $140,400 and the scale house cost is $27,100 which was deducted from the $1,845,570 = $1,678,070.
- The site work cost for just the Pre-Processing Facility was then assumed to be 1/3 of that resulting number $1,678,070 x 0.33 = $553,800 plus the cost of one scale $70,200 for a total cost of $624,000.

Project Name: Task 9 - Center Street Yard Solid Waste Transfer Station
Project Number: 30001583
Date: 8/21/2019

Preliminary

Opinion of Probable Cost

Line Item No.	Description of Work	Quantity	Unit	Unit Cost ($)	Total Cost ($)	Notes
1	mobilization / demobilization	1	ls	$ -	$ 76,805.19	5% Of items 3 thru 22
2	site preparation	30,976.0	sq. yd.	$ 1.09	$ 33,763.84	clearing and disposal of existing items
3	site grading and subgrade preparation	278,800.0	sq. ft.	$ 2.75	$ 766,700.00	estimated from site plan
4	finish grading	30,976	sq. yd.	$ 1.11	$ 34,383.36	estimated from site plan
5	earthwork	4,700	cu. yd.	$ 0.92	$ 4,324.00	Transfer station and detention ponds
6	asphalt (4 " bituminous asphalt over 8" aggregate base course)	20,497	sq. yd.	$ 27.28	$ 559,158.16	Asphalt $17.07/sq. Yd ABC 10.21/sq. Yd.
7	6" concrete curb	625	lf.	$ 6.10	$ 3,812.50	Parking lot edging
8	sewer lateral (6" dia)	390	lf.	$ 4.36	$ 1,700.40	estimated from site plan
9	sanitary sewer main (8" dia)	528	lf.	$ 6.10	$ 3,220.80	estimated from site plan
10	sanitary sewer manhole (4' dia)	2	ea.	$ 3,076.00	$ 6,152.00	estimated from site plan
11	waterline (C 900 8" Dia.)	1,670	lf.	$ 13.99	$ 23,363.30	Loop from intersection of North Center and Lehi Rd. and project entrance at North Center
12	water service 2"	100	lf.	$ 27.60	$ 2,760.00	estimated from site plan
13	fire hydrant	2	ea.	$ 2,300.00	$ 4,600.00	estimated from site plan
14	roadway asphalt repair from utility installation	721	sq. yd.	$ 27.28	$ 19,668.88	Waterline and sanitary sewer line in Lehi Road
15	valley gutter (4' wide reinforced concrete)	750	lf.	$ 23.73	$ 17,797.50	Concrete valley gutters draining to detention ponds
16	erosion control	1	ls	$ 10,000.00	$ 10,000.00	Lump sum budget item
17	site lighting	1	ls	$ 10,000.00	$ 10,000.00	Lump sum budget item
18	dry utilities (power, fiber)	1	ls	$ 10,000.00	$ 10,000.00	Lump sum budget item
19	signage	1	ls	$ 5,000.00	$ 5,000.00	Lump sum budget item
20	fencing (6' chain link)	1,400	lf.	$ 22.77	$ 31,878.00	Fencing around project perimeter and road to North Center Street
21	fencing (6' block wall)	610	lf.	$ 19.60	$ 11,956.00	Wall along West Lehi Road frontage
22	Landscaping	56,640	sf	$ 0.17	$ 9,628.80	estimated from site plan
23	Scale	2	ea.	$ 70,200.00	$ 140,400.00	Pit less scale, remote reader and printing device, concrete ramps at approach and exit
24	Scale House	1	ea.	$ 27,100.00	$ 27,100.00	10' x 10' pre-engineered / AC / door and window / plug and play wiring and communications
25	Construction Survey				$ 31,397.35	2% of items 2 thru 22
	TOTAL WITHOUT CONTINGENCY				**$ 1,845,570.08**	

Notes: 1.) Based on Concept Site Plan - Fig 5-2

2.) Cost from RS Mean with application of 0.92 cost adjustment for City Index for Mesa AZ

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Preliminary

Opinion of Probable Cost

Component	Total Cost[1]	Total Cost -30%	Total Cost 50%	Notes
Sitework[2]	$624,000	$436,800	$936,000	33% of Civil/Sitework, incl. one scale.
Pre-Processing Facility Building	$4,582,500	$3,207,800	$6,873,800	incl. 14,300sf interior @ $225/sf, 7,800sf exerior @ $175/sf
Depackaging System	$766,800	$536,800	$1,150,200	vendor quote + installation
Grit Screening	$49,000	$34,300	$73,500	vendor quote + installation
FOG Receiving	$427,700	$299,400	$641,600	vendor quote + installation
Storage, Pumping Systems & Piping (FOG, HSW, etc.)	$250,000	$175,000	$375,000	estimated pumps, tanks, piping
Subtotal	**$6,700,000**	**$4,690,100**	**$10,050,100**	
Indirect Costs				
General Conditions (8%)	$536,000	$375,200	$804,000	8% of Direct Subtotal
Overhead, Mob/Demob, Bond, Insurance (12%)	$804,000	$562,800	$1,206,000	12% of Direct Subtotal
Total Indirect Costs	**$1,340,000**	**$938,000**	**$2,010,000**	
Other Costs				
Profit (8%)	$643,200	$450,200	$964,800	8% of Direct + Indirect Subtotals
Total Other Costs	**$643,200**	**$450,200**	**$964,800**	
Subtotal	**$8,683,200**	**$6,078,300**	**$13,024,900**	**Total without Contingency**
Contingency (20%)	$1,736,600	$1,215,600	$2,604,900	20% of Total
Total Estimated Probable Construction Cost	**$10,419,800**	**$7,293,900**	**$15,629,800**	**Total with Contingency**

[1]The following items are excluded from the Opinion of Probable Construction Cost:
- Geotechnical Investigation & Site Remediation
- Design and Permit Fees
- Rolling Equipment, Dumpsters, and Misc. Ancillary Items
- Control System Programming

[2]Assumes only sitework for Pre-Processing Facility as stand-alone installation without adjacent similar facilities.

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APPENDIX C

Anaerobic Digestion Capabilities Concept Memorandum

ARCADIS Design & Consultancy for natural and built assets

CERTIFICATE NO. 39480 BRIAN J. BUBELA Date Signed 9-19-2019 ARIZONA, U.S.A.

City of Mesa, Arizona

FOOD TO ENERGY CO-DIGESTION FEASIBILITY STUDY

Anaerobic Digestion Capabilities Concept Memorandum

FINAL

September 2019

CONTENTS

APPENDICES

ACRONYMS AND ABBREVIATIONS

AOC	Abnormal Operating Conditions
ASU	Arizona State University
BMP	Biochemical Methane Potential
Cf	Cubic Feet
CH_4	Methane
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2e	CO_2 emissions equivalents
COD	Chemical Oxygen Demand
CFR	Code of Federal Regulations
DGE	diesel gallon equivalence
DIGs	Anaerobic Digesters
dtpd	Dry tons per day
EPA	Environmental Protection Agency
FOG	Fat, Oil, and Grease
fps	Feet Per Second
GBTs	Gravity Belt Thickeners
GHG	Greenhouse Gas
gpm	gallons per minute
gpd	gallons per day
H_2S	Hydrogen Sulfide
HHV	Higher Heating Value
HP	horsepower
kWh	kilowatt hour
lbs	pounds
mmBtu	One Million British Thermal Units
MT	metric tons
NG	Natural Gas
NH_4-N	Ammonia Nitrogen
NWWRP	Northwest Water Reclamation Plant
OLR	Organic Loading Rate
O&M	Operations and Maintenance
OSW	Organic Solid Waste
PS	Primary Sludge
PSA	Pressure Swing Absorption
psig	pounds per square inch
RIN	Renewable Index Number
RNG	Renewable Natural Gas
SCFH	Standard Cubic Feet per Hour
SCFM	standard Cubic Feet per minute
sCOD	Soluble Chemical Oxygen Demand
SRT	Solids Retention Time
TAS	Thickened Waste Activated Sludge
tCOD	Total Chemical Oxygen Demand
TKN	Total Kjeldahl Nitrogen
TOX	Thermal Oxidizer
tpd	tons per day
TS	Total Solids
TSS	Total Suspended Solids
VS	Volatile Solids
VSS	Volatile Suspended Solids
VSR	Volatile Solids Reduction
WAS	Waste Activated Sludge
wt	wet tons

1 INTRODUCTION

The objective of this Anaerobic Digestion Capabilities Concept Memorandum is to evaluate the feasibility of implementing co-digestion of organic waste feedstock, such as commercial food waste, or organic solid waste (OSW) and/or fats, oils, and grease (FOG), with municipal wastewater sludge at the Northwest Water Reclamation Plant (NWWRP) in Mesa, Arizona. The two anaerobic digesters at NWWRP have excess organic solids loading capacity and therefore have the potential to accept additional organic waste that would otherwise go to landfills. Acceptance of this waste will also increase biogas production which could be used for generating electricity and/or the production of renewable natural gas (RNG). The City of Mesa owns and operates a local natural gas distribution piping network and solid waste collection fleet utilizing CNG trucks, creating a favorable partnership opportunity to pursue this co-digestion project.

In order to evaluate NWWRP's co-digestion capabilities, an interactive Mass and Energy Flow Model (Flow Model) was developed – a tool that dynamically and holistically tracks flows of solids and energy in its various forms throughout the treatment processes. Multiple scenarios were evaluated in the model to determine optimal and operationally friendly loading rates for OSW and FOG and how resulting biogas can be best utilized. The following five sets of scenarios were examined:

Set 1: Co-generation without Mixed HSW organic slurry addition

Set 2: Co-generation with Mixed HSW organic slurry addition

Set 3: RNG Generation with Mixed HSW organic slurry addition

Set 4: Co-generation and RNG Generation with Mixed HSW organic slurry addition

Set 5: Participation in the Low Carbon Fuel Standard (LCFS) Program

The scenarios evaluated examine the optimal amount of mixed HSW organic slurry loading to digesters to conform with operational best practices to limit digester loading rates and deliver pumpable material to NWWRP. Another important variable was examined as to whether just one or both digesters should be accepting imported organic feedstocks, as accepting imported waste in just one digester could preserve partial D3 RIN classification; for further information explaining D3 versus D5 RIN classifications, refer to 'Tech Memo 6 – Biogas Utilization & Project Incentives'. Another variable evaluated was the biogas utilization options of generating electricity with a CHP system or producing RNG via a new biogas upgrading system. The scenarios are evaluated based on annualized savings which includes both annualized capital costs and annual O&M considerations. Also quantified for each scenario is the Scope 2 greenhouse gas (GHG) emission reduction, which gives insight into the optimization of energy use and sustainability benefits of each scenario. The purpose is to both determine the design sizing parameters for the pre-processing facility proposed at the City's Center Street Yard and to identify the most beneficial end use for the biogas produced at NWWRP.

2 EXISTING CONDITIONS

Available plant data, field information obtained from site visits, and discussions with plant operational staff were used to quantify parameters of existing solids and energy processes. The processes considered are those included in the Flow Model, which starts at the solids generating processes (primary and secondary clarifiers) and traces the solids and energy flows to final end use of biosolids and biogas. Liquid process stream attributes of the plant and energy usages due to pumping are not incorporated into this analysis, however nutrient recycling loads from side streams was considered. The following sections provide a summary of the existing processes and corresponding input parameters to the Flow Model.

2.1 Primary and Waste Activated Sludge

Primary sludge (PS) is pumped from the primary clarifiers and the waste activated sludge (WAS) is pumped from the secondary clarifiers into a blend tank, located in the Solids Handling Building. The Plant previously operated both a PS wet well and an WAS wet well in parallel. However, due to the volume of sludge flows, the WAS storage tank was found to have sufficient blending volume for all sludge flows and the PS storage tank was taken out of regular use.

Daily and monthly flow data for both PS and WAS were provided by Plant staff, as well combined flow of PS and WAS into the blend tank. Daily and monthly data was provided on the % Total Solids (TS), TS loading, % Volatile Solids (VS), and VS loading for the combined PS and WAS flow into the Blend Tank. From these values, average solids loading of PS and WAS were generated as shown in Table 1.

Table 1. Average Primary Sludge and Waste Activate Sludge Parameters

Parameter	Primary Sludge (PS)	Waste Activated Sludge (WAS)	Unit
Flow	260,900	112,100	gallons/day
Total solids	1.0%	0.8%	%
Total Solids	21,400	7,200	lbs/day
Volatile Solids	79%	79%	%
Volatile Solids	17,000	5,700	lbs/day

2.2 Sludge Thickening

The Plant typically operates one centrifuge continuously, seven days per week. The design hydraulic loading of each centrifuge is 500 gpm and NWWRP staff stated that the centrifuges are currently running at half capacity. The centrifuge thickened sludge is discharged to a thickened sludge well below and then pumped by progressive cavity thickened sludge pumps to the digesters via the sludge heating and recirculation line. Table 2 shows the estimated sludge parameters in and out of the thickening centrifuges. The TS feed to the two digesters occur in alternating batch operations where 600 gallons are pumped to one of the two digesters then valving alternates and 600 gallons are pumped to the other digester. The alternating digester feeding process is continuous.

At times, the TS batch feed is increased to 1,000 gallons to coincide with Caterpillar generator peak-shaving operations (Genset Operations) so as to produce additional biogas and extend the biogas runtime to about 5 hours before Genset operations are switched to natural gas fuel for the remainder of the 12-hour peak-shaving period. The sludge loads as summarized in Table 1 and Table 2 were used as the primary inputs to the Solids and Energy Flow Model.

Table 2. Blended Sludge and Thickened Sludge Parameters

Parameter	Unthickened Blend Sludge	Thickened Blended Sludge	Unit
Average Flow	373,000	69,600	gallons/day
Total Solids	0.9%	4.9%	%
Total Solids	28,600	28,600	lbs/day
Volatile Solids	79%	79%	%
Volatile Solids	22,700	22,700	lbs/day

2.3 Anaerobic Digestion

NWWRP operates two active primary egg-shaped digesters. Both digesters have a capacity of 875,000 gallons (116,979 cf). The primary digesters are fed relatively equal mixes of sludge types on a time-based feeding operation. The existing NWWRP egg-shaped digester shape improves mixing efficiency and promotes the resuspension and removal of grit and other heavy materials. The existing draft-tube mixing system is a positive means of mixing the surface of the digester controlling scum and foaming, thereby ensuring a more homogeneous biosolid product. Philadelphia Mixing Solutions, the existing draft tube manufacturer, has confirmed that the existing draft tube mixing would provide sufficient mixing for the estimated Co-Digestion operations with the addition of Mixed HSW at the following parameters: 42,000 gpd flow, 6.2% TS and 400 cP viscosity at 98^{o}F.

The digesters have a recirculation heating system through which sludge is drawn through four centrifugal sludge heating recycle pumps (two standby) and three tube-in-tube sludge heat exchangers (one standby), heated by a hot water loop and pumped back to the digesters. The recycle pumps have a rated capacity of 250 gpm each. The sludge heat exchangers are rated for a sludge flowrate of 150 gpm each. The heating supply comes from a plant hot water loop that is heated by a set of boilers. Plant staff report that these boilers are exclusively fired off natural gas Table 3 and Table 4 summarize the digestion loading and performance parameters determined from provided plant data. The Solids and Energy Flow Model was calibrated to align digester parameters and outputs to the data summarized in Table 3 and Table 4.

Table 3. Digester Loading Parameters

Parameter	Digester 1	Digester 2	Total	Unit
Average Flow	35,240	34,330	69,570	gallons/day
Total Solids	4.9%	4.9%	4.9%	%
Total Solids	14,510	14,130	28,640	lbs/day
Volatile Solids	79%	79%	79%	%
Volatile Solids	11,500	11,200	22,700	lbs/day

Table 4. Digester Performance Parameters

Parameter	Digester 1	Digester 2	Total	Unit
Solids Retention Time	24.8	25.5	25.2	Days
Volatile Solids Reduction (VSR)	7,030	6,850	13,880	pounds/day
% Volatile Solids Reduction	61%	61%	61%	%
Gas Yield	13.7	13.7	13.7	Cf/ lb VSR
Organic Loading Rate	0.10	0.10	0.10	lb VS/cf/day
Biogas Produced	66.9	65.2	132.1	Scfm
Biogas HHV	616	616	616	Btu/cf
Biogas Energy Production	2.47	2.41	4.88	mmBtu/hr

NWWRP's digester parameters as derived from plant data appear to be within the typical targets or typically expected ranges, indicating that data derived values can be considered accurate. The VSR value of 61% is somewhat higher than the typical value of 45-55%, however, NWWRP digests approximately 3 times more PS than WAS on a mass loading basis, which would increase the expected %VSR. The digester parameter of Gas Yield aligns with the literature value range of 12 to 18 ft^3/lb of volatile solids destroyed, which also suggests accuracy in the biogas metering and VSR data.

2.4 Sludge Dewatering

Digested sludge is sent to the digested sludge well, located in the Digester Control Building. The digested sludge is then sent from the digested sludge wet well through grinders and pumped to the centrifuges digested sludge pumps which are capable of handling 3% - 4% TS, as confirmed by the Plant Staff.

The dewatering centrifuges are located on the upper level of the Solids Handling Building. There are two dewatering centrifuges with one unit typically in service (one standby). The system is designed to run one centrifuge at a continuous hydraulic loading rate of 150 gpm. According to available hourly flow data, the dewatering centrifuges appear to operate for 8 hrs/day for 5 days/week and sends the dewatering centrate into the sewer directed toward the 91st Avenue WRP. A polymer dosing rate of approx. 5.8 gallons per dry ton was provided by NWWRP staff.

Table 5 and Table 6 present the current dewatering loading and performance parameters developed from the data and calibrated for alignment in the Solids and Energy Flow Model. The Flow Model is utilized to predict dewatering loads and associated discharge cake as well as energy and polymer consumption as a function of the digester output performance.

Table 5. Current Dewatering Loading Parameters

Parameter	Digested Sludge	Unit
Average Flow	69,570	gallons/day
Total Solids	2.7%	%
Total Solids	15,830	lbs/day
Volatile Solids	65%	%
Volatile Solids	10,240	lbs/day

Table 6. Current Dewatering Operations and Performance Parameters

Parameter	Dewatering Centrifuges	Unit
Operation Hours per Week	8 hrs/day, 5 days/week (40 hours/week)	
Typical Units in Service	1	
Estimated Hydraulic Loading per Unit	48	gallon/minute
Design Hydraulic Loading per Unit	150	gallon/minute
Design Power Draw per Loading	250	HP/ gallon/minute
Estimated Total Power Draw	80	HP
Polymer Dose	5.83	gallon/dry ton
Polymer Cost	$ 7.96	$/gallon
Annual Polymer Cost	$ 96,200	$/year

2.5 Final Solids Outlet

The dewatered digested sludge, or biosolids cake, is deposited into two cake storage hoppers located directly below the centrifuges in the Solids Handling Building. The hopper then deposits the biosolids directly into hauling trucks in an enclosed and odor controlled loading bay on the first floor of the Solids Handling Building.

NWWRP currently uses a contract hauler to deliver the dewatered sludge cake to a privately-owned landfill. Biosolids are offloaded 5 days per week. On average, NWWRP pays their contract hauler $14.25 per wet ton for disposal to a landfill as daily cover, making the final solids outlet relatively cost effective.

Final solids disposal data for wet mass hauled and contracted cost provided by NWWRP staff was used as a final check to ensure that the Solids and Flow Model was calibrated to current conditions. Final mass hauled from the plant is typically the most accurate and cost sensitive data being recorded for solids management programs. Table 7 compares the recorded NWWRP hauled loads and cost to the same baseline values generated through the Flow Model.

Table 7. Final Biosolids Disposal Parameters

Parameter	2017 - 2018 Solids Outlet NWWRP Data	Flow Model Values Dewatered Biosolids	Unit
Wet Solids	59,380	59,520	lbs/day
Total Solids	21.8%	21.8%	%
Total Solids	12,950	12,980	lbs/day
Volatile Solids	65%	65%	%
Volatile Solids	8,380	8,400	lbs/day

Due to the relatively affordable biosolids disposal costs, it is not recommended that the City of Mesa investigate the feasibility and benefits of more advanced biosolids treatment, such as generating Class A biosolids.

2.6 Biogas Utilization

Biogas is collected from a gas dome at the top of each digester and piped to the lower level of the Digester Control Building where gas is sent through two foam separators, one dedicated to each digester. The biogas lines are then joined into one 10-inch header and sent below grade to the gas compressor room attached to the Solids Handling Building.

In the gas compressor room, NWWRP currently operates a gas conditioning system consisting of a compressor and a dryer for moisture removal. As reported by Plant Staff, the liquid ring compressor is sized for 220 cfm and operates at its upper pressure limit of 80 psig which then feeds the downstream gas dryer designed for the same pressure. There is a recirculation loop with a globe valve located in the compressor room that allows compressed and dried biogas discharge to be recycled back to the compressor suction to allow for enhanced control of biogas flow rates through the compressor. The compressor suction pressure increases as the gas pressure downstream (in storage tank) increases which requires adjustment of the recirculation globe valve to compensate. The compressor will shut down if the compressor suction pressure drops to 4.5” W.C. and trigger a low suction pressure alarm. After treatment via the gas conditioning system, the pressurized biogas is fed either directly to the cogeneration engine or to a pressurized digester gas storage tank.

The existing single engine unit is a Caterpillar G3512E, which operates on biogas or natural gas (but not a blend) at 1.5 psig. Currently, biogas directly from the digester is supplemented with biogas from the storage tank or natural gas to peak shave electrical utilization during peak daytime hours. Normal engine operation takes place between 11am – 11pm during Summer and Summer – Peak seasons, and 5am – 9 am & 5pm – 9pm during the Winter season. During these peak periods, there are additional price increases during daily ‘On-Peak’ periods as compared to ‘Shoulder-Peak’ periods.

Table 8 shows the comparison of costs associated with electrical power costs during seasonal and daily periods.

Table 8. 2018 Costs Associated with Electrical Power Costs

	Off-Peak		Shoulder-Peak		On-Peak	
Season	hrs/day	$/kWh	hrs/day	$/kWh	hrs/day	$/kWh
Summer - Daily [May - Jun, Sep - Oct]	12	$ 0.0439	6	$ 0.1012	6	$ 0.1076
Summer - Peak [Jul - Aug]	12	$ 0.0504	6	$ 0.1063	6	$ 0.1425
Winter [Nov - Apr]	16	$ 0.0405	4	$ 0.0779	4	$ 0.0783

The engine is fed biogas at a rate of 132 scfm directly from the digesters and supplemented with approximately 11 scfm from the digester gas storage tank. As reported by Plant Staff, the engine currently generates 525 kW of electricity when running which is approximately 87.5% of its rated capacity of 600 kW. Based on the fuelling rate of 143 scfm of biogas at 616 Btu/cf HHV producing 525 kW, the engine is estimated to be operating at 23% electrical efficiency, which is below the typical electrical efficiency for a modern cogeneration engine. Engine electrical efficiencies will vary significantly based on size and model type, but engines sized in the 500 to 1,000 kW range are typically 33% to 38% efficient when operating at full rated loads.

The biogas storage tank is currently utilized at the liquid ring compressor’s maximum discharge pressure of 80 psig. Once the storage tank is depleted (which takes approximately five hours under current operations) the engine is switched over to natural gas for about 3 hours as the storage tank is refilled, then switched back over to biogas for the remainder of the peak period. Additional biogas produced during the time in which the engine is operating on natural gas beyond the storage tank capacity, or when the engine is not in operation, is sent directly to the waste gas burner.

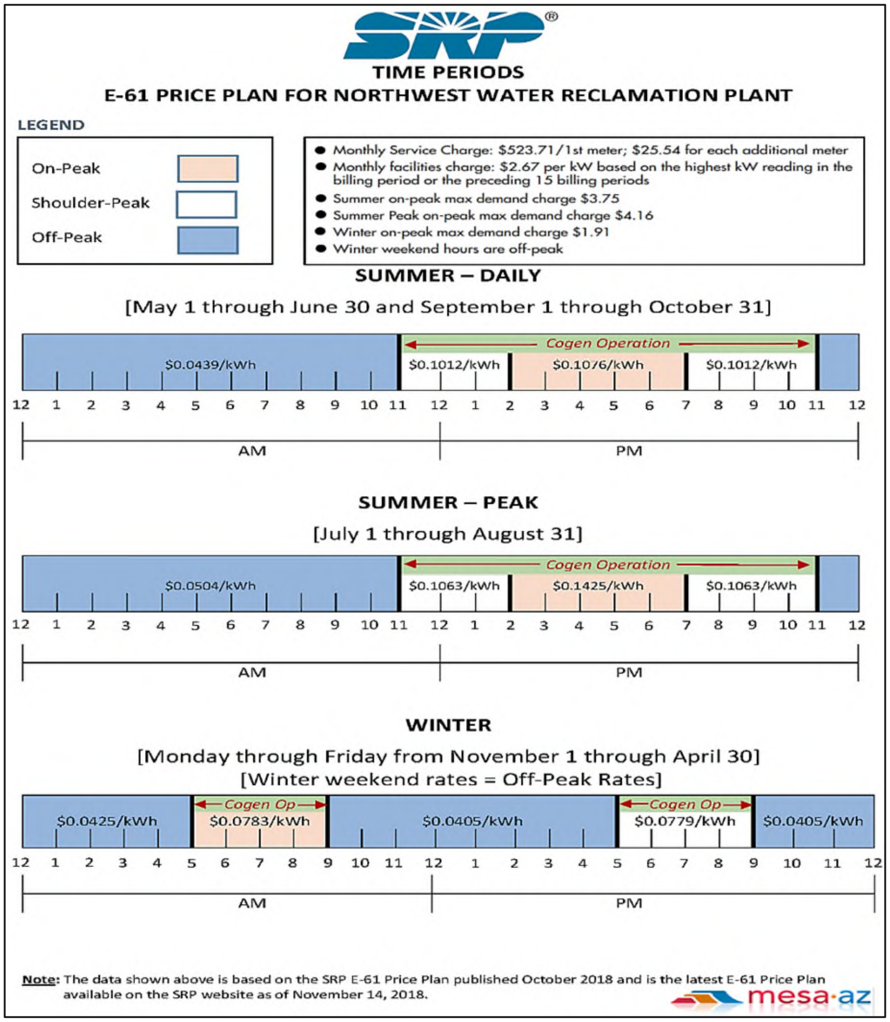


Figure 1. 2018 Price Plan from NWWRP (the City of Mesa)

Average daily gas flows data to the engine are shown in Figure 2 below. From the Nov 2017 to Nov 2018 daily biogas flow data provided, the engine was in operation for 210 days of the year and was in service on average for 10 hours per day. This makes the engine operations approximately 23% uptime or availability. A portion of the engine downtime is intentional due seasonal periods (winter) with relatively low electrical power cost from the utility when the engine is taken offline, with additional general downtime for engine and biogas systems maintenance requirements.

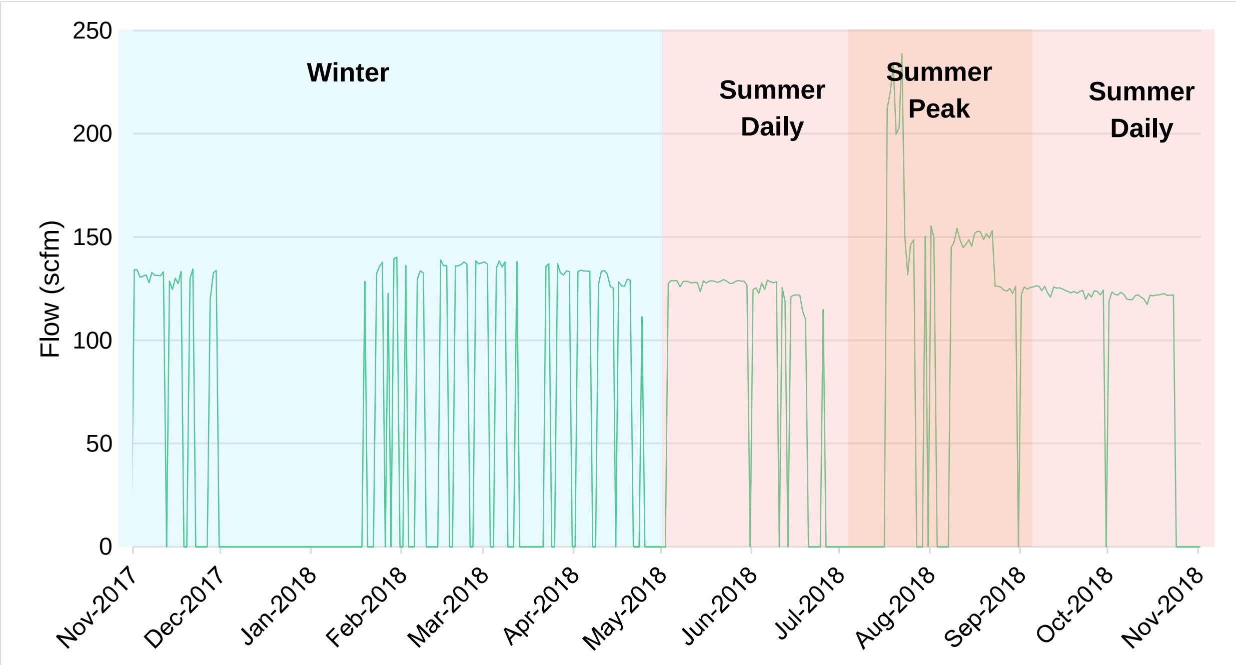


Figure 2. 2018 Seasonal and Daily Costs Associated with Electrical Power Costs

The excess biogas is sent directly to an enclosed flare onsite. The existing enclosed Callidus Technologies Inc. flare was installed in 2000 and is rated to approximately 30,000 scfh of biogas. While evaluating the existing flare's design capacity to under co-digestion conditions it was determined that the flare is significantly aged and NWWRP has no redundancy for digester gas disposal should the existing flare fail.

Additionally, at the current production rate of 132 scfm, or 7,920 scfh, the existing flare is sized for flows nearly 4 times larger than the current biogas flows at NWWRP, likely meaning biogas is incompletely combusted when flared. Even under co-digestion conditions the projected average biogas flow is 18,000 scfh. Therefore, it is recommended that NWWRP replace the current flare system with a new flare system sized to the projected average biogas generation rates.

2.7 Mesa Sanitation CNG Fleet

Compressed Natural Gas (CNG) Fleet – As of 2019, the City of Mesa's compressed natural gas (CNG) fleet has 46 vehicles and is expected to reach 74 vehicles in the next 3 years. From November 2017 to October 2018, Mesa consumed over 625,400 diesel gallon equivalence (DGE) per year (1,710 per day); equating to about $281,800 in fuel charges.

3 ASU DIGESTER BENCH TESTING

The Biodesign Swette Center for Environmental Biotechnology (BSCEB) at Arizona State University (ASU) conducted a bench study to evaluate the potential impact of food waste and FOG addition on anaerobic digestion. ASU evaluated the potential benefits and risks of co-digesting by operating six 2-litre reactors anaerobic digesters inoculated with NWWRP thickened sludge.

Additionally, the City of Mesa performed an OSW Collection Pilot and a Food Audit of local pre-consumer and commercial OSW producers in the area. Under the OSW Collection Pilot, samples of OSW were collected from five vendors of various industry types as shown in Table X. In January 2019, ASU began receiving OSW from City of Mesa, FOG from City of Tempe, and OSW from ASU's cafeterias. Comprehensive sampling of the OSW and FOG were performed as an integral part of research and understand the available OSW in the greater Mesa area.

3.1 Control Bench Digesters

The baseline conditions, or 'control', was developed by ASU by testing the characteristics of the reactors when loaded with thickened sludge directly supplied by NWWRP. All reactors were seeded with thickened sludge and operated at baseline conditions for 2 months to ensure the digesters achieved stability. Testing of the reactors began on October 29th, 2018.

Table 9 presents the ASU reported values thickened sludge characteristics. Table 10 and Table 11 below, compare the ASU reported values to the NWWRP reported values.

Table 9. Bench Thickened Sludge Characteristics

Parameter	Thickened Sludge Feed to Bench Reactors	Unit
Total Suspended Solids (TSS)	46	g SS/L
Volatile Suspended Solids (VSS)	41	g SS/L
TSS/VSS	81.4 %	%
Total Chemical Oxygen Demand (tCOD)	57.8	g COD/L
Soluble Chemical Oxygen Demand (sCOD)	2.6	g COD/L
Alkalinity	880	mg $CaCO_3$/L
Ammonium	149	mg NH_4-N/L
pH	6.2	
Total Kjeldahl Nitrogen (TKN)	2.6	mg N/L

Table 10. Control Bench Digestion Characteristics (Thickened Sludge-Only)

Parameter	ASU Control Bench Reactor	NWWRP Operational Data (For Reference)	Unit
Total Suspended Solids (TSS)	28	19[1]	g SS/L
Volatile Suspended Solids (VSS)	19	13[1]	g SS/L
TSS/VSS	67%	79%	%
Total Chemical Oxygen Demand (tCOD)	30.4	-	g COD/L
Soluble Chemical Oxygen Demand (sCOD)	1.5	-	g COD/L
Alkalinity	4,410	-	mg $CaCO_3$/L
Ammonium	863	549	mg NH_4-N/L
pH	7.4	7.4	
Total Kjeldahl Nitrogen (TKN)	1,700	-	mg N/L
Biogas HHV	568	616	Btu/cf

1. Total dissolved solids assumed to be negligible

Table 11. Control Bench Digestion Parameters (Thickened Sludge-Only)

Digestion Parameters	ASU Control Bench Reactor	NWWRP Operational Data (For Reference)	Unit
Solids Residence Time	25.9	24.8	Days
% Volatile Solids Reduction	48%	61%	%
Gas Yield (cf/lb VSR)	21.1	13.7	cf/lb VSR
Organic Loading Rate	0.09	0.10	lb VS/cf/day

In general, the ASU control reactor accurately represented the NWWRP digesters. The reactor size, thickened sludge feeding frequency, and the reactor mixing is most likely the reason for the disparity between the NWWRP digesters and the ASU reactor(s)the VSR and gas yield.

3.2 OSW and FOG Characterization

Samples of pre-consumer and commercial food waste, or organic solid waste (OSW), were collected from five vendors of various industry types for an OSW collection pilot by the City of Mesa and a bench digestion test performed by Arizona State University (ASU). These samples were analyzed for various characteristics. Descriptions of the OSW generators and result of preliminary feedstock analysis available to date are summarized in Table 12 and Table 13 below.

Table 12. OSW Collection Pilot Testing Vendor and Waste Details

Vendor	Industry Type	Waste Characterization	Observed Contamination
Bashas’	Grocery	Bakery, Deli (meats, sandwiches, sides), Produce (vegetables)	Rigid plastic food containers, cartons,
EVIT	Cafeteria & Restaurant Kitchens	Produce (vegetables)	Film plastics, Flexible plastic beverage containers
United Food Bank	Food Bank	Packaged foods (meat, canned vegetables, baked goods), Produce (fruits & vegetables)	Metal cans, Rigid and flexible plastic containers, Cartons, Film plastics
Mesa Public School	Cafeteria Kitchen	Prepared meals (meat, carbohydrates, produce)	Food wrappings, Flexible plastic beverage containers
Tempe FOG Collective	Grease Interceptor Waste	Fats, Oil, Grease, White water	Sediment, utensils

Table 13. Organic Solid Waste & FOG Characteristics

Food Waste Characteristics	Food Waste ASU Bench Test Values	FOG ASU Bench Test Values	Unit
Total Solids	23%	3.8%	%
Moisture	77%	96.2%	%
VSS/TSS	93.5%	88.5%	%
Total Chemical Oxygen Demand (tCOD)	59.0	13.1	g COD/L
Soluble Chemical Oxygen Demand (sCOD)	208.1	166.4	g COD/L
pH	4.28	4.48	
Protein [Lowry Method]	45%	28%	%
Fats/Lipids	12%	60%	%
Carbohydrates	48%	3%	%

The characteristics, as presented in Table 13, were used to determine the flows and characteristics of mixed HSW organic slurry transferred from the pre-processing facility to NWWRP. Compared to sludge, OSW has a higher percentage of readily degradable solids that may vary based on the specific load.

The reported lipids and carbohydrates percentages are within the expected ranges for commercial food waste and FOG. However, the protein percentages are considerably above the typical ranges. Industry standards for similar food waste streams, such as pre-consumer and commercial kitchens, are reported to have between 15-25% proteins (as % of VS). Therefore, a reading of 48% protein is 2 to 3 times higher than the typical range. FOG is typically 0% proteins (as % of VS); therefore, 28% proteins is not considered to be representative of the average protein content that will be encountered in imported FOG streams.

Biogas production is directly related to the volatile solids destroyed by anaerobic biochemical reactions. Typical biogas yields vary between types of waste being digested, as shown in Table 14. The OSW biogas yield was estimated as 16 cf/lb VS destroyed from available literature values and experience with the typical waste types being targeted for diversion to the digesters. This value will be updated when bench test data becomes available.

Chemical Oxygen Demand (COD) concentration is another parameter typically used for determining the amount of readily degradable organic material within potential digester feedstocks. COD will also be used as a parameter to project and verify biogas production from various feedstocks as the data becomes from bench testing.

FOG is an energy-rich substance which is highly degradable in an anaerobic digester. The benefits of FOG addition on volatile solids reduction (VSR) and biogas yield are well documented. It is assumed that 95% of FOG VS are readily degradable from reported literature values and experience with the unit processes. Gas yield from FOG was assumed to be 20 cf/lb VS destroyed. These values will be updated when bench test data becomes available.

Table 14. Manual of Practice 8 Biogas Production Rates from Various Organic Materials (MOP8, 2017)

Material	Gas Production per unit mass Destroyed Cf/lb VS destroyed
Typical Sludge	13 – 18
Fats/Lipids	20 – 25
Grease	17
Proteins and Carbohydrates	12

Samples of commercial food waste were collected from five vendors of various industry types for an OSW collection pilot by the City of Mesa and a bench digestion test performed by Arizona State University (ASU). Information related to the five vendors and TS percentages for their associated OSW are summarized in Table 15 below. ASU began receiving food waste on January 14, 2019 from the Mesa bench food waste temporary pre-processing at Center Street Hazardous Household Materials (HHM) Facility.

Table 15. City of Mesa Food Waste Audit Results

OSW Source	Type of Source	Total Solids (%)
Trader Joe's	Grocery Store	27.8%
Safeway	Grocery Store	32.5%
Whole Grain Bread Co.	Bakery	57.9%
Organ Pipe Pizza	Restaurant	53.6%
United Food Bank	Food Bank	32.1%
Average		40.8%

Under a full-scale OSW receiving and processing program, it is expected that the characteristics, as shown above, will be representative of the processed HSW. It is planned that following the collection of the waste from generators, the OSW and FOG will be decontaminated and processed into a mixed HSW organic slurry at a separate facility proposed at Center Street Yard. Specific details regarding the proposed site, facility layout, and equipment will be presented separately in the ‘Pre-Processing Facility Concept Memorandum’. Therefore, it can be assumed that the mixed HSW slurry delivered to NWWRP contains negligible contamination.

3.3 Co-Digestion Bench Test Results

ASU introduced food waste into Bench Reactors B - E on January 11, 2019. On January 18, 2019 the food waste loading was ramped on a flow rate basis to 100% and 150% of the thickened sludge flow rate into the reactors. ASU also introduced FOG on January 18, 2019 and ramped up loading on a flow rate basis to 5% and 20% of ‘food waste + thickened sludge’ flow rate as of January 23.

Anaerobic digesters would ideally be fed at a consistent and constant rate to provide optimal conditions for microorganisms to thrive and minimize the potential for upsets from shock loading. To prevent shocking the reactors, ASU began adding small volumes of OSW to reactors on January 11 and FOG on January 21. Reactor feed rates were incrementally increased the until the reactors reached the full target feed rate as shown in Table 16.

At the full target feed rates, all experimental reactors fed and sample (gas & effluent liquid) taken on Mondays, Wednesdays, and Fridays. The ‘control’ reactor feed rates were not altered. Additional gas analysis on Saturday or Sunday was conducted as needed to prevent overfill.

Following discussions between ASU and Arcadis, it was decided that the OSW and FOG slurry fed to the digesters should be adjusted to 10 - 12% TS target to better match the intended full-scale operating conditions. The characteristics and calculated parameters of ‘the Target Loading’ Reactor are shown below in Table 17.

Table 16. ASU Reactor Operating Conditions

Reactor	Volumetric Feed Ratios			HRT (day)
	Thickened Sludge	OSW (at 12% TS)	FOG	
Baseline (Control)	1.0	0.0	0.0	25.9
Target Loading 1*	1.0	0.3	0.0	20.0
Target Loading 2*	1.0	0.3	0.0	20.0
Higher FW Loading	1.0	0.4	0.0	18.5
Lower FOG Loading	1.0	0.12	0.5	15.5

* Considered most representative of full-scale application operating conditions

Table 17. "Target Loading 1" Reactor Comparison to the Control Reactor

Parameter	Control Reactor	Target Loading 1 Reactor "LS-FW"	Unit
Organic Loading Rate	0.097	0.143	lb VS/cf/day
VS / TS Ratio	67%	73%	%
Soluble COD	1,562	3,676	mg COD/L
Total COD	30,930	35,889	mg COD/L
Ammonium Nitrogen	1,009	1,090	mg NH_4-N/L
Total Kjeldahl Nitrogen	7.9	7.9	mg TKN/L
Orthophosphate	530	590	mg PO_4/L
Total Phosphorus (TP)	600	690	mg PO_4/L
pH	7.4	7.4	
Alkalinity	4,582	4,728	mg/L
Volatile Solids Reduction	49.0%	50.4%	% VS
Biogas Yield	18.5	26.0	cf/lb VS destroyed day
Energy Content	535	565	BTU/cf

In general, the ASU target reactor accurately represented the expected changes in digested performance. The disparity between the NWWRP digesters and the ASU reactor 'control' VSR and gas yield in the reactors. However, the trends accurately represent the expectations for co-digestion. Specifically, the biogas yields, while the 18.5 cf/lb VS destroyed is significantly higher than the NWWRP is currently reporting. A significant increase in gas is expected due high percentage of grease, fats, and lipids.

Additionally, the VSR is expected because the OSW and FOG is expected to have high percentages of readily degradable volatile solids. The expected VSR and biogas yields are presented available in the Model Scenarios.

4 PROPOSED OPERATIONS

The following section introduces the new processes that could potentially be implemented at NWWRP to accept imported organic waste and enhance biogas utilization. These new processes are described including integration strategies into existing plant operations.

4.1 Primary and Waste Activated Sludge

Under the proposed operations, there are no significant changes to the primary sludge (PS) processing or waste activated sludge (WAS) collection systems. The following section introduces a new process that could potentially be implemented at NWWRP to improve WAS degradability. Performance parameters, O&M and estimated capital costs for implementation are also provided in this section. These new processes can be activated as part of the Solids and Energy Flow Model to evaluate various scenarios for energy recovery.

WAS Lysis

WAS Lysis is a process that can be used to rupture cell walls within the biological WAS, thereby increasing digestibility of this material and allowing better viscosity at higher concentrations. This drives a variety of benefits including increased digester SRT, reduced digester heating loads, more biogas generation, less hydraulic and mass loading to dewatering, and less wet mass for final disposal. The WAS lysis system examined was the Pondus system. This uses caustic soda addition to bring sludge flows up to pH 11 and low-grade heating to 150ºF to break down the cell membranes of WAS. When WAS cells are ruptured, internal acids are released returning the sludge flow to near neutral pH. Mixing of heated WAS back with cold primary sludge provides an essentially heating neutral operations compared to traditional mesophilic digester heating.

The major consideration for implementation of Pondus at NWWRP is that is requires a separate WAS flow that is separately thickened and then heated and lyzed. Currently PS and WAS are blended in a single tank and thickened in a single centrifuge. Introduction of Pondus would require utilizing the separate existing PS and WAS wells as originally intended and operating two separate thickening centrifuges. Since the plant currently has two centrifuges, a third unit may need to be added for redundancy. Table 18 gives the parameters for Pondus incorporated into the Solids and Energy Flow Model.

Table 18. Pondus System Parameters for Flow Model

Parameter	Model Value	Unit
Thickened WAS flow rate to Pondus	23,760	gpd
Thickened WAS % TS to Pondus	6%	%
Thickened WAS Mass Loading	7,220	lbs/day
Increase in Thickened WAS Digestibility	35% - 68%	%

50% NaOH Consumption	35.7	gpd
Estimated NaOH Cost	$1.80	$/gallon
Capital Cost	$3,360,000	USD

4.2 Mixed HSW Organic Slurry Equalization and Injection

Mixed HSW organic slurry Offloading and Equalization Design. The slurry will be transferred from the pre-processing facility to NWWRP via tanker truck, with vehicles designed to transfer and pump liquified loads in a sealed containment vessel to minimize the risk of spills and odor. It is recommended that a target of 12% - 15% total solids (%TS) for mixed HSW organic slurry be delivered to NWWRP to both ensure pumpability and minimize hauling loads between facilities. Therefore, depending on the daily waste characteristics arriving at the pre-processing facility, dilution water may need to be added to the slurry in order to reach the appropriate %TS. Details regarding the dilution requirements prior to NWWRP are summarized separately in the ‘Pre-Processing Facility Concept Memorandum’.

The mixed HSW organic slurry from the tanker truck will be offloaded into a holding tank at NWWRP for equalization prior to injection. The proposed approach is to utilize the currently unused 50,000-gallon primary sludge (PS) wet well located in the Solids Handling Building. Utilizing this existing tank minimizes the capital costs of the project and provides an equalization tank located near the Solids Handling Building loading bay which is ventilated and provides adequate odor control for the OSW offloading station.

Figure 3 and Figure 4 show the recommended arrangement for mixed HSW organic slurry receiving, equalization and injection into the digesters by reutilizing the existing PS wet well as a repurposed mixed HSW organic slurry equalization tank.

Mixed HSW organic slurry Injection System Design. Under this project, new dilution capabilities will be included in the upgrades to the PS wet well tank being repurposed as a mixed HSW equalization tank. The mixed HSW organic slurry handling system will accommodate the 10-15% total solids slurry at a continuous feeding rate. The mixed HSW organic slurry equalization tank shall be equipped with the option to dilute the slurry with WAS, or plant effluent, if needed.

The tank will also be equipped with a set of recirculation/mixing pumps with grinders attached to keep the solids in suspension in the upgraded slurry equalization tank to avoid excessive sedimentation within the tank.

There are currently two alternatives for mixed HSW organic slurry injection at NWWRP.

The first alternative is to inject the slurry directly from the HSW equalization tank into the digesters. The HSW equalization tank will be equipped with another smaller set of feed pumps to the digester. The mixed HSW organic slurry digester feed pumps will be designed specifically for the slurry at 10-15% TS. If NWWRP elects to accept the maximum slurry flows, the constant feed rate will be approximately 10 gallons per minute (gpm) on a 24 hours/day basis, or 30 gpm for a constant feed during daily business hours (8-hour day). At this flow condition the constant feed rate will be accomplished with a small, positive displacement digester feed pump. Capital and operation expenses associated with reutilizing the PS wet well are presented in Table 19.

The second alternative injects the slurry into the adjacent thickened sludge wet well, at a similar feed rate. The existing thickened sludge wet well pumps would continue to be used to pump the mixed sludge and HSW streams into the digesters.

Table 19. HSW Offloading, Receiving, and Equalization Parameters

Parameter	Model Value	Unit
Capital Cost	$476,000	USD
Annual O&M Cost	$5,000	$/year
Power Draw	15	kW

It is recommended that NWWRP retrofit the existing Primary Sludge Wet Well for mixed slurry equalization and continuously pump the HSW slurry into the Thickened Sludge Wet Well, as is shown below in Figure 3 and Figure 4.

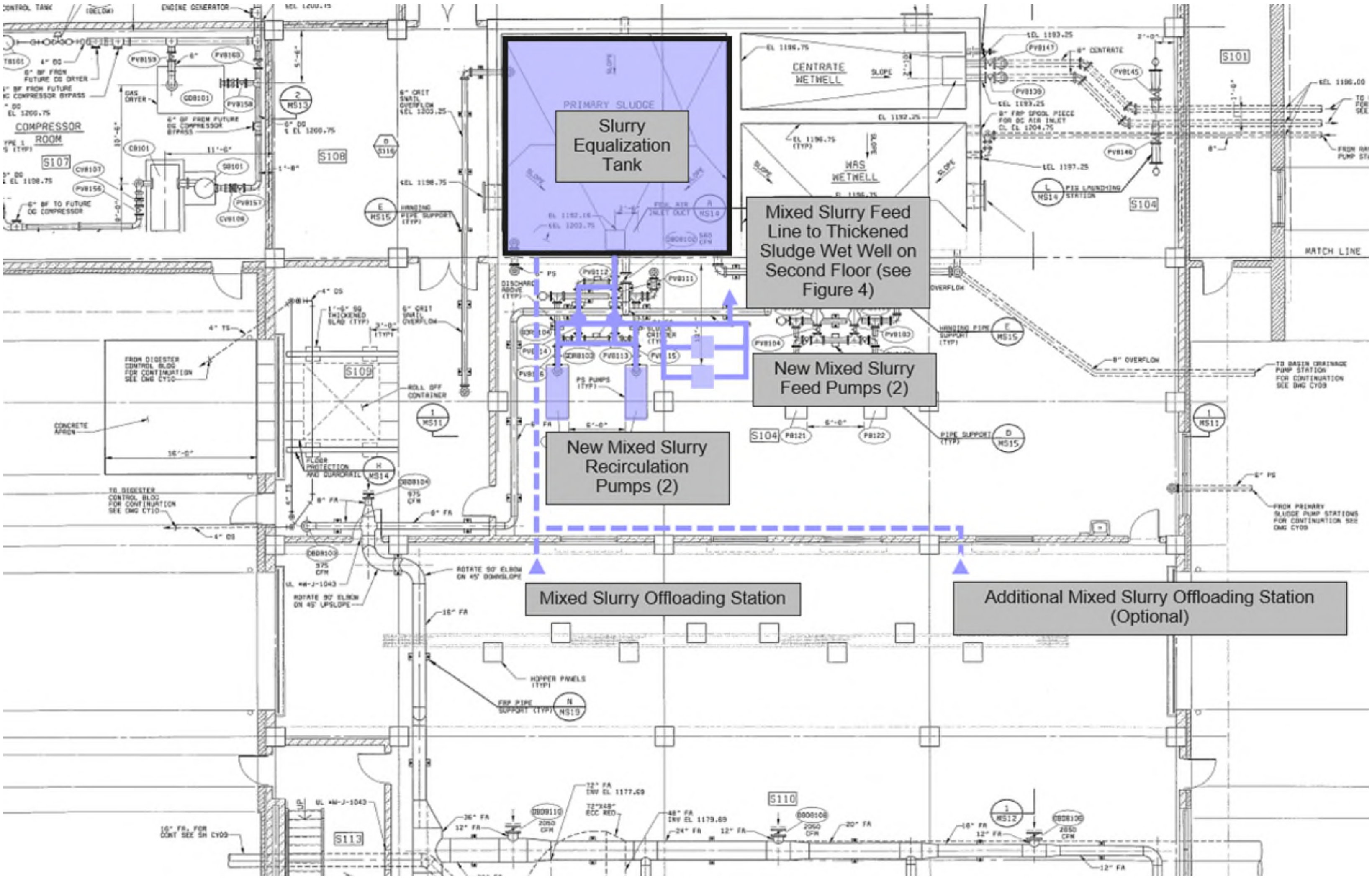


Figure 3. Direct Equalization Tank Feed Alternative: Mixed HSW Organic Slurry Offloading and Rehabilitating the Existing Primary Sludge Wet Well Layout (Solids Building, First Floor)

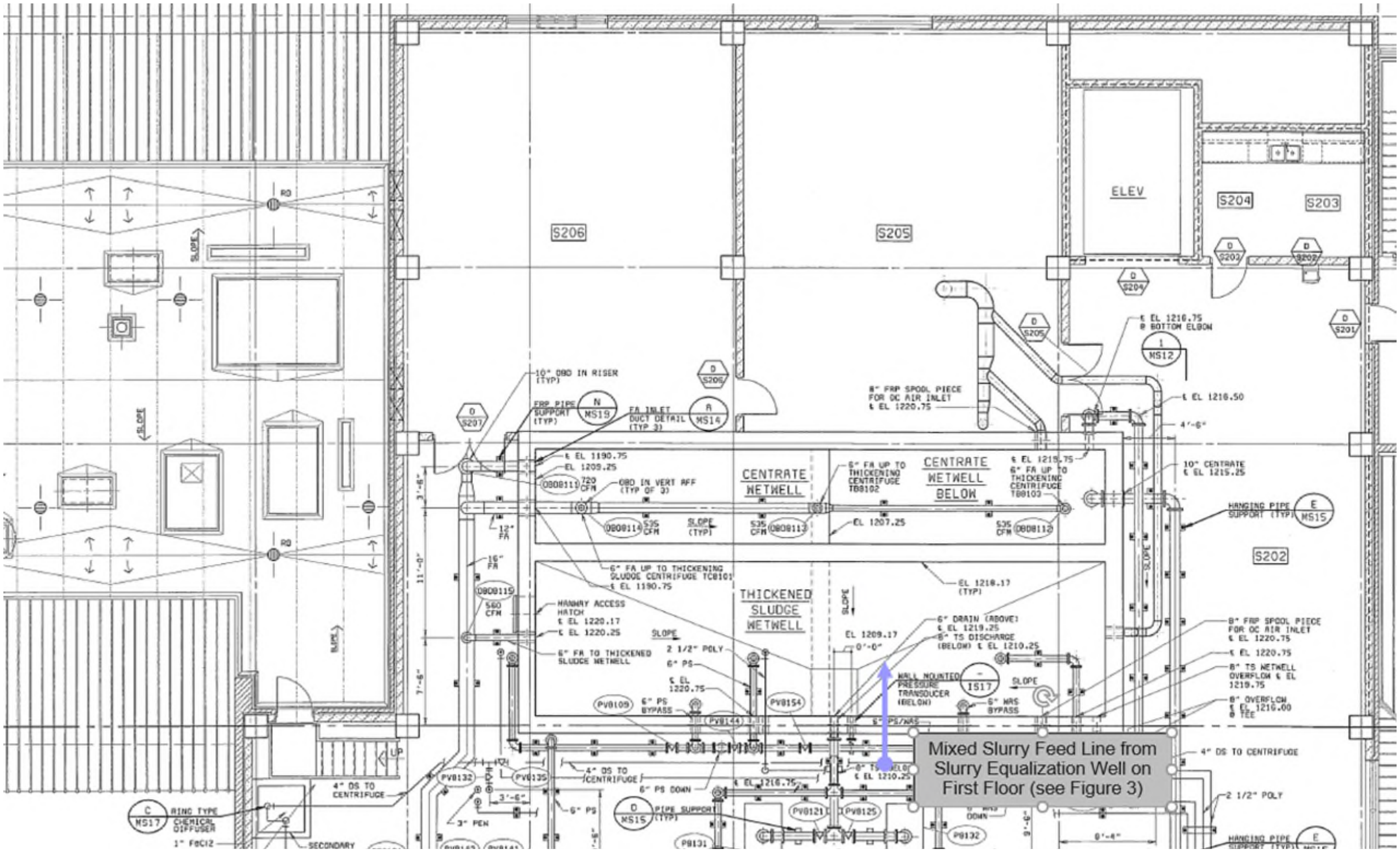


Figure 4. **Direct Equalization Tank Feed Alternative: Mixed HSW Organic Slurry Transfer to Digester Control Building Layout (Solids Building, First Floor)**

4.3 Biogas Utilization

The co-digestion of food waste has the potential to more than double the current digester biogas production at NWWRP. Among the many available options for biogas utilization, the most viable options for NWWRP include the following alternatives.

Cogeneration with Existing Engine

Currently, biogas directly from the digester is supplemented with biogas from the storage tank or natural gas to peak shave electrical utilization during peak daytime hours, as described in Section 2.6 Biogas Utilization. Additional biogas from HSW addition could potentially improve engine operations by supplying the total amount of gas required to run the engine without supplementing any gas from the storage tank, simplifying operations and mitigating the need to switch over to natural gas while the storage tank is being refilled after depletion. Alternatively, the existing engine may be operated continuously throughout the day and night while biogas is available.

Expanded Cogeneration

Digester biogas as a versatile renewable energy source. Biogas can often offer wastewater treatment plants cost savings or income in the form of generated heat, electricity, and/or natural gas. Electricity and heat cogeneration options include internal combustion engines, microturbines, stirling engines, and fuel cells. Internal combustion engines are the most common application due to the greater energy efficiency and multi-part heat recovery system, including jacket cooling water, intercooling, and exhaust heat. Microturbines and fuel cells generally produce electricity in smaller increments and require the biogas to be treated to higher quality and higher pressure that the internal combustion engine. This requires more advance treatment technology resulting in higher capital expenditure, operation and maintenance requirements, and electricity draws. Stirling engines, or external combustion engines, do not require highly treated biogas, however, are only available in low electricity production increments.

As NWWRP already operates an internal combustion engine and has the space to expand the existing system, therefore, other cogeneration options are not financially viable for NWWRP at this time.

Another alternative of interest included expanding the existing cogeneration system by adding a second, similar sized engine model in the existing engine room to expand the electric production capacity from biogas. The selected model for CHP expansion was the Caterpillar G3516 which is an 800-kW engine, with roughly the same footprint as the existing 600 kW Caterpillar G3512E engine. A budget price for quote for the CHP equipment package was $750,000, which includes freight to the site, the generator unit, radiator unit, exhaust silencer, and engine start up. It should be noted that no heat recovery systems were included as NWWRP does not currently recover heat from the existing CHP engines and does not plan to implement this in the future. Additional costs required for installation would include constructing the various piping and electrical interconnections required for the various engine system components.

A new H2S removal system was recommended upstream of biogas compression to protect the new CHP engine equipment from corrosion. Biogas would then pass through the existing compression and moisture removal system and be fed to the expanded set of engines (1 existing, 1 new). Engine fuel would supplemented with biogas from the storage tank or fuelled by natural gas to peak shave electrical utilization during peak daytime hours, as described in Section 2.6 Biogas Utilization. Additional biogas from HSW addition could potentially expand both engines operations by supplying the total amount gas required to run the engine without supplementing any gas from the storage tank, simplifying operations and reducing the need to switch over to natural gas when the storage tank is being filled after depletion. Alternatively, both engines may be operated continuously throughout the day and night while biogas is available.

Analyses involving the existing CHP system assumes no biogas pre-treatment for siloxanes and H_2S. CHP engine specifications typically require feed gas that is less than 200 ppm H_2S; since biogas at NWWRP is, on average, below this threshold, significant O&M savings are not anticipated if biogas is treated for H_2S prior to use in the CHP system. NWWRP's biogas has siloxane concentrations of approximately 3,500 µg/m^3 (which is 3.5 ppm) comprised mostly of D4 and D5 siloxanes, which is within the typical range for WWTP biogas. Siloxanes at these concentration will foul engine cylinders and valve chambers, meaning siloxane treatment upfront of the CHP system would greatly ease the burden on the engine operation and maintenance staff and extend the useful life of the engine.

Unison estimated that a biogas pre-treatment system, including H_2S, siloxane and moisture treatment, would cost approximately $540,000 and Arcadis estimates that the installed cost would be approximately $825,000. With siloxane treatment, Arcadis estimates NWWRP would see an extension to major maintenance procedures by 33%, i.e top ends would be extended from 20,000 operating hours to 30,000 and overhauls would be extended from 40,000 operating hours to 60,000 operating hours. Current O&M costs for the CHP system are approximately $0.036/kWh produced which translates to approximately $62,000 per year in O&M costs for the CHP system under current engine operations. A 33% reduction to the operating costs would yield an O&M cost of $0.024/kWh produced, which is a typical operating cost for an engine, and would translate to $41,000/year in O&M costs, which is an annual savings of $21,000/year. Unison estimated siloxane media changeout cost of $14,500/changeout, and it is estimated that at least once changeout per year would be required. Therefore, after accounting for siloxane media costs, annual savings are reduced to $6,500 per year, and this value neglects the power costs and associated O&M costs for the pre-treatment system. Considering this, it is not anticipated that installing a biogas pre-treatment system would yield a rapid payback period considering it generates annual savings of less than $6,500 per year with approximately $825,000 in capital expenditure required.

An additional engine may have significant effects on the air pollutants at NWWRP. An analysis of the expanded CHP systems effect on the Air Quality Permit Analysis is provided in Appendix B.

RNG Production

Under this alternative, biogas would be sent to a renewable natural gas (RNG) upgrading system. RNG is biogas that has been treated to remove contaminants and inerts, such as CO_2, to meet the natural gas pipeline quality specifications included in Appendix C. RNG can be generated either via a membrane or pressure swing absorption (PSA) upgrading systems. Both technologies have proven performance at municipal wastewater facilities for digester gas upgrading, with larger systems on the order of 500 scfm or greater tending to favour PSA and smaller systems tending to favor membranes. The upgrading skid being considered for the NWWRP including biogas from mixed HSW addition is sized at 400 scfm input biogas which falls right in between the scale sizes for the two technologies The two RNG upgrading systems evaluated for this study were: a 400 scfm BioCNG™ membrane upgrading skid manufactured by Unison Solutions and a 400 scfm MolecularGate™ PSA upgrading skid manufactured by Guild Associates. The BioCNG™ system utilizes an Air Liquide membrane system that is furnished by Unison; the BioCNG trademark is a result of a partnership between Air Liquide and Unison for the use of membrane systems in municipal wastewater treatment settings. The systems are considered to have similar capital costs and operating needs, the main difference being that a membrane system requires H_2S, moisture, and siloxane pre-treatment while PSA systems do not.

Both RNG upgrading technologies require the biogas feed to be pressurized in the range of 150-200 psig, requiring a significant power load to generate RNG. The RNG system feed compressor must be located in close proximity to the upgrading skid to minimize pressure losses and simplify piping to the compressor since recycle streams are necessary. As a result, the current 80 psig liquid ring compressor cannot be used for the feed compression to RNG and the new RNG feed compressor cannot replace the liquid ring compressor in its current footprint. The RNG product gas will have a pressure between 90 -140 psig, meaning that the product gas pressure will need to be stepped down prior to injection into the adjacent natural gas (NG) distribution pipeline.

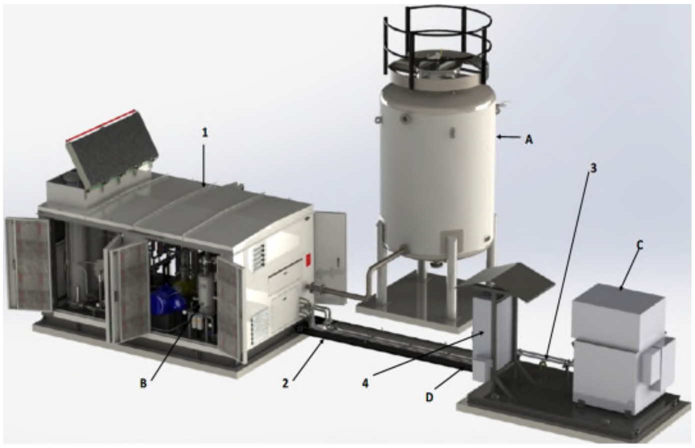


Figure 5. and Figure 6. BioCNG^{TM} Membrane Upgrading Skid and PSA Upgrading Skid

Biogas to RNG via Membrane Skid

The membrane upgrading skid employs a polymer membrane that is highly selective against water and CO_2 and slightly selective against O_2 to yield a product gas that is approximately 98% methane and a tail gas that is approximately 4% methane and 95% CO_2. Due to the membrane's high selectivity for methane, approximately 97% of the methane in the feed biogas is captured; PSA capture efficiency is approximately 92%, meaning that RNG generation potential is maximized with membrane technology.

Table 20. Membrane Skid Parameters

Parameter	Model Value	Unit
Capital Cost	$3,446,000	$
Annual Maintenance Cost	$22,000	$/year
Rated Capacity	400	scfm
Power Draw at Rated Capacity	154	kW
CH_4 Capture	97%	%
Gas Pre-treatment Cost	$0.85	$/mcf Biogas fed
Availability	95%	%

Since H_2S can foul the membranes, the biogas feed must be pre-treated for H_2S prior to processing via the membrane. H_2S pre-treatment would occur in a 17' tall media scrubbing vessel that is located separately from the treatment skid. The media to be used for H_2S scrubbing requires saturated gas for effective performance, therefore, H_2S treatment must occur prior to feed gas drying and compression.

The biogas feed is also treated for siloxanes in a separate scrubbing system located downstream of the feed gas compression on the treatment skid itself and requires a consumable media. The total biogas pre-treatment cost of approximately $0.85 per Mcf of biogas feed – currently the specific H_2S media cost is $0.10 per Mcf of biogas fed and the specific siloxane media cost is approximately $0.75 per Mcf of biogas fed.

Biogas is fed to the membrane system and pressurized to 200 psig, the power draw of 154 kW at its full rated capacity of 400 scfm. The RNG, or product gas, comes off the skid at approximately 140 psig. See Figure 7 for a process flow diagram and sample layout of the BioCNG membrane upgrading system. The capital and operation expenses associated with the membrane system are summarized in Table 20.

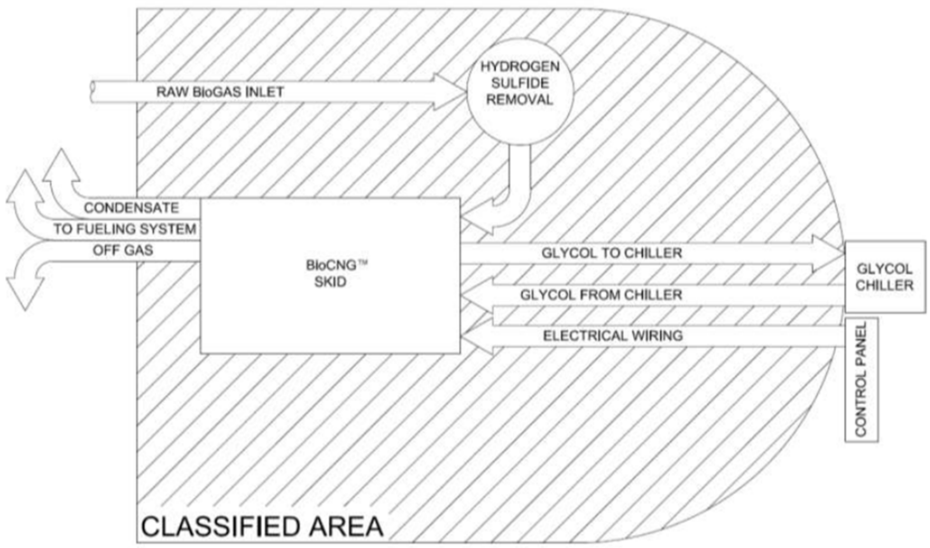


Figure 7. BioCNG Membrane Upgrading System

Biogas to RNG via Pressure Swing Adsorption (PSA) Skid

The PSA skid uses a regenerable adsorption media to separate the methane from the other constituents in biogas. The PSA skid separates molecules based on size, meaning that it is less selective than the membrane system and is not capable of removing O2 and N_2 in the biogas feed. As a result, it is important that O_2 concentrations in the biogas feed be kept below 0.1%, which is not anticipated to be an issue with properly operated anaerobic digesters. The PSA skid product gas is approximately 96% methane and a tail gas that is approximately 11% methane and 86% CO_2. This equates to a lower methane capture compared to the membrane system at 92% versus 97% meaning RNG generation rates will be slightly lower when using a PSA than when using a membrane.

Table 21. PSA Skid Parameters

Parameter	Model Value	Unit
Capital Cost	$2,679,000	$
Annual Maintenance Cost	$30,000	$/year
Rated Capacity	400	scfm
Power Draw at Rated Capacity	171	kW
CH_4 Capture	92%	%
Gas Pre-treatment Cost	$0	$/mcf Biogas fed
Availability	95%	%

Unlike the membrane system, the PSA skid removes all contaminants in one step, meaning that no separate treatment is required for siloxanes and H_2S. As a result, there are no pre-treatment media costs associated with the PSA system.

The membrane skid requires biogas feed pressures of 100 psig and the product gas comes off the skid at approximately 90 psig. Despite the fact that the PSA skid requires the feed gas to be pressurized to 100 psig compared to 200 psig for the membrane system, the PSA skid has a higher power draw of 171 kW compared to 154 kW for the membrane skid due to the fact that the PSA skid requires a vacuum compressor to regenerate the adsorption media in addition to the initial feed compression. The maintenance cost of the PSA skid is higher than the membrane skid at $30,000 per year versus $22,000 due to the increase in maintenance requirements associated with the PSA skid vacuum compressor. See Figure 8 below for a process flow diagram of the PSA system. The capital and operation expenses associated with both systems are summarized in

Table 21.

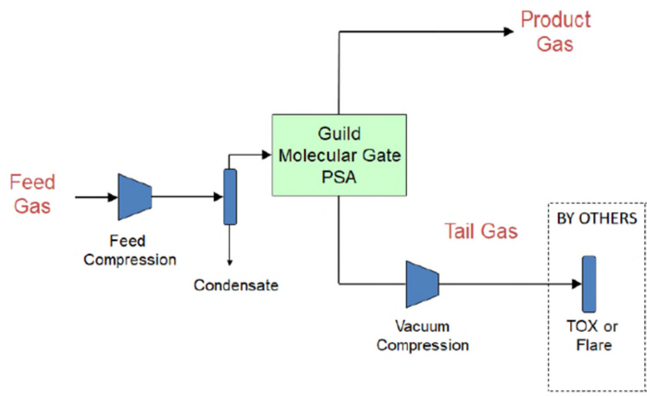


Figure 8. Guild PSA Upgrading System

RNG Tail Gas Treatment

Upgrading biogas to RNG generates two product streams: the energy rich RNG product gas and the energy lean tail gas, primarily composed of rejected inerts, such as contaminants and 4 -11% methane (by volume). The methane capture of RNG upgrading systems range from 92 - 97%. Due to the lean heating value of the RNG tail gas, in order to meet air permitting limits, a thermal oxidizer system must be used to treat the tail gas.

Figure 9. Thermal Oxidizer

A thermal oxidizer employs temperatures over 1500°F and residence times of 15 - 30 minutes to yield a methane and contaminant destruction in excess of 95%. The high temperature and residence times allow a thermal oxidizer to combust the tail gas at a methane content of approximately 12%. The PSA skid, minimal make up NG is required to meet the required heating value since the tail gas is approximately 11% methane while the membrane skid tail gas would require approximately 20 scfm of makeup NG at the thermal oxidizer's rated capacity. Capital and operation expenses associated with thermal oxidizer are presented in Table 22.

Table 22. Thermal Oxidizer Flow Parameters

Parameter	Model Value	Unit
Capital Cost	$489,000	$
Annual Maintenance Cost	$15,000	$/year
Power Draw	22	kW

Biogas Piping System

In the current biogas handling system, biogas from each digester is collected via one 8" pipe. At the current average biogas generation rate of 66 scfm, the gas velocity is 3.2 feet per second (fps), well below maximum best practice velocity of 12 fps. At maximum HSW loading to the digesters, the biogas generation rate per digester under this analysis was calculated to be 139 scfm, equating to a gas velocity of 6.6 fps. The current digester handling system could accept a maximum of 250 scfm of biogas from each digester before the best practice maximum velocity of 12 fps is reached.

For connection to a new RNG upgrading system a new 10-inch stainless steel biogas piping connection would be installed in the digester control building in the header pipe just downstream of the existing foam separators. This new 10-inch biogas line would connect to a new RNG upgrading system located to the West of the existing Digester Control Building. The RNG upgrading system would have independent feed compressors, gas pre-treatment/chilling, and the RNG upgrading unit process integrated into a comprehensive gas treatment skid. Product gas would be routed through new 2-inch buried piping connections directly to a new NG pipeline interconnection near the southwest corner of the plant yard. This NG new interconnection point and metering station would be coordinated with the planned NG relocation/rehabilitation work in this area. Tail gas would be routed to a thermal oxidizer for final treatment.

Figure 10 through Figure 12 show the process flow diagram and the proposed layout for biogas piping to the Co-generation and RNG skids.

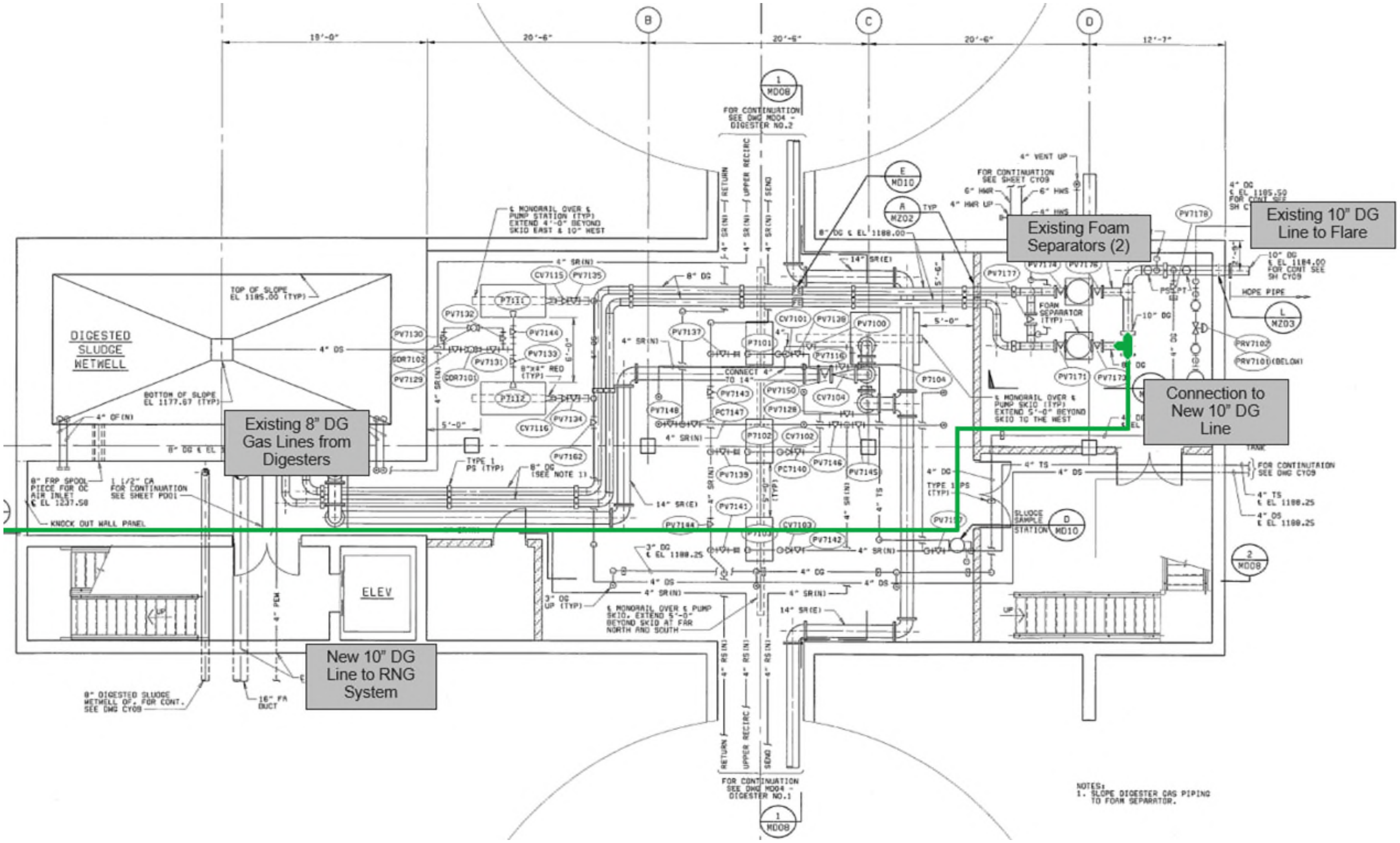


Figure 10. Proposed Biogas System in Digester Gas Building Layout

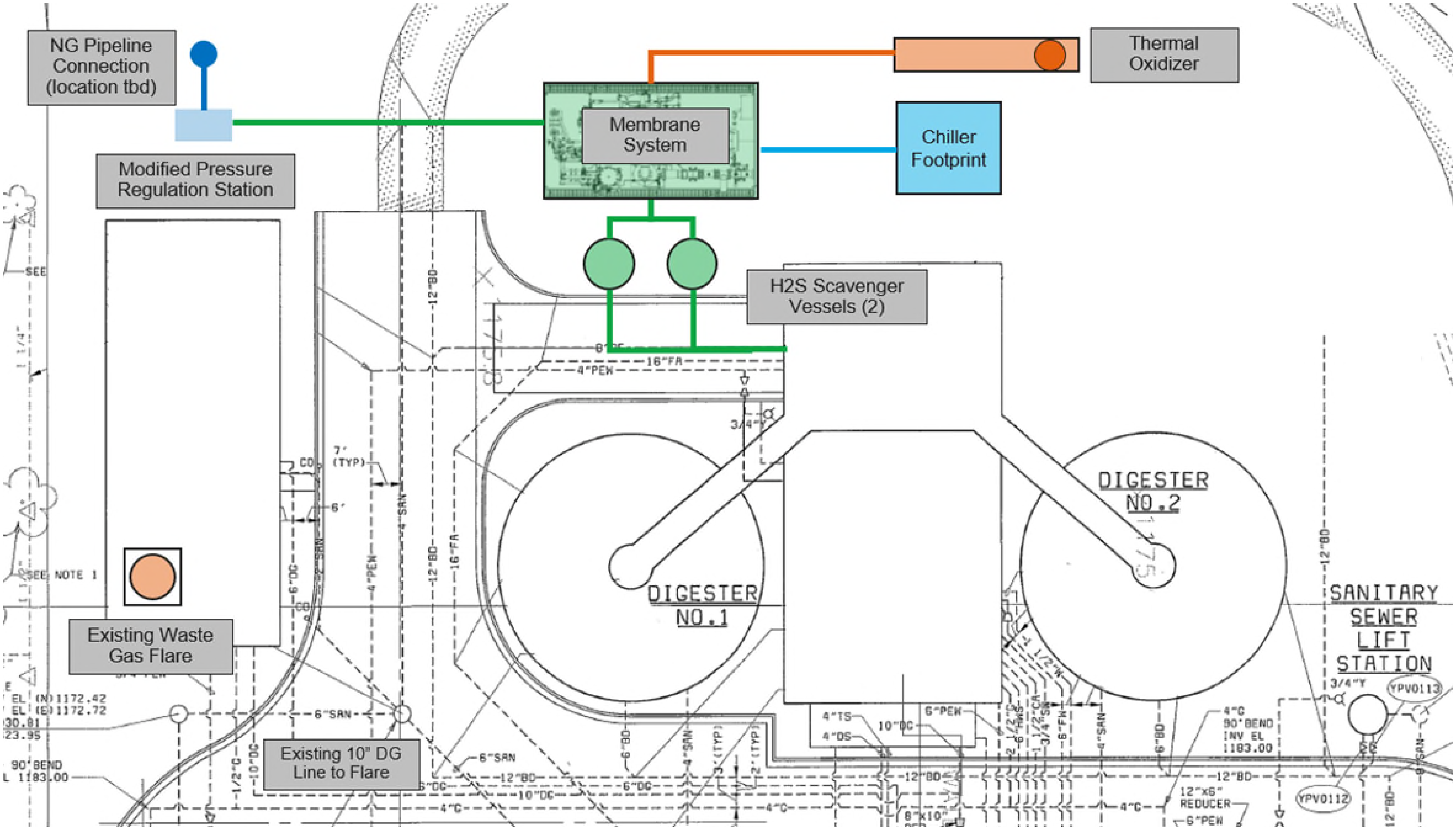


Figure 11. Proposed RNG System Layout Alternative 1: Membrane with Thermal Oxidizer

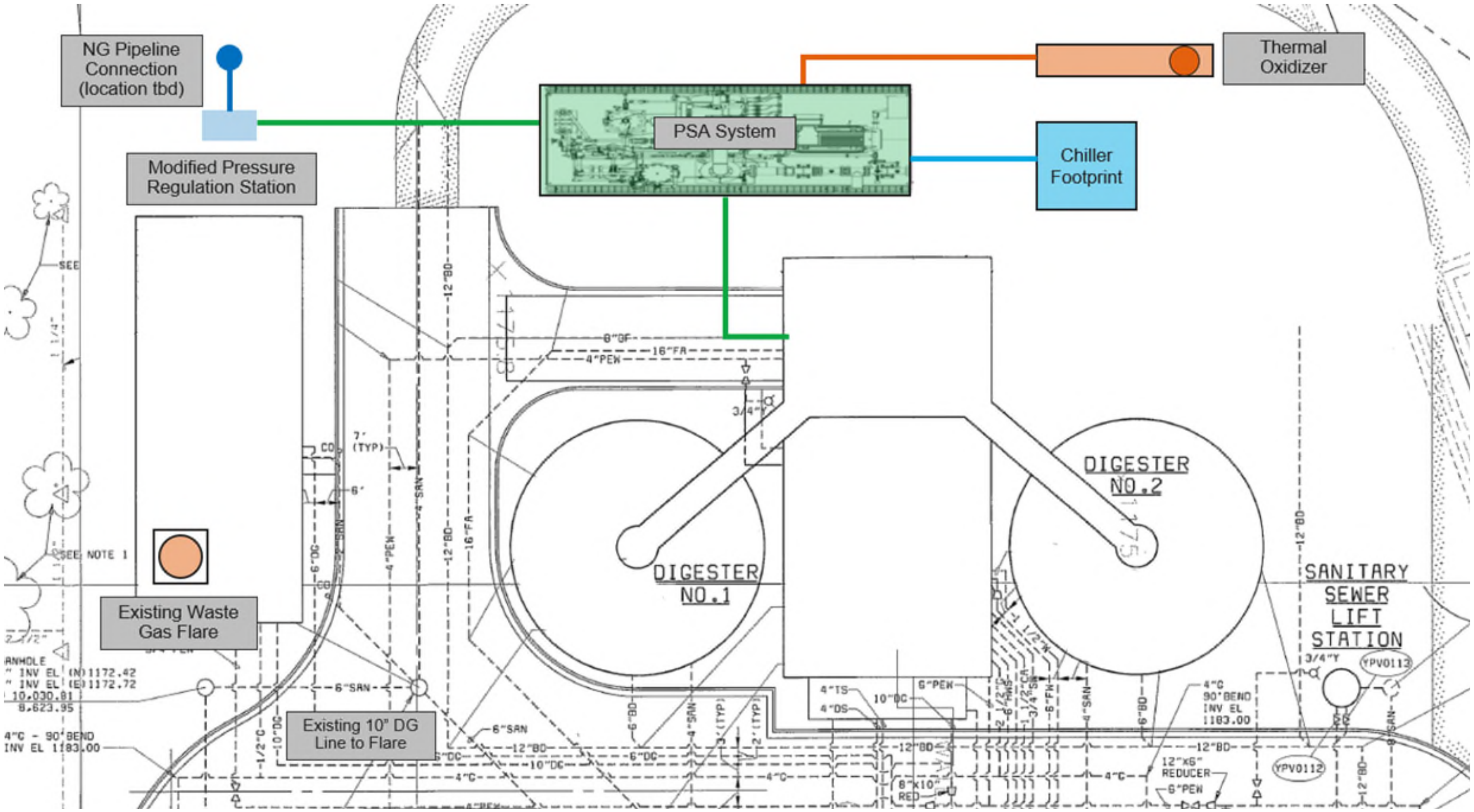


Figure 12. Proposed RNG System Layout Alternative 1: PSA With Thermal Oxidizer

RNG to NG Utility Pipeline

The turnkey RNG upgrading skid is provided with automatic gas purity controls designed for unattended operation. Product RNG gas is 90-150 psig. The existing Riverview gas system operates at approximated 45 PSI, therefore, the RNG product gas must be depressurized prior to injection into the NG utility pipeline. This would provide an ideal pressure buffer that would be regulated to 45 psig at the metering station.

A modified pressure regulation system must be installed between the RNG and Riverview system to avoid over-pressurization issues and to come into compliance with DOT codes. This modified station will be designed to directly connect the RNG production system to the Riverview pipeline and shall be designed meet the definition of a service line in the pipeline safety regulations. This modified station shall include two regulator shut-off valves in the event of over pressurization within the system. Over pressure protective devices are required at every pressure reducing station that supplies gas from any system to another system with a lower maximum allowable operating pressure by the natural gas industry safety codes and laws. A regulator shut-off valve accomplishes over pressurization protection by containment. The pipeline injection system will shut off completely until the cause of the over pressurization is determined and the device is manually reset. Therefore, during these periods, the natural gas will require redirection. It is recommended that additional steps are taken that, in the case of over pressurization, the RNG can be redirected for utilization in the boilers or the engines. As a last resort, the RNG will be redirected directly to the waste gas burner.

Generally, modern gas regulators are highly reliable devices; however, failure could potentially occur due to several reasons such as physical damage, equipment malfunction, and the presence of foreign material in the gas stream. There is no design standard that is applicable to all situations, however, the industry encourages multiple layers of protection to mitigate the potential of failure. Common over-pressurization protection designs include the following.

- Use of in-line monitor regulators that control pressure upon failure of the primary control regulator.
- Use of relief devices that vent excess gas pressure to the atmosphere.
- Use of automatic-shutoff devices, such as positive shut off valves and fail close regulators to interrupt the supply of gas.
- Installation of filters and strainers to eliminate debris entering a regulator.
- Deployment of signalling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.

An analysis of the Riverview Gas System current demand was performed. Based on the modelled RNG production values, the Riverview system does not have consistent and collective natural gas demand to accommodate the RNG production at NWWRP. See Table 23 and Figure 13 for details on the highest expected RNG production and the Riverview Gas System daily consumption details.

Table 23. Estimated RNG Production and Riverview Gas System Flow Parameters

Estimated RNG Production at NWWRP		
Condition	**Value**	**Unit**
Peak RNG Flow	11,233	scfh
Avg RNG Flow	8,700	scfh
Daily Average Riverview Gas System Flow		
Condition	**Value**	**Unit**
Total Average	6,104	scfh
Avg Night (10 PM - 6 AM)	4,025	scfh
Avg Day (6 AM - 10 PM)	7,142	scfh

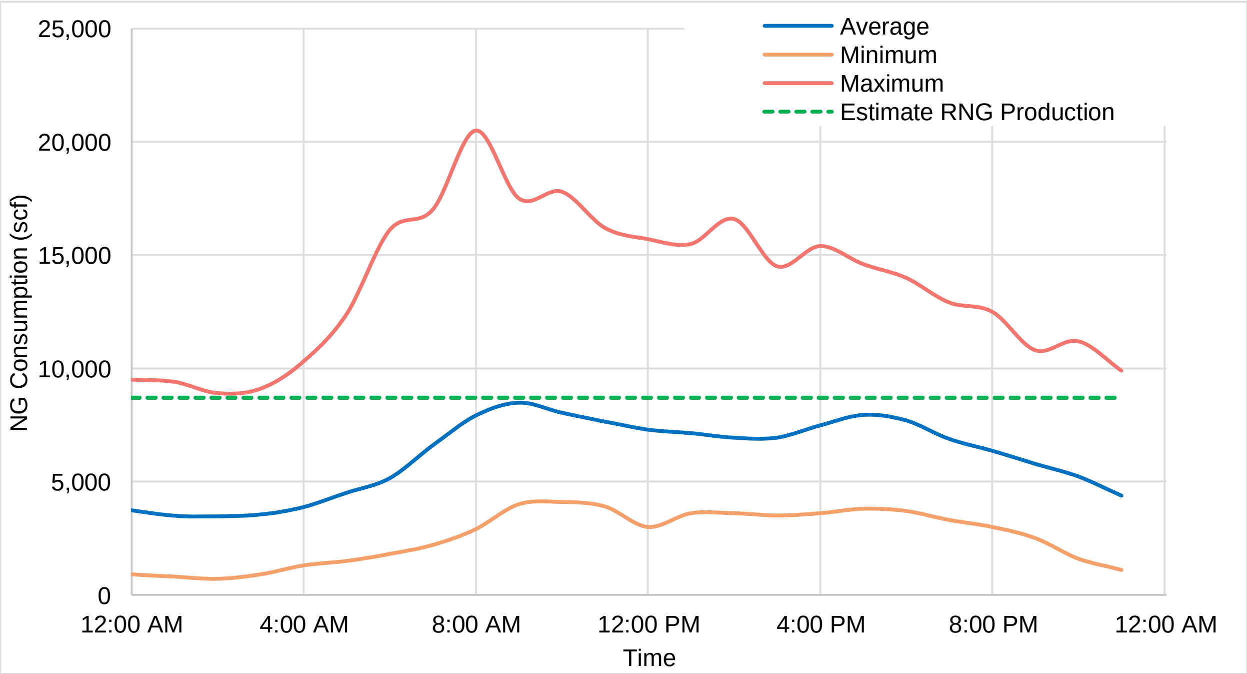


Figure 13. Riverview Gas System Average Daily Consumption

It was communicated that the Mesa gas system, the nearest natural gas system to the Riverview gas system, has substantial demand. Therefore, it is recommended that modified regulation station(s) are installed between the Riverview gas system to the Mesa gas system at

GRS93 and/or GRS56 – The station feeding between the Riverview 45 PSI and Mesa 25 PSI systems would have to be a modified design to allow for one-way directional flow. Each modified pressure regulation station is expected to cost approximately $50,000. The location of the interconnections is provided in Figure 14 below.

Figure 14. Riverview Gas System Plan

It was discussed that there may be a potential to convert the existing Riverview 45 PSI system to a 25 PSI system. Should this option be pursued, only a simple pipe connection with a one-way valve and meter between the system would be necessary. This solution would be considerably less expensive.

5 SOLIDS AND ENERGY MODEL

This section includes a more detailed discussion of the plant level solids and energy flow modelling framework and methodology, as well as the modelling analyses and results to drive decision making regarding mixed HSW organic slurry loadings and biogas utilization strategies.

5.1 Framework for Flow Model

The primary process inputs to the Flow Model are the amount of primary sludge and WAS being generated and treated at NWWRP as well as the load of OSW and FOG being added to plant digesters. These values are set as described in Table 1; however, can be easily modified as user inputs for future plant changes or as additional data becomes available. The user can then evaluate modifications to the existing facilities by selecting to activate potential processes or directing items such as biogas energy or supplemental natural gas fuel to various processes. Activating a future process changes the mass and energy flows affected by that process throughout the plant while also activating capital and O&M costs associated with that future process. The flow model user interface is shown in Figure 19 below.

Two of the most important inputs to the Flow Model are the amount of OSW and FOG hauled to the pre-processing facility and the division of sludge and mixed HSW organic slurry loading to the digesters. From these model values, results are generated for the digestion capacity and digester products including biogas energy produced and the amount of biosolids generated. All the performance values for current conditions were calibrated to the available plant information provided as discussed in the previous section

Energy is input into plant processes through biogas production or through the purchase of natural gas. In the model, varying energy flows can be directed to various utilization processes such as the existing CHP engine or a new upgrading system for RNG production. The amount of energy flowing into a given process was modified based on the particular scenario being examined.

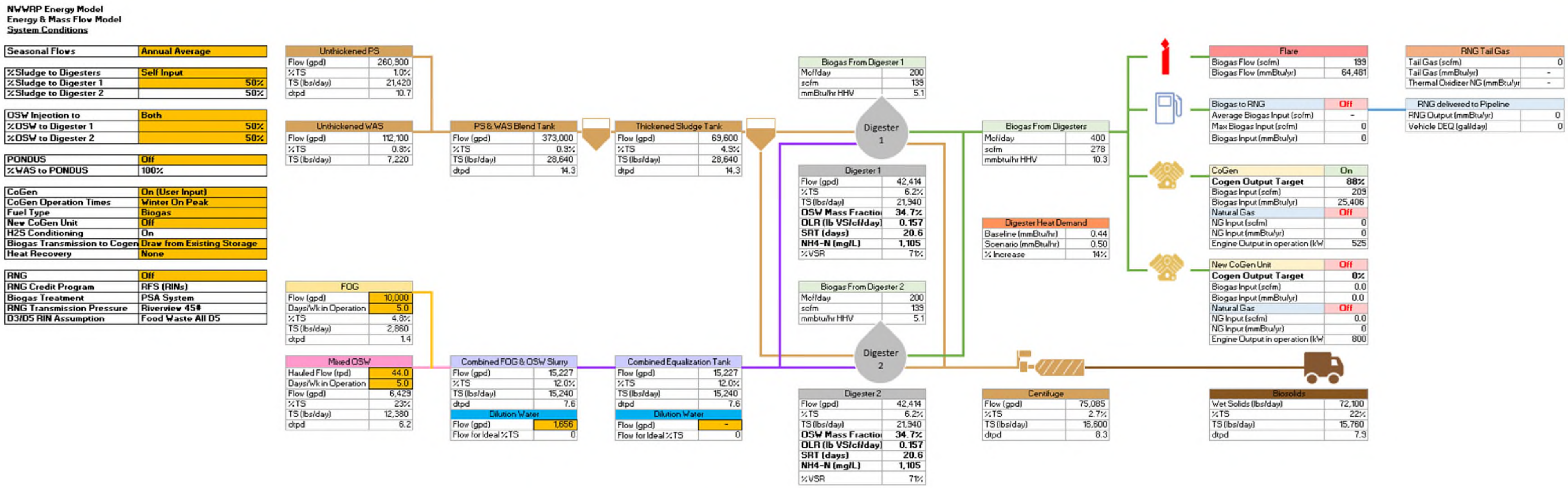


Figure 15. Arcadis Mass and Energy Model Dashboard

The main outputs of the Flow Model are preliminary annualized 'Savings Over Baseline' and GHG emission reduction.

Annualized Scenario Savings

Annualized scenario savings was the selected economic metric for evaluating potential scenarios. This includes a totalized value of many cost items on an annual basis such as electrical power use and generation savings, natural gas usage or offsetting, vehicle fuel offsetting as well as items like RIN revenue and savings from landfill tipping fees by diverting OSW. Capital costs for new processes are translated into an annualized cost, similar to an annual payment that would be made on a bond, with an assumed term of 20 years at 3% interest rate. Additional O&M costs and energy needs are also accounted for in new processes activated.

All scenarios evaluated assumed utility energy prices of $4.74/mmBtu for natural gas, based on average natural gas charges to NWWRP between February 2017- August 2018; and varying electric rates based on the provided rate schedules as summarized in Table 8. The rate for sending material to a landfill via a 3rd party hauler was $14.25 per wet ton of sludge and $30.31 for OSW. When OSW is diverted to the digesters, the related hauling fee was assumed to be offset. When RNG was being produced and sent to the City CNG vehicle fleet, a fuel offset price of $0.46 per diesel gallon equivalent (DGE) was used. RIN pricing was based on an annual average value over the past year which was $1.85/ethanol gallon equivalent for a D3 RIN and $0.34/ethanol gallon equivalent for a D5 RIN. All these unit cost input values may be varied within the model.

GHG Emission Reduction

The greenhouse gas (GHG) emission reduction was also quantified for each scenario, with the main reduction source being energy recovered from renewable biogas. Energy generated from biogas will offset energy that must be generated from fossil fuels. The amount of GHG reduction will depend on the type of energy being offset. The value for CO_2 equivalents associated with electricity usage (1,384.8 CO_2 lb/MWh) was retrieved using eGRID 2016 (the most recent available version), which is an EPA created software application. eGRID is used to derive composite data from regional electric generation zones to approximate the composite amount of CO_2e emitted for each MWh of electricity produced in the region. The reported value is from the AZNM eGRID sub-region, which contains the Mesa area.

Diesel gallon equivalence is approximated at 125,000 btu per gallon diesel fuel and CO_2 equivalents associated with diesel usage (22.40 CO_2 lb/gal).

The net GHG emissions for each scenario are calculated as the reduction resulting from using biogas for power generation instead of the power draw, combustion of natural gas, and use of vehicle fuel involved with each scenario. It should be noted that for the parameter 'GHG Reduction' a positive number indicates an overall reduction in emissions while a negative number indicates an overall increase in emissions.

5.2 Digestion Limitations

When considering co-digestion of organics, it is critical to focus on multiple factors in order to ensure that the food waste is not negatively impacting operations. The following process performance parameters and costs are adapted from reported project data, literature values, and experience with the unit processes. These performance parameters are built into the logic of the Flow Model.

The process performance parameters are adapted from reported project data, literature values, and prior experience with co-digestion, as well as ASU's bench tests. The target digestion parameter values, as shown in Table 24, are recommended to ensure stable co-digestion at NWWRP. It is important to clarify that the suggested limits are the targeted long-term operation values. The six primary digestion parameters which were evaluated are as follows:

- SRT / Hydraulic Loading Capacity
- Organic Loading Rate / Volatile Solids Loading Capacity
- Organic Mass Fraction
- Ammonium Concentration
- Volatile Fatty Acid (VFA) to Alkalinity Ratio
- Soluble Chemical Oxygen Demand (sCOD)

Table 24. Suggested Digestion Parameter Values

Digestion Parameter	Target	Limits	Unit
Solids Residence Time	20	17.5 (Min)	Days
Organic Loading Rate	0.185	0.2 (Max)	lbs VS/cf/day
Organic Mass Fraction	35%	50% (Max)	%
Ammonium Concentration	1,500	2,000 (Max)	mg NH4-N/L
pH	7	6.5 (Min) 7.6 (Max)	
Soluble Chemical Oxygen Demand (sCOD)	5,000	10,000 (Max)	mg COD/L

SRT / Hydraulic loading capacity

The most critical parameter to examine is the effect of the OSW addition on digester solids retention time (SRT), most notably maintaining an SRT above 15 days in the digesters for all digester influent conditions to meet land application permit requirements as per EPA 40 CFR Part 503 Biosolids Regulations. A minimum SRT ensures that the necessary microorganisms are being produced at the same rates they are wasted through biosolids effluent. To promote efficient digester operations, SRT under average conditions is typically targeted to be 20 days, or greater, to account for extended peak flows seen by the Plant. To ensure an appropriate digestion conditions are maintained, it is recommended that the average digester SRT not fall below 15 days under the maximum organic waste loading conditions.

Organic Loading Rate / Volatile solids loading capacity

Organic loading rate (OLR) to the digester is another key parameter that can be used as a digestion stability limit. Since OSW and FOG are concentrated in organic load, avoiding overloading the digesters and the potential for going sour is critical for operations. A typical organic loading range for efficient digester performance treating municipal WWTP sludges is 0.12-0.16 lbs VS/cf/day. NWWRP currently operates at an average 0.10 lbs VS/cf/day. There has been considerable research conducted into the loading rate limits when OSW is introduced, with most findings indicating higher loading rates are possible due to the more readily degradable nature of the OSW relative to sludge.

From experimental data and full-scale work feeding OSW to digesters at other installations, the maximum range of stability for OLR has been observed to be around 0.18 to 0.20 lbs VS/cf/day when there is adequate time allowed for digester acclimation. Arcadis has direct experience at Gloversville-Johnstown WWTP in upstate New York where dairy waste was added in excess of 0.25 lbs VS/cf/day at steady state conditions.

For NWWRP, it is recommended that a relatively conservative OLR limit of 0.185 lbs VS/cf/day be targeted under the maximum organic waste loading conditions. Considerations for items such as modular expansion of OSW processing equipment should be made to allow expansion of loading rates in the future if deemed operationally feasible after initial OSW loading rates are reached.

Organic Mass fraction

The organic mass loading fraction, or the volatile solids (VS) from OSW & FOG as compared to the organic mass of sludge VS into the digester is another critical parameter to avoid overloading of the digester. Typical organic mass faction of OSW & FOG to sludge is 35% from reported literature values and experience with full-scale installations receiving large percentages of imported organic waste. Arcadis has direct experience at Gloversville-Johnstown WWTP in upstate New York where dairy waste was added as more than 50% of digester organic mass loading under steady state conditions. For NWWRP it is recommended that 35% be the target Organic Mass Fraction loading limit with considerations for modular future expansion if additional loading is deemed operationally feasible after initial OSW loadings are conducted.

Ammonium Concentration

At the expected maximum organic waste addition based on and Organic Mass Fraction of 35%, the increase in ammonia loading from OSW was examined to determine potential impacts on digester performance and overall plant nutrient balance. Nitrogen, in the form of ammonium, is released during digestion due to the breakdown of proteins which are then recycled to 91st Avenue WRP as centrate.

Currently, OSW readily degradable VS were estimated to be 20% protein by mass. For the purpose of this analysis, protein hydrolysis was estimated to yield 20% by mass nitrogen, meaning every ton of accepted OSW increases the nitrogen loading to the digester by approximately 15 lbs. The effects of the ammonium loads from OSW are also examined in terms of the projected effect in overall plant nutrient balance. The current centrate TKN concentration within the digesters is 550 mg/L based on plant data which is assumed to be entirely ammonium and considered a good proxy for digester concentrations. From experience with plants conducting pre-digestion lysis and enhanced cell digestion, ammonium limits become limiting and tend to produce negative operational effects at concentrations approaching 1,500-2,000 mg/L. It was estimated that 20% of the mixed HSW organic slurry will be protein that will increase the ammonium concentrations in the digesters and recycle loads from the centrate.

The NWWRP dewatering centrifuge treatment downstream of the digesters is in turn sent via sewer to the head of the 91st Avenue WRP. This increase in centrate ammonium concentration may have resulted in additional struvite production if the centrate was reintroduced to the NWWRP liquid stream. However, based on the diversion of centrate away from NWWRP, it is not expected that the addition of HSW effect operations at NWWRP, or negatively affect 91st Avenue WRP due to the dilution within the Mesa sewer system prior to the plant.

pH/sCOD

Organic solid waste is rich in carbohydrates and proteins which can hydrolyze quickly during digestion. The rapid production of VFAs can overwhelm methanogenesis, in part due to the slower growth kinetics of acetoclastic methanogens, resulting in an overall drop in pH [1] [2]. The desired range for methanogens is generally between 6.5 and 7.6. However, it is recommended to maintain digester pH between 6.8 - 7.2.

Under pH of 6.5, digester is in danger of souring. While this is not expected to take place at NWWRP due to the multiple equalization and acclimation procedures in place. Section 7.3 includes a detailed breakdown of the start-up, operational and monitoring procedures for the digester in order to minimize the risk of digester upset during co-digestion commencement and ramp up. It is recommended that NWWRP take both daily pH readings as well as VFA/Alkalinity ratio reading. VFA/Alkalinity values between 0.3 and 0.4 are typically indicators of stable anaerobic digester. [3] Should NWWRP prefer chemical addition to ensure appropriate pH. Biocarbonate alkalinity can may be added to system, however sodium hydroxide is recommended since it is already maintained on site

Limiting Loading Factor

Based on the preliminary model results with varying OSW and FOG loading to the digesters, the limiting loading factor was found to be the Organic Mass Fraction of 35%. At this Organic Mass Fraction, SRT was still in excess of 20 days, OLR was approximately 0.16 lb VS/cf/day. Increases in ammonium concentrations were not limiting as discussed further below based on the assumed protein content of the mixed HSW organic slurry received. This 35% mass fraction factor was set as the limiting condition when evaluating future digester loading scenarios.

6 MODEL SCENARIO EVALUATION

Multiple scenarios were generated within the model to evaluate NWWRP's co-digestion capabilities, using the digester limitations discussed above. Five sets of scenarios and subsequent scenarios are examined as follow:

Set 1: Co-generation without Mixed HSW Addition

Set 2: Co-generation with Mixed HSW Addition

Set 3: RNG Generation with Mixed HSW Addition

Set 4: Co-generation and RNG Generation with Mixed HSW Addition

Set 5: Participation in the Low Carbon Fuel Standard (LCFS) Program

As described in Section 6.1 below, for each scenario the main comparison values are preliminary annualized 'Savings Over Baseline' and GHG emission reduction. Annualized 'Savings Over Baseline' includes many cost items on an annual basis such as electrical power use and generation savings, natural gas usage or offsetting, vehicle fuel offsetting over the baseline as well as items like RIN revenue and savings from landfill tipping fees by diverting OSW. Alternatively, the net GHG emissions for each scenario are calculated as the reduction resulting from using biogas for power generation to offset the emissions associated with electric power draws, the combustion of natural gas, or use of vehicle fuel involved with each scenario. It should be noted that for the parameter 'GHG Reduction' a positive number indicates an overall reduction in emissions while a negative number indicates an overall increase in emissions.

6.1 Set 1: Co-Generation without Mixed HSW Addition

Set 1 scenarios represent current potential operating scenarios for NWWRP to serve as a basis for comparison for the subsequent scenarios analyzed. Typically, the baseline scenario is represented as the "do nothing" scenario, where the plant does not install or optimize any treatment processes. In this case, the scenarios model the existing CHP engine running during different seasonal and daily peaking periods. Currently, the Plant operates the co-generation system all seasons during peak and shoulder peak hours. Power charges were set using the 2018 electricity rate schedule during seasonal and daily periods, summarized in Table 8 and Figure 2. A 90% engine availability was set to account for downtime due to general maintenance requirements. An engine maintenance rate of $0.036 per kWh/ generated was used to estimate annual engine maintenance costs. Power draw associated with compressing biogas to 75 psig prior to use in the engine was also considered within the model. Scenarios evaluation lower biogas feed pressures to the engine was examined in a subsequent scenario analysis.

To evaluate the most economical engine run-time scenario, the CHP engine performance was evaluated at different seasonal and peak/off-peak periods. The different periods used were developed from the SRP pricing plan and are summarized in Figure 19 and

Table 25 below.

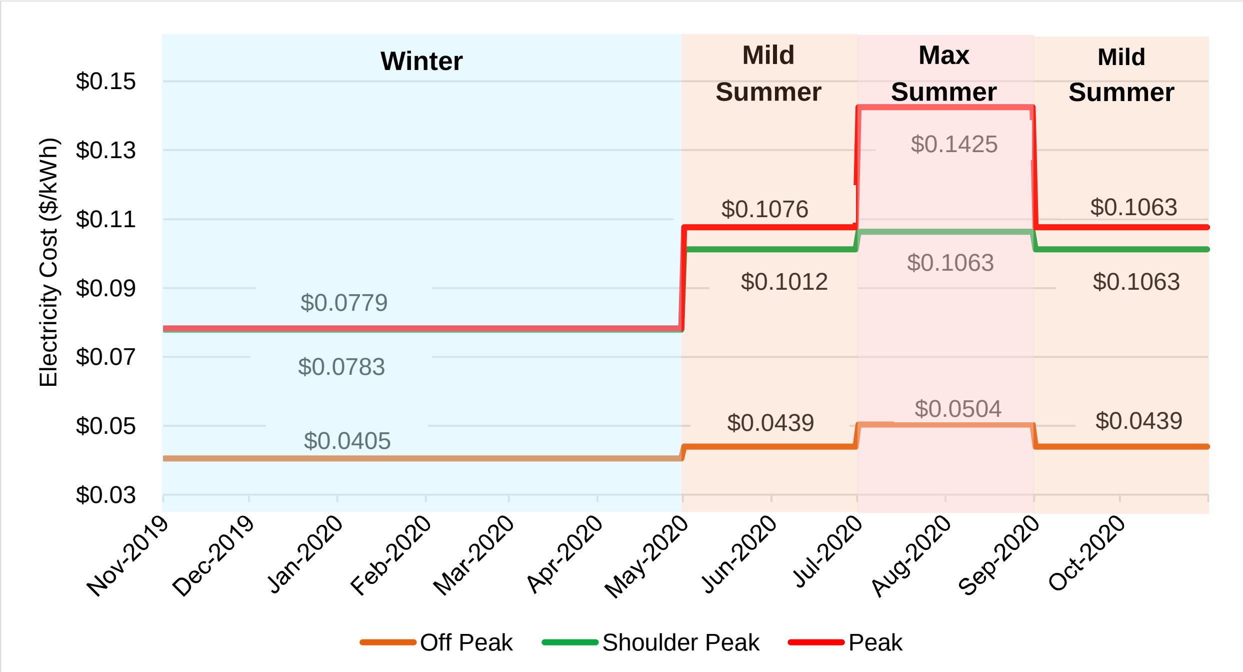


Figure 16. 2018 Seasonal Electrical Power Costs

Table 25. Co-Generation Seasonal and Daily Charge Summary

Seasonal Period	Days/yr	hours/day	hours/yr	$/kWh	kWh/yr	$/yr
Max Summer On-Peak	62	6	335	0.1425	267,840	$ 38,000
Mild Summer On-Peak	122	6	659	0.1076	527,040	$57,000
Max Summer Shoulder-Peak	62	6	335	0.1063	267,840	$28,000
Mild Summer Shoulder-Peak	122	6	659	0.1012	527,040	$53,000
Winter On-Peak	181	4	652	0.0783	521,280	$41,000
Winter Shoulder-Peak	181	4	652	0.0779	521,280	$41,000
Max Summer Off-Peak	62	12	670	0.0504	535,680	$27,000
Mild Summer Off-Peak	122	12	1,318	0.0439	1,054,080	$46,000
Winter Off-Peak	181	16	2,606	0.0405	2,085,120	$84,000

Evaluation in the energy flow model confirms that the most cost-effective use of biogas is to peak-shave as being done under current CHP operations, which is operating the CHP during peak and shoulder peak periods every day of the year. Therefore, the “All year On-Peak and Shoulder-Peak” scenario is used as a baseline to display the existing annual cost savings and greenhouse gas (GHG) reductions of running the co-generation system. The results of the Set 1 scenarios analyses are summarized below.

Scenario 1.1. 'Summer On-Peak Only'

Scenario 'Summer On-Peak Only' models the annual cost savings and GHG reductions if NWWRP operates the engine during "Mild Summer On-Peak" seasonal periods only. This scenario serves as the lowest annualized offsetting scenario available to the Plant if they continue operating their existing co-generation system at 87.5%. In this scenario, the engine operates approximately 994 hours per year, consuming 4,843 mmBtu/year HHV of biogas and 2,832 mmBtu/year HHV of NG. The average power cost offset for this scenario is $0.1194 per kWh, which is 81% higher than the average power cost of $0.0659 per kWh.

The remaining 89% of the biogas generated outside the operational period and which is not stored for later use is flared. This scenario has a negative annual savings since NG purchased for digester heating and CHP fuelling is $37,000 while net CHP electric offsets after O&M is $35,000. GHG reductions are negative since associated NG GHG emissions are 414 MT CO_2e while reductions associated with electric generation are 286 MT CO_2e.

Scenario 1.2. 'Summer On-Peak and Shoulder-Peak'

Scenario 'Summer On-Peak and Shoulder-Peak' models the annual cost savings and GHG reductions if NWWRP operates the engine during "Mild Summer Shoulder-Peak" seasonal periods, as shown in Figure 16. 2018 Seasonal Electrical Power Costs

Table 25. In this scenario, the engine operates approximately 1,987 hours a year, consuming 9,686 mmBtu/year HHV of biogas and 5,664 mmBtu/year HHV of NG. The average power cost offset for this scenario is $0.111 per kWh, which is 69% higher than the average power cost of $0.0659 per kWh.

The remaining 77% of the biogas generated outside the operational period and which is not stored for later use is flared. This scenario generates $16,000 in additional savings and 145 additional MT CO_2e in GHG reductions over scenario 1.1.

Scenario 1.3. 'All Year On-/ Shoulder-Peak' / <u>'Enhanced Baseline' Scenario</u>

The 'Enhanced Baseline' Scenario assumes optimized current operations, meaning that there is no unplanned CHP downtime under this scenario. Under this scenario models the annual cost savings and GHG reductions when NWWRP operates the engine during "Winter On-Peak" seasonal periods, as shown in Figure 16. 2018 Seasonal Electrical Power Costs

Table 25. Therefore, under this scenario, there is no high-strength waste collected and delivered to the NWWRP. This scenario assumes that City uses biogas to run the City's existing engine generator system to generate electricity on-site and peak-shave (both peak- and should peak-periods, all year around). The biogas is used as it is generated and supplemented with biogas stored in the existing storage tank to operate the engine at approximately 87.5% capacity, equating to 525 kW of power generation. Natural gas is fed to the engine when biogas in not

available (while the storage tank is being filled). It is assumed that the engine has a 90% annual availability.

This serves as an ultimate 'Baseline' Scenario to display the progress NWWRP has already made prior to this evaluation. In this scenario, the engine operates approximately 3,290 hours a year, consuming 16,037 mmBtu/year HHV of biogas and 9,378 mmBtu/year HHV of NG.

The remaining 62% of the biogas generated outside the operational period that is not stored for later use is flared. The average power cost offset for this scenario is $0.0981 per kWh which is 49% higher than the average power cost of $0.069 per kWh. Annual savings for this scenario air lire $7,000 higher than scenario 1.2 and the highest of the scenarios analyzed in this scenario set. GHG reductions increase by 202 MT CO2e per year over scenario 1.2 due to the increased CHP uptime.

This Scenario is considered 'enhanced' because it is the basis for current operations, however, we have confirmed that the existing CHP is not operated every day during peak and shoulder periods. Therefore, we consider this the baseline, should NWWRP enhance their current operation.

Scenario 1.4. 'All Year On-/Shoulder-Peak + Summer Off-Peak'

Scenario 'All Year On-Peak and Shoulder-Peak+ Summer Off-Peak' models the annual cost savings and GHG reductions if NWWRP operates the engine during all seasons during the "Mild Summer Off-Peaks" seasonal periods, as shown in Figure 16. 2018 Seasonal Electrical Power Costs

Table 25. In this scenario, the engine operates approximately 5,178 hours a year, consuming 25,723 mmBtu/year of biogas and 15,041 mmBtu/year of NG. The average power cost offset for this scenario is $0.0785 per kWh, which is 19% higher than the average power cost of $0.0659 per kWh. This margin is not sufficient to offset the cost of NG and the O&M on the CHP causing the annual savings in this scenario to decrease by $20,000 compared to scenario 1.3.

The remaining 40% of the biogas generated outside the operational period and which is not stored for later use is flared. GHG reductions increase by 301 MT CO2e per year relative to scenario 1.3 due to the increased CHP uptime, however the increased O&M demand paired with the decrease in annual savings make this scenario unfavorable compared to scenario 1.3.

Scenario 1.5. 'All Year 24/7'

Scenario 'All Year 24/7' models the annual cost savings and GHG reductions if NWWRP operates the engine for its maximum possible uptime of 90% of the year, or 7,884 hours per year. In this scenario, the engine consumes 38,427 mmBtu/year of biogas and 22,469 mmBtu/year of NG. The remaining 10% of the biogas generated outside the operational period and which not stored for later use is flared.

Due to the further reduction of average power cost offset compared to scenario 1.4, the annual savings in scenario 1.5 decrease by $33,000 relative to scenario 1.4, resulting in this scenario having the lowest total annual savings of all scenarios analysed in this set.

Set 1 Comparison Summary

The engine operational expenses were estimated to be $0.036 per kWh generated and the biogas compressor and dryer were estimated to draw 95 kW at the typical engine fuel rate of 143 scfm of biogas. Evaluating under these conditions, the savings generated while running the engine during the off-peak periods year-round are insufficient to offset the operational costs for the engine. As a result, it is recommended that Mesa NWWRP continue to operate the engine only during peak periods year-round, corresponding to a cumulative run time of 3,290 hours per year and an annual uptime of approximately 38%. This is understood to be representative of current engine operations and was set as the baseline for all future scenario analyses. The Set 1 scenarios are summarized in Table 26. Co-Generation without Mixed HSW organic slurry Addition Scenario Model ResultsTable 26 and Figure 17.

Table 26. Co-Generation without Mixed HSW organic slurry Addition Scenario Model Results

Scenario	Annualized Scenario Savings [$]	GHG Reduction [MT CO_2e]	Total Project Cap Ex	Diesel Gallon Equivalents/ Day
1.1. ‘Summer On-Peak Only’	($2,000)	(128)	$0	-
1.2. ‘Summer On/Shoulder-Peak’	$14,000	23	$0	-
1.3. ‘All Year On/Shoulder-Peak / ‘Enhanced Baseline’	$21,000	221	$0	-
1.4. ‘All Year On/Shoulder-Peak + Summer Off-Peak’	$1,000	522	$0	-
1.5. ‘All Year 24/7’	($32,000)	918	$0	-

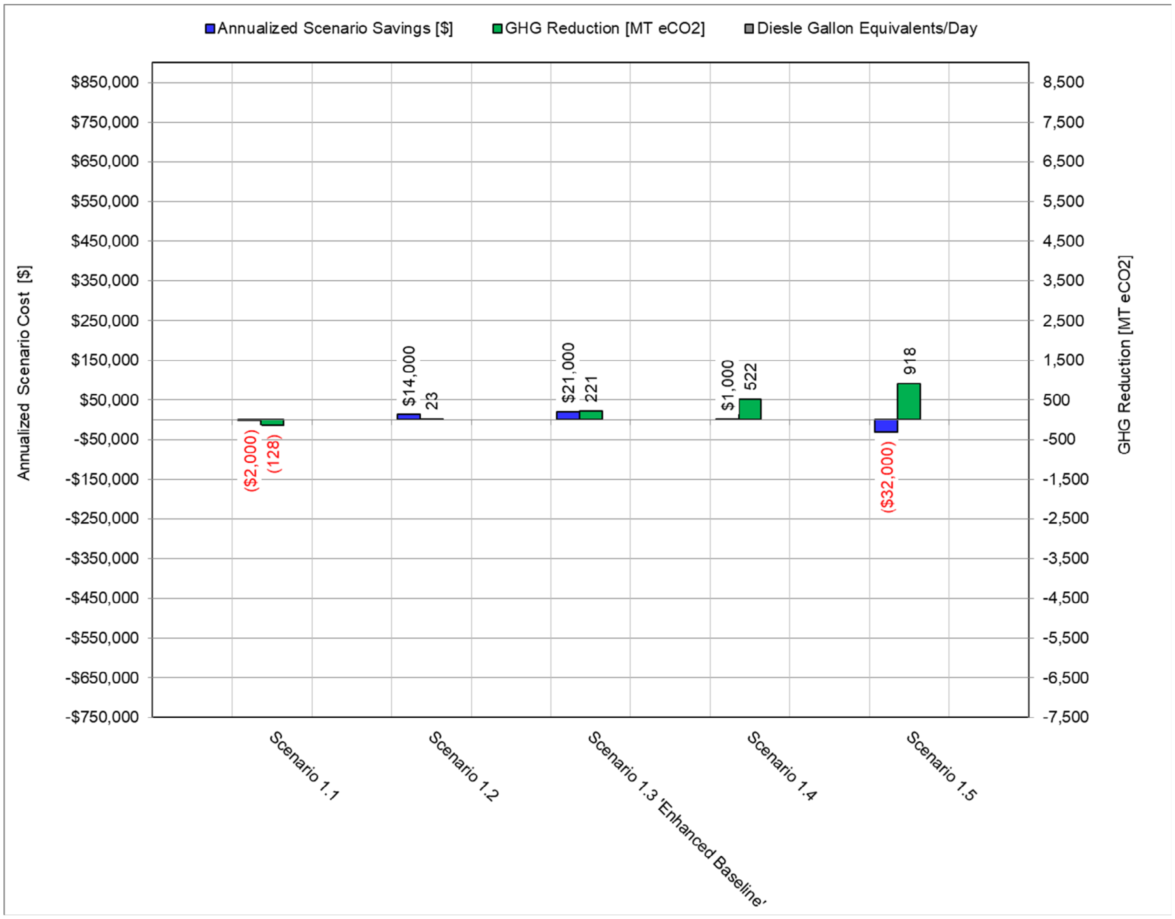


Figure 17. Co-Generation without Mixed HSW organic slurry Addition Scenario Comparison

6.2 Set 2: CHP engine with Mixed HSW Addition

Set 2 scenarios explore ways in which NWWRP may increase savings and reduce GHG emissions by accepting the mixed HSW organic slurry to the digester and maximizing biogas utilization with the existing co-generation operations. This would include a capital project to implement a Slurry Offloading and Receiving station as described in Section 4.2. In this set of scenarios, the mixed HSW organic slurry is added to either one digester or both digesters at the limiting 35% VS load mass fraction. Scenarios 'CHP at 100%' shows the theoretical performance that if NWWRP maximizes biogas usage to the engine to 100% of its rated input fuel capacity. All scenarios assume the current engine operations at only On-Peak and Shoulder Peak periods throughout the year would be maintained. A summary of the results of the Set 2 scenarios can be found below.

Scenario 2.1. 'HSW to 1 DIG – 'All Year On-/ Shoulder-Peak' CHP at 87.5%'

Under this scenario, 22 tons per day (tpd) of OSW and 5,000 gallons per day (gpd) of FOG are sent to one digester and CHP is used to peak shave year-round during both on-peak and shoulder-peak periods. Therefore, NWWRP operates the engine during "Winter On-Peak" seasonal periods, as shown in Figure 16. 2018 Seasonal Electrical Power Costs

Table 25. Total biogas generation increases to 204 scfm with the addition of HSW from 132 scfm under the 'Enhanced Baseline' Scenario, equating to a 55% increase in biogas generation.

The additional biogas generation means that supplemental NG is negligible, with the CHP operating on biogas over 99% of its uptime. However, since the biogas flared during CHP downtime increases as well, biogas utilization under this scenario is 38%, the remaining 62% of biogas generated is flared. This scenario generates an annual savings of ($539,000) which is $560,000 lower than the baseline annual savings. The decrease in annual savings results from the fact that the scenario includes $732,000 per year in annualized capital costs associated with the pre-processing facility and equipment, and the savings generated from running the CHP on biogas for a greater proportion of its uptime is insufficient to offset these costs. The reduction in NG consumption in the CHP increases GHG reductions by 247 MT CO_2e per year over the baseline.

Scenario 2.2. 'HSW to 1 DIG – CHP at 100%'

Under this scenario, the HSW feeding conditions are identical to those in scenario 2.1 at 22 tpd OSW and 5,000 gpd FOG and the cumulative biogas generation rate of 204 scfm. CHP is used to peak shave year-round during both on-peak and shoulder-peak periods. Therefore, NWWRP operates the engine during "Winter On-Peak" seasonal periods, as shown in Figure 16. 2018 Seasonal Electrical Power Costs

Table 25. CHP generation under this scenario is increased to the full rated engine capacity of 600 kW.

As a result, CHP biogas consumption increases to 239 scfm, however, the required supplemental NG to the CHP engine increases to approximately 15% of uptime, instead of the 1% of uptime in Scenario 2.1. Due to the increased biogas consumption during CHP uptime, the biogas utilization under this scenario increases relative to the 'Baseline' Scenario, 38% of biogas is utilized and the remaining 62% being flared. The annual savings in this scenario remains at ($539,000) and GHG reductions are slightly decreased compared to Scenario 2.1 due to the increased NG consumption, decreasing from 468 MT CO_2e per year to 450 MT CO_2e per year. As with Scenario 2.1, the annual savings are significantly lower than the baseline due to the $732,000 per year in annualized capital costs associated with the pre-processing facility and equipment.

Scenario 2.3. 'HSW to both DIGs – CHP at 87.5%'

Under this scenario, HSW loading rates are identical to Scenario 2.3 at 44 tpd OSW and 10,000 gpd FOG, with equal parts of the HSW slurry injected into each digester. CHP is used to peak shave during both peak and shoulder peak periods year-round. Therefore, NWWRP operates the engine during "Winter On-Peak" seasonal periods, as shown in Figure 16. 2018 Seasonal Electrical Power Costs

Table 25.

Biogas generation increases to 278 scfm, a 110% over the 'Enhanced Baseline' Scenario. CHP generation rates is set at 525 kW, or 87.5% load, and no supplemental NG is required by the CHP. The amount of biogas flared under this scenario increases to 81% with the remaining 19% being used in the CHP. The annual savings in this scenario remain negative at ($358,000), which represents a $181,000 increase in annual savings over scenarios 2.1 and 2.2. The $181,000 increase in annual savings under this scenario is primarily derived from increased OSW tipping fee offsets and FOG tipping fees. GHG reductions in this scenario decrease relative to scenarios 2.1 and 2.2 to 438 MT CO_2e due to the fact that a larger power draw is required for OSW pre-processing which is not offset by a similar increase in CHP generation since only 1 scfm of NG is being offset in this scenario with the remainder of the increased biogas generated being flared.

Scenario 2.4. 'HSW to both DIGs – CHP at 100%'

Under this scenario, HSW loading rates are identical to Scenario 2.3 at 44 tpd OSW and 10,000 gpd FOG, with equal parts of the HSW slurry injected into each digester. CHP is used to peak shave during both peak and shoulder peak periods year-round. Therefore, NWWRP operates the engine during "Winter On-Peak" seasonal periods, as shown in Figure 16. 2018 Seasonal Electrical Power Costs

Table 25.

Biogas generation increases to 278 scfm, a 110% over the ‘Enhanced Baseline’ Scenario. CHP generation is expanded to 600 kW, from the baseline generation of 525 kW to the full rated engine capacity with generation at Since biogas generation is 274 scfm, supplemental NG is not required for CHP in this scenario. This scenario generates ($349,000) in annual savings which represents a $190,000 increase in savings over Scenario 2.1, ‘Slurry to 1 DIG – CHP at 87.5%’, and Scenario 2.2, ‘Slurry to 1 DIG – CHP at 100%’ and a $10,000 increase in savings over Scenario 2.3 ‘Slurry to both DIGs – CHP at 87.5%’. Both the $10,000 increase in savings and 124 MT CO_2e increase in GHG reductions result from the increase in power generation under this scenario since all other parameters analysed remain identical.

Scenario 2.5. ‘HSW to both DIGs – Expanded CHP at 100%’

The 'HSW to both DIGs – Expanded CHP at 100%' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in both digesters. This scenario assumes that, in addition to the existing 600 kW engine, NWWRP would install an additional 800 kW engine that uses 194 scfm biogas at its rated capacity and has a 38% electric efficiency compared to the current engine’s electric efficiency of 23%.

Previously, it had been communicated that an expansion to the CHP system would require an upgrade to the electrical distribution system because the NWWRP transmission grid has a maximum operating capacity of 525 kW. Following an investigation of the NWWRP transmission grid conducted by Arcadis, it was concluded that NWWRP’s transmission grid is currently set up to accommodate a second CHP engine and no upgrades to the transmission grid would be required to expand CHP capacity. However, it is important to highlight that, due to the much higher sensitivity of modern CHP engine units to fouling via H_2S and siloxanes in the biogas feed, biogas pre-treatment would be required if an additional CHP engine is installed, incurring $200,000 in added capital cost under this scenario.

The City’s expanded engine generator system generates electricity both on-peak and shoulder-peak periods, all year around. Therefore, NWWRP operates the engine during “Winter On-Peak” seasonal periods, as shown in Table 28. The biogas is used as it is generated and supplemented with biogas stored in the existing storage tank to operate the engines. Natural gas is fed to the engine when biogas in not available (while the storage tank is being filled). It is assumed that the engines have a 90% annual availability.

Under this scenario, the loading rates were set at 44 tpd of OSW and 10,000 gpd of FOG, with half the total load being sent to each digester. Biogas generation increases to 278 scfm, a 110% over the ‘Enhanced Baseline’ Scenario. Both engines are operated at their full rated capacity of 600 kW and 800 kW for a total power generation of 1.4 MW. The existing CHP engine is entirely fuelled on biogas and the additional CHP engine is fuelled by biogas for 20% of its uptime and NG for the remainder of its uptime. The annual savings under this scenario are ($336,500), which is the highest annual savings of the scenarios analysed in this scenario set. GHG reductions are considerably higher than in Scenarios 2.1 through 2.4 at 1,303 MT CO_2e with the second highest reduction at 562 MT CO_2e because power generation is more than doubled under this scenario.

Set 2 Comparison Summary

From the results of this analysis, it appears that accepting HSW and using the additional biogas in the current CHP system is not economically beneficial. The high capital costs associated with the pre-processing facility and equipment for the OSW and the FOG processing coupled with the fact that, while the increase biogas generation rates generated from HSW reduce or eliminate the need to supplement NG to the CHP, operationally motivated CHP downtime during off-peak periods still results in a significant proportion of biogas being flared, meaning that the increase in biogas production is not being leveraged for significant economic benefit.

At increasing rates of HSW acceptance, economics improve primarily due to the tipping fee and tipping fee offsets and marginally from the increase in biogas generation. It is important to highlight that the economics of accepting OSW are highly dependent upon the tipping fees of $30.31 per wet ton. The Set 2 scenarios are summarized in Table 27 and Figure 18.

Table 27. CHP engine with Mixed HSW organic slurry Addition Scenario Estimates

Scenario	Annualized Scenario Savings [$]	GHG Reduction [MT CO_2e]	Total Project Capital Expenditure	Diesel Gallon Equivalent/ Day
1.3. 'Enhanced Baseline'	$21,000	221	$0	-
2.1. 'Slurry to 1 DIG – CHP at 87.5%'	($539,000)	468	$10,895,800	-
2.2. 'Slurry to 1 DIG – CHP at 100%'	($539,000)	450	$10,895,800	-
2.3. 'Slurry to both DIGs – CHP at 87.5%'	($358,000)	440	$10,895,800	-
2.4. 'Slurry to both DIGs – CHP at 100%'	($349,000)	562	$10,895,800	-
2.5 'Slurry to both DIGs – Expanded CHP'	($336,500)	1,303	$12,220,800	-

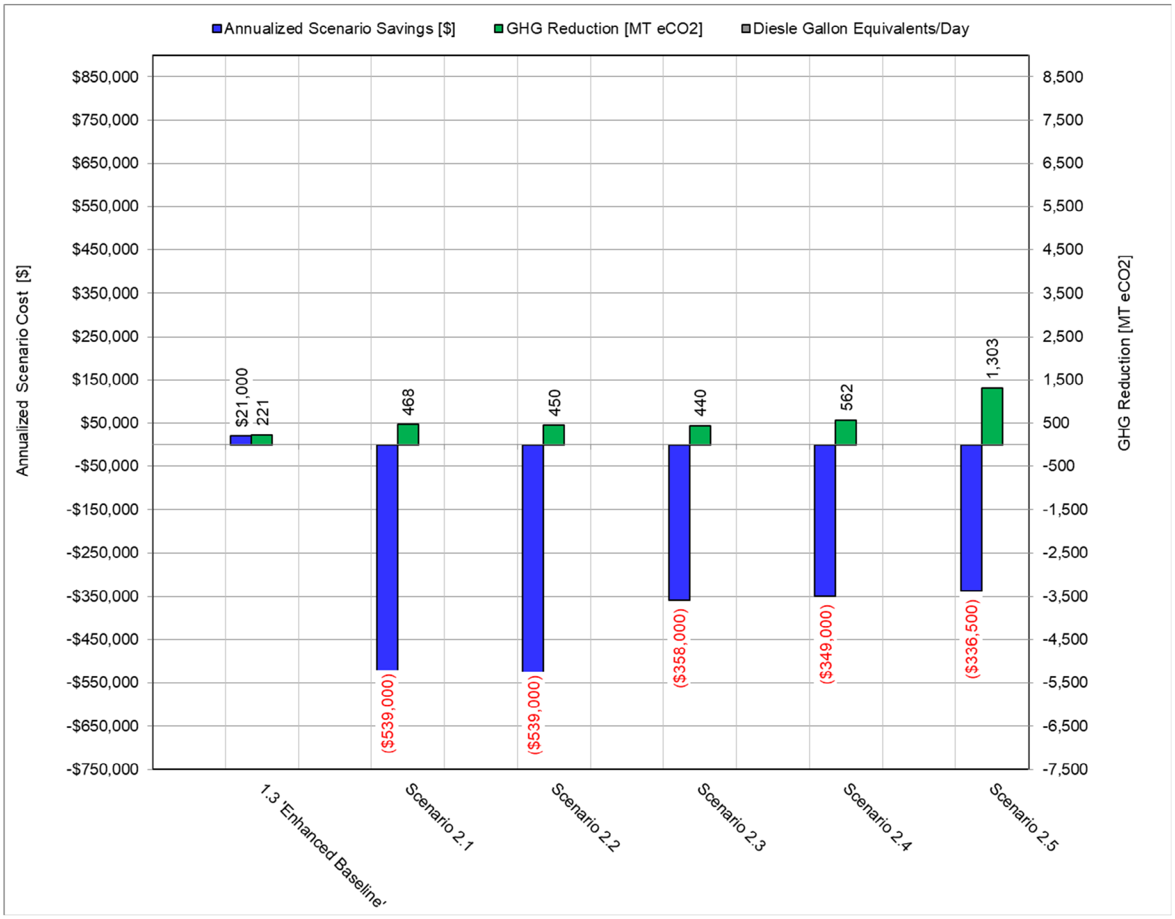


Figure 18. CHP engine with Mixed HSW organic slurry Addition Scenario Comparison

Set 2 Conclusions

From the results of this analysis, it appears that accepting HSW and using the additional biogas in the current CHP system is not economically beneficial. The high capital costs associated with the pre-processing facility and equipment for the OSW and the FOG processing coupled with the fact that, while the increase biogas generation rates generated from HSW reduce or eliminate the need to supplement NG to the CHP, operationally motivated CHP downtime during off-peak periods still results in a significant proportion of biogas being flared, meaning that the increase in biogas production is not being leveraged for significant economic benefit.

At increasing rates of HSW acceptance, economics improve primarily due to the tipping fee and tipping fee offsets and marginally from the increase in biogas generation. It is important to highlight that the economics of accepting OSW are highly dependent upon the tipping fees offset of $30.31 per wet ton.

6.3 Set 3: RNG Generation with Mixed HSW Addition

Set 3 scenarios explore ways in which NWWRP can increase savings and GHG reduce emissions by accepting OSW and FOG and maximizing biogas utilization by generating renewable natural gas (RNG). This would involve a capital project to install an RNG upgrading system as described in Section 4.3. The scenarios also include potential benefits of generating RIN credits and offsetting Sanitation CNG vehicle fuel costs.

All six scenarios explore the potential benefits of adding varying the mixed HSW organic slurry to one, both, or neither of the digesters. Scenarios 3.2 and 3.4 present the ideal future condition demonstrating the theoretical change in the process in which D3 and D5 RIN credits are distributed based on mass fraction of organic waste loaded to the digester as detailed in ‘Biogas Utilization & Project Incentives’ Memorandum. The current RFS stipulates if any amount of HSW is added to a digester, then all biogas produced becomes classified as eligible for D5 RINs. As the concept of distinguishing D3 and D5 RIN credits based on a mass ratio of organic waste to sludge in a digester is developed, the conceivable annualized savings increase significantly. These two ‘D3/D5 Mass Fraction’ scenarios are considered in order to demonstrate the annual revenue achievable under the anticipated future conditions. Recently, RIN credit values have decreased significantly from their 2017 peak values making RIN credit volatility an important factor to consider when evaluating future RIN revenue potential. Based on discussion with policy and market experts, a D3 RIN value of $1.85 per RIN and a D5 RIN value of $0.34 per RIN was selected as a long-term planning value on which to base the scenario analyses.

Lastly, Scenarios 3.5 and 3.6 evaluate the effects generating RNG with no HSW addition. The scenarios show the theoretical benefits of generating RNG solely from current sludge flow and from implementing the Pondus system to hydrolyze the thickened WAS at the Plant. The annual savings under both scenarios do not account for the capital and O&M expenditure of an offloading and receiving station. However, these scenarios do not generate any income from tipping fees.

Subsequent sections describe the scenario parameters in greater detail. A summary of the results of the Set 3 scenarios can be found below.

Scenario 3.1A ‘HSW to 1 DIG – D3/D5 RNG + Membrane Upgrading Skid

The 'HSW to both DIGs – D3 and D5 RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) into one digester. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the membrane system has a 95% annual availability. Since HSW is added to one digester, this scenario generates both D3 (non-HSW digester) and D5 (w/HSW digester) RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the engine generator system is not operated.

Under this scenario, 22 tpd of hauled OSW and 5,000 gpd of FOG are being sent to a single digester. All biogas is sent to the membrane upgrading system to generate both D3 and D5 RINs, yielding a total of approximately $568,000 in RIN credits. In addition to RIN revenues, tipping fee offsets from OSW generate $118,000 per year in avoided costs and FOG tipping revenues are $26,000 per year. The $14,830,800 in capital expenditures under this scenario includes expenditures necessary for the waste pre-processing facility, pre-processing equipment, organic waste receiving at NWWRP, the membrane upgrading system, a thermal oxidizer system for tail gas treatment and transmission of RNG to the NG transmission pipeline.

Under these conditions, NWWRP is expected to generate approximately 1,362 diesel gallon equivalents (DGE) per day. This DGE represents 79% of the current CNG fleet demand in Mesa and is expected to offset approximately $229,000 in fuel costs per year. GHG reductions for this scenario are 3,507 MT CO_2e due to the substantial vehicle fuel offsets generated under this scenario.

Scenario 3.1B ‘HSW to 1 DIG – D3/D5 RNG + PSA Upgrading Skid

The 'HSW to both DIGs – D3 and D5 RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) into one digester. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the PSA system has a 95% annual availability. Since HSW is added to one digester, this scenario generates both D3 (non-HSW digester) and D5 (w/HSW digester) RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the engine generator system is not operated.

Under this scenario, 22 tpd of hauled OSW (approx. 3,200 gpd) and 5,000 gpd of FOG are being sent to a single digester. All biogas is sent to the membrane upgrading system to generate both D3 and D5 RINs, yielding approximately $539,000 in RIN credits. In addition to RIN revenues, tipping fee offsets from OSW generate $118,000 per year in avoided costs and FOG tipping revenues are $26,000 per year. The $14,213,800 in capital expenditures under this scenario includes expenditures necessary for the waste pre-processing facility, pre-processing equipment, organic waste receiving at NWWRP, the PSA upgrading system, a thermal oxidizer system for tail gas treatment and transmission of RNG to the NG transmission pipeline. This capital expenditure is lower compared the capital expenditure under Scenario 3.1A due to the lower capital cost associated with a PSA system compared to a membrane system,

Under these conditions, NWWRP is expected to generate approximately 1,291 diesel gallon equivalents (DGE) per day; this value is lower than the DGE generation under Scenario 3.1A because the membrane system has a higher methane capture at 97% versus 92% for the PSA system. This DGE represents 75% of the current CNG fleet demand in Mesa and is expected to offset approximately $217,000 in fuel costs per year. GHG reductions for this scenario are lower than those under Scenario 3.1A at 3,333 MT CO_2e versus 3,507 MT CO_2e because the PSA system generates slightly less vehicle fuel compared to the membrane system and has a higher power draw than the membrane system.

However, despite these factors, the PSA system increases annual savings by $84,000 over Scenario 3.1A indicating that the PSA is a more economically favourable RNG upgrading technology than the membrane system. As a result, all subsequent analyses involving RNG generation are modelled using a PSA system.

Scenario 3.2 'HSW to 1 DIG – D3/D5 RNG Mass Fraction' Scenario

This scenario evaluates the benefits if the EPA adjust the RIN credit distribution on a mass ratio of organic waste to sludge into a single digester. The maximum waste accepted under this scenario is 22 tpd of hauled OSW (approx. 3,200 gpd) and 5,000 gpd of FOG.

Therefore, this scenario reflects the potential benefit of sending the maximum amount of D3 RIN biogas and D5 RIN biogas to generate RNG by accepting waste into only one digester. If NWWRP dedicates one digester to co-digestion and one digester to digesting sludge only. All D3 and D5 RIN biogas would be sent directly to the RNG system, generating approximately $983,000/year in RIN credits. This represents a $444,000 increase in RIN revenue relative to Scenario 3.1B and generates a positive savings of $199,000 per year or $178,000 savings over the baseline.

Scenario 3.3 'HSW to both DIGs – All D5 RNG' Scenario

The 'HSW to both DIGs – All D5 RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in both digesters. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is added to both digesters, this scenario generates only D5 RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the engine generator system is not operated.

The maximum waste accepted under this scenario is 44 tpd of hauled OSW (approx. 6,400 gpd) and 10,000 gpd of FOG. Sending the maximum amount of D5 RIN biogas to generate RNG would generate approximately $299,000 from RIN credits. Under these conditions, NWWRP is expected to generate approximately 1,722 DGE per day. This DGE represents 100% of the current CNG fleet demand in Mesa and offsetting $289,000 in fuel costs per year. Despite the fact that vehicle fuel generation under this scenario is 33% higher than in Scenario 3.1B, due to the lower value of D5 RINs, RIN credit revenue decreases by $240,000 therefore; the primary financial benefits of accepting additional HSW and generating additional vehicle fuel comes from OSW tipping fee offsets, FOG tipping fees and CNG fuel cost offsets. Annual savings under this scenario increase by $12,000 per year to ($233,000), however, this value is highly dependent upon the OSW tipping fee of $30.31 per wet ton and if the tipping fee were to increase in the future, annual savings would further improve.

Scenario 3.4 'HSW to both DIGs – D3/D5 Mass Fraction' Scenario

This scenario evaluates the benefits if the EPA adjusted the RIN credit distribution on a mass ratio of organic waste to sludge into both digesters. The maximum waste accepted under this scenario is 44 tpd of hauled OSW (approx. 6,400 gpd) and 10,000 gpd of FOG.

This scenario reflects the potential benefit of diverting the maximum amount of organic waste from landfills. This scenario reflects the potential benefit of sending the maximum amount of D3 RIN biogas and D5 RIN biogas to generate RNG by accepting waste into both digesters. If NWWRP dedicates one digester to co-digestion and one digester to digesting sludge only. It is estimated that equal amount of sludge be sent to both digesters to maximize the organic mass fraction. All D3 and D5 RIN biogas would be sent directly to the RNG system, generating approximately $1,165,000 in RIN credits per year, which is an $866,000 increase in RIN revenue over scenario 3.4. DGE generation rates remain unchanged from scenario 3.3 at 1,792 DGE per day, generating $289,000 in fuel cost offsets per year. Annual savings under this scenario are positive at $633,000 per year which represents a $612,000 increase in savings over the baseline.

Scenario 3.5 ‘No HSW – All D3 RNG’ Scenario

This scenario reflects the potential benefit of sending the maximum amount of D3 RIN biogas to generate RNG by not accepting any organic waste. The capital expenditures under this scenario are $10,895,800 lower than in Scenarios 3.1B through 3.4 since this configuration does not require a pre-processing facility or pre-processing equipment. The $3,318,000 capital expenditure required under this scenario includes the capital expenditure for the PSA upgrading system, thermal oxidizer for tail gas treatment and transmission of the RNG product gas to the NG transmission pipeline.

Under this scenario, all biogas would be sent directly to the RNG system, generating approximately $772,000 in RIN credits per year, which is the highest RIN revenue potential of all scenarios not involving a D3/D5 mass fraction split. Under these conditions, NWWRP is expected to generate approximately 818 DGE per day, meaning this scenario yields the lowest CNG fleet demand offset at approximately 48% of the current demand. This offset generates approximately $138,000 per year in fuel cost savings.

Of the scenarios analysed, this scenario generates the highest annual savings without assuming a D3/D5 mass fraction split at $497,000 per year, which represents a $456,000 increase in annual savings over the baseline. The increased annual savings under this scenario primarily result from the elimination of the capital costs associated with the organic waste pre-processing facility and equipment in addition to the fact that RIN revenues are higher under this scenario since all RNG generated qualifies for D3 RIN credits. Additionally, since this scenario does not require a pre-processing facility, this scenario would have a greatly accelerated timeline for completion relative to any scenarios involving organic waste acceptance.

Scenario 3.6 ‘No HSW – All D3 RNG + Pondus’ Scenario

This scenario reflects the potential benefit of using Pondus to increase WAS degradability and leveraging the increase in biogas generation to increase D3 RIN revenue. Additionally, Pondus decreases the amount of biosolids generated, decreasing sludge hauling costs. No organic waste is accepted under this scenario, all biogas is converted to RNG and D3 RINs are exclusively generated. D3 RIN revenues under this scenario are $862,000 per year, a $90,000 increase in RIN revenue over Scenario 3.5. Under these conditions, NWWRP is expected to generate approximately 913 DGE per year. This DGE represents 53% of the current CNG fleet demand in Mesa and is expected to offset $153,000 per year.

Despite the increase in biogas generated and D3 RIN revenue collected, the annual savings under this scenario are $156,000 lower than under Scenario 3.5 due to the $3,630,000 in additional capital expenditures for the Pondus system under this scenario.

Set 3 Comparison Summary

The Set 3 scenarios are summarized in Table 28 and Figure 19.

Table 28. RNG Generation with Mixed HSW organic slurry Addition Scenario Estimates

Scenario	Annualized Scenario Savings [$]	GHG Reduction [MT CO_2e]	Total Project Capital Expenditure	Diesel Gallon Equivalents/ Day
1.3. ‘Enhanced Baseline’	$21,000	221	$0	-
3.1A ‘Slurry to 1 DIG, D3/D5, Membrane’	($329,000)	3,507	$14,830,800	1,362
3.1B ‘Slurry to 1 DIG, D3/D5, PSA’	($245,000)	3,333	$14,213,800	1,291
3.2 ‘Slurry to 1 DIG, D3/D5 Mass Fraction’	$199,000	3,333	$14,213,800	1,291
3.3 ‘Slurry to both DIGs, all D5’	($233,000)	4,886	$14,213,800	1,722
3.4 ‘Slurry to both DIGs, D3/D5 Mass Fraction’	$633,000	4,886	$14,213,800	1,722
3.5 ‘No Slurry, all D3’	$497,000	1,709	$3,318,000	818
3.6 ‘No Slurry, all D3 + Pondus’	$341,000	1,847	$5,217,600	913

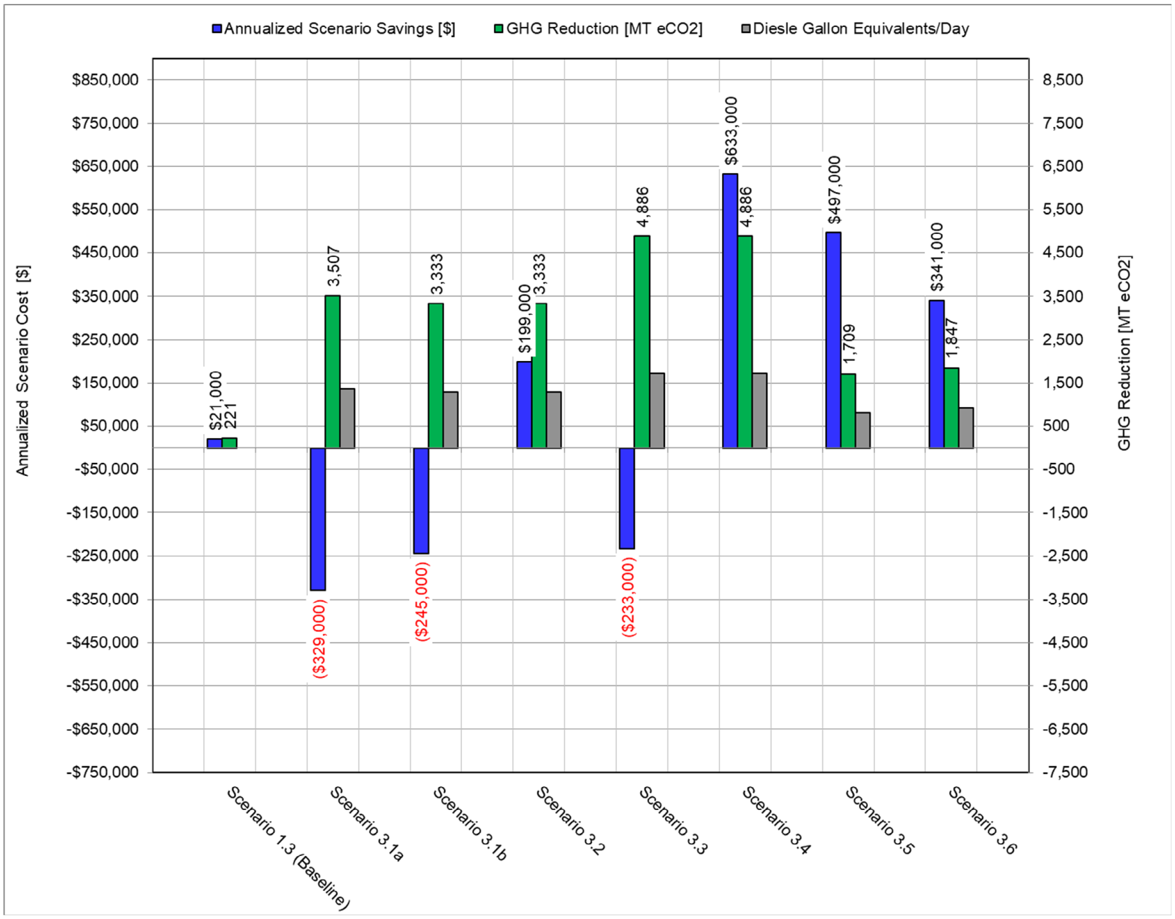


Figure 19. RNG Generation with Mixed HSW organic slurry Addition Scenario Comparison

Set 3 Conclusion

From the results of this analysis, it appears that accepting mixed HSW organic slurry into one digester (Scenario 3.1B) generates annualized savings 5% higher than accepting mixed HSW organic slurry into both digesters (Scenario 3.3). Scenario 3.5, accepting no mixed HSW organic slurry generated the highest yielding annualized savings of $497,000, a $730,000 increase in annual savings relative to accepting mixed HSW organic slurry into both digesters (Scenario 3.3). While there is a substantial difference between D3 and D5 RIN credit values, the economic benefits associated with tipping fees, tipping fee offsets and increased vehicle fuel cost offsets contribute to improving the economics of D5 RINs; the primary factor resulting in the significant decrease in annual savings over the baseline are largely attributed to the significant costs associated with amortizing the capital expenditures for the OSW pre-processing facility and equipment.

The Set 3 evaluation indicates the most cost-effective configuration is to generate RNG from the existing biogas generated at the Plant without any slurry addition because the ‘No Mixed HSW organic slurry’ (Scenario 3.6). In addition to being the most economically favorable scenario, this configuration would have the shortest timeline for implementation since it does not require the construction of an organics pre-processing facility.

A significant increase in the projected annual savings is projected if D3 and D5 RINs could be assigned based on a mass loading faction basis. This would require specific BMP testing of all accepted feedstocks and would be a significant step in adjusting the EPA valuation of biogas from mixed OSW and FOG and sludge digesters

Lastly, the Scenario 3.6 indicates that operating the Pondus system at NWWRP is not financially beneficial. The increased RIN revenue and decreased sludge hauling costs Pondus generates are insufficient to offset the capital and O&M expenditure associated with the Pondus system.

6.4 Set 4: Co-Generation and RNG Generation with Mixed HSW Addition

Set 4 scenarios explore ways in which NWWRP can increase savings and reduce GHG emissions by accepting mixed HSW organic slurry and maximizing biogas utilization to renewable natural gas (RNG) generation and enhancing the existing co-generation operations. Subsequent sections describe the scenario parameters in greater detail. A summary of the results of the Set 4 scenarios can be found below.

Scenario 4.1 'HSW to 1 DIG – Existing CHP + RNG' Scenario

This scenario evaluates the potential benefit of sending the maximum amount of D3 RIN biogas to generate RNG and a portion of the D5 RIN biogas to the CHP engine. 22 tpd of OSW and 10,000 gpd of FOG accepted to a single digester under this scenario. 100% of the biogas from the digester receiving mixed HSW organic slurry is sent to the CHP during peak periods with natural gas being supplemented when biogas availability falls below the minimum engine turndown of 70%. It is important to highlight that under this configuration, the most economically beneficial option is no longer to run the CHP during peak and shoulder peak periods year round; the maximum annual savings occur when biogas is used to generate D5 RINs instead of power during all periods except for the 'Max Summer On-Peak' period. Therefore, for this analysis, CHP is only operational during the 'Max Summer On-Peak' period and when the CHP is operational, it is assumed that it is run at its full rated capacity of 600 kW. The existing 80 psig liquid ring compressor and pressure storage vessel remain in use under this scenario.

The second digester would be dedicated to digesting sludge only, and all D3 RIN biogas would be sent directly to the RNG system even during CHP uptime. When the engine is not in operation, the D5 RIN biogas from the co-digestion digester is sent to the RNG system. Under these conditions, total RIN revenues are $533,000 per year and 1,258 DGE per day are generated. This DGE generation rate represents 73% of the current CNG fleet demand in Mesa and would offset $211,000 per year in fuel costs.

Compared to Scenario 3.1B 'Slurry to 1 digester, D3/D5, PSA, operating CHP on biogas during 'Max Summer On-Peak' periods increased annual savings by $2,000 per year to ($243,000) per year.

Scenario 4.2 'HSW to 1 DIG – Low Pressure CHP + RNG' Scenario

This scenario reflects the potential benefit of replacing the current 80 psig liquid ring compressor with a 1.5 psig blower system to reduce the power draw of the CHP biogas feed system. The model parameters for the two options are summarized in Table 29.

Table 29. Low Pressure Biogas Feed System Parameters

Parameter	Existing Biogas Feed System	Low Pressure Biogas Feed System	Unit
Capital Expenditure	$0	$510,000	USD
Power Draw	72	19	kW

Digestion parameters are identical to Scenario 4.1, with 22 tpd of OSW and 5,000 gpd of FOG being accepted to a single digester. CHP is only operated on biogas during 'Max Summer On-Peak' periods and is operated at its full rated capacity of 600 kW. When the engine is not in operation, the D5 RIN biogas from the co-digestion digester is sent to the RNG system.

Under these conditions, total RIN revenues remain at $533,000 per year and 73% of the current CNG fleet demand in Mesa is offset, generating $211,000 in fuel cost savings per year. Annual savings under this scenario decrease by $39,000 relative to Scenario 4.1, indicating that the reduction in parasitic power draw for the biogas feed system is insufficient to offset the increased capital cost associated with the 1.5 psig blowers.

Scenario 4.3 'HSW to both DIGs – Existing P CHP + RNG' Scenario

The 'HSW to both DIGs – Existing P CHP + RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in both digesters. This scenario assumes that City primarily generates RNG and uses a portion of the biogas in its CHP system to peak shave. CHP is only operated on biogas during the 'Max Summer On-Peak' seasonal period and is operated at its full rated capacity of 600 kW during operation. Since HSW is added to both digesters, this scenario generates only D5 RIN credits. The existing 80 psig liquid ring compressor and pressure storage vessel remain in use under this scenario.

When the engine is not in operation, all D5 RIN biogas from the co-digestion digester is sent to the RNG system, generating approximately $289,000 in RIN credits. Under these conditions, NWWRP is expected to generate approximately 1,665 DGE per day. This DGE represents 97% of the current CNG fleet demand in Mesa, offsetting $280,000 per year in fuel costs.

Compared to injecting the mixed HSW organic slurry into a single digester under Scenario 4.1, co-digesting in both digesters and using D5 RINs to fuel the existing CHP system increases annual savings by $7,000 due to the increase in savings generated from increased tipping fee and vehicle fuel offsets. However, relative to Scenario 3.4 'Slurry to both digesters, D3/D5 Mass Fraction' the annual savings under this scenario decrease by $3,000 per year. Since under this scenario, no NG is supplemented to the CHP, the results of this scenario indicate that D5 RNG is more lucrative when used to collect RIN credits than when used in the CHP engine.

Scenario 4.4. 'HSW to both DIGs – Low P CHP + RNG' Scenario

Under this scenario, the co-digestion parameters set under Scenario 4.3 are retained, RNG and CHP operation remain unchanged and the biogas feed system is upgraded to the low-pressure feed system analyzed in Scenario 4.2. The annual savings under this scenario decrease by $37,000 relative to Scenario 4.3, re-iterating the findings in Scenario 4.2.

Scenario 4.5. 'No HSW – all D3 RNG + NG Peak CHP' Scenario

The 'No HSW – all D3 RNG + NG Peak CHP' Scenario assumes that the City will not collect, process, or inject any HSW at NWWRP. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is not added to either digester, this scenario generates only D3 RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG).

Under this scenario, the City uses natural gas to run the City's existing engine generator system to generate electricity on-site; for this scenario, the maximum annual savings occur when the CHP engine is run during 'Mild Summer Shoulder-Peak" seasonal periods, as shown in Table 28. Therefore, this scenario was analyzed assuming CHP is operational during max and mild summer on-peak and shoulder-peak periods. Natural gas fed to the engine to operate at its full rated capacity of 600 kW. It is assumed that the engine has a 90% annual availability.

The annual savings under this scenario increase by $15,000 relative to Scenario 3.6, 'No-Slurry - all D3 RNG' indicating that it is most financially beneficial to operate the CHP on NG to peak shave during peak and shoulder peak during the summer. Of all scenarios evaluated without assuming a D3/D5 mass fraction RIN split, this scenario generates the highest annual savings at $512,000 per year, which represents a $491,000 increase in savings over the baseline scenario.

Set 4 Comparison Summary

The set 4 Scenario analyses are summarized in Table 30 and Figure 20.

Table 30. Co-Generation and RNG Generation with Mixed HSW organic slurry Addition Scenario Estimates

Scenario	Annualized Scenario Savings [$]	GHG Reduction [MT CO_2e]	Total Project Cap Ex	Diesel Gallon Equivalents/ Day
1.3. ‘Enhanced Baseline’	$21,000	221	$0	-
3.5. ‘No Slurry – all D3 RNG’	$497,000	1,709	$3,318,000	818
4.1. ‘Slurry to 1 DIG – Existing P CHP + RNG’	($243,000)	3,270	$14,213,800	1,258
4.2. ‘Slurry to 1 DIG - Low P CHP + RNG’	($282,000)	3,281	$14,823,800	1,258
4.3. ‘Slurry to both DIGs – Existing P CHP + RNG’	($236,000)	4,789	$14,213,800	1,665
4.4. ‘Slurry to both DIGs – Low P CHP + RNG’	($273,000)	4,811	$14,823,800	1,665
4.5. ‘No Slurry – all D3 RNG + NG Summer Peak CHP’	$512,000	1,622	$3,318,000	818

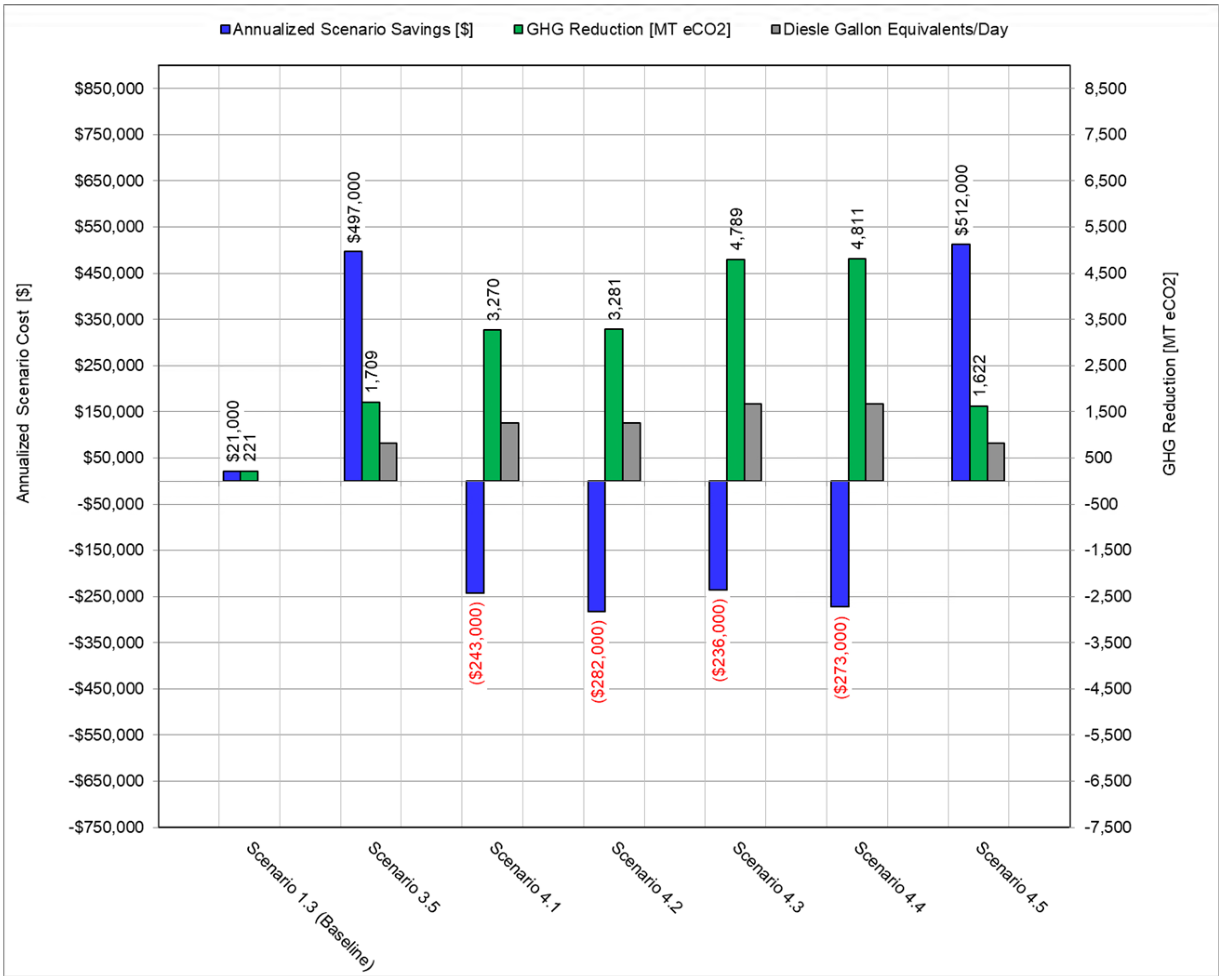


Figure 20. Co-generation and RNG Generation with Mixed HSW organic slurry Addition Scenario Comparison

Set 4 Conclusions

The results of this analysis indicate that it is not economical to divert biogas from the RNG system to the CHP during peak power periods. Operating a new low-pressure gas feed to the engine does not improve annual saving, because the annualized capital expenditures for low pressure feed system exceed the savings generated by the reduction in power draw.

As a result, it is recommended that the CHP exclusively be fuelled with NG and all available biogas be used to generate RNG. NG is preferable to biogas as fuel to the CHP due to the fact that D5 RIN credits are more valuable than offsetting power even at ‘Max Summer On-Peak’ periods and utilization of NG avoids the power draw and O&M associated with the biogas drying and compression. The CHP could be maintained as NG peak shaving process for as long as the engine equipment life allows.

6.5 Set 5: Participation in the Low Carbon Fuel Standard (LCFS) Program

In addition to RIN credits under the RFS, Mesa could qualify for The Low Carbon Fuel Standard (LCFS) by sending RNG to a California based fleet end user. The LCFS was designed as a performance-based regulation, such that the program incentivizes production and use of low-carbon transportation fuels based on a given fuel's lifecycle GHG emissions per unit of energy—or carbon intensity (CI) as rated by the California Air Resources Board (CARB). Carbon intensity is measured as grams of CO_2e per megajoule (MJ) of energy and one LCFS credit is generated for every metric ton of reduction of CO_2e emissions

Under the program, RNG derived from wastewater biogas is an ultra-low-carbon fuel option with relatively low CI values that will differ from plant to plant but will typically range from the low forties to single digits. For example, one California WWTP produces RNG with a CI of 7.75 (per CARB's fuel pathways table) while a second California plant is producing RNG with a CI of 30.92, which translates to LCFS credit values ranging from $17.32 per mmBtu to $12.80 per mmBtu respectively when using the August, 2019 LCFS credit value of $190. For the purpose of this analysis, Mesa's CI was conservatively estimated at 30, translating to $12.86 in LCFS credits per mmBtu of RNG generated. It is important to highlight that in order to qualify for the LCFS, the RNG must be injected into a pipeline with a theoretical physical pathway to the California based end user. As a result, if the Riverview pipeline is not physically connected to a pipeline leading to the California based end user, an alternate pipeline interconnection would be required, increasing the capital expenditure required under this option.

Scenario 5.1 'No Slurry – all D3 RNG and LCFS' Scenario

It was estimated that RIN revenue retained decreases from approximately 85% to 65%. Retained RIN revenue decreases since Mesa would no longer be providing its own CNG fleet as an end user, thus necessitating the involvement of both a RIN and LCFS broker to identify and arrange an offtake agreement with a California based CNG fleet. These additional responsibilities increase the broker's RIN revenue cut, and it is estimated that as little as 50-60% of the LCFS credit revenue would be retained by Mesa in addition to $30,000 per year in annual compliance costs to participate in the CA LCFS program. Nonetheless, doing so would result in an incremental value of $6.43 per mmBtu of RNG. Additionally, accessing the California market is projected to require offering very competitive pricing on the base RNG heating value; therefore, it is assumed that the end user CNG fleet would purchase the RNG for an average $0.40 per DGE, or 13% below the City's current average CNG costs.

Using these parameters, under the all D3 RIN scenario, generating LCFS credits increases annual savings by $35,000 per year over scenario 3.5 'No Slurry – all D3 RNG' to $532,000, representing a $511,000 increase in annual savings over the baseline.

Scenario 5.2 'Slurry to both DIGs – all D5 RNG and LCFS' Scenario

When co-digesting 44 tpd OSW and 10,000 gpd FOG, generating LCFS credits increases annual savings by $338,000 over 3.3 'Slurry to both DIGs - all D5 RNG'. The more favorable economics of generating LCFS credits when co-digesting are largely due to the fact that LCFS credits do not decrease in value when co-digesting in a similar fashion to RIN credits.

As a result, approximately $242,000 per year in revenue is generated from D5 RIN credits whereas $590,000 per year in revenue is generated from LCFS credits. Therefore, when co-digesting, the LCFS better allows NWWRP to scale its RNG revenue than the RFS.

Set 5 Conclusions

When co-digesting, participating in the LCFS is more economically favorable than participating solely in the RFS program. However, the methodology for calculating LCFS credit values for different fuels introduces competitive disadvantages that may hinder the long-term prospects for accessing the LCFS credit market as a producer of wastewater biogas. More specifically, because dairy gas often has highly net-negative CI values, RNG from dairy gas (and other agricultural feedstocks) is considerably more valuable than wastewater biogas under the California program.

While dairy biogas currently accounts for less than 5% of the LCFS market, expansion of dairy RNG production in California and across the US likely means that the window for getting wastewater biogas into California is 4-5 years or less, ultimately meaning that Mesa will likely not be able to begin co-digesting quickly enough to profitably generate LCFS credits. In addition, the California natural gas vehicle market is nearing saturation as close to 95% of the CNG/LNG vehicles operating in the state already use RNG. Much of this RNG is still coming from out-of-state landfills with higher CI scores but accessing the CA market will soon require producers to displace landfill RNG by offering very competitive pricing.

Due to the additional annual savings potential participation in the LCFS can yield, it is recommended that Mesa investigate the possibility of participating in the LCFS in the short term. It is important to note, however, that the economic benefits of this scenario are contingent upon finding a theoretical physical pathway to the California based end user. Therefore, the City must first conduct an investigation to confirm whether there is a theoretical pathway to the California based end user via the currently proposed interconnection and if an alternate interconnection would be required, the costs must be updated and the economic analysis re-run to determine the financial feasibility of this option.

It is also important to highlight that successfully executing the proposed scenario requires a rapid project timeline since anticipated market pressures and trends make it appear unlikely that Mesa will be able to profitably generate LCFS credits beyond 4-5 years in the future. The Set 5 Scenario analyses are summarized in Table 31 and Figure 21.

Table 31. Co-Generation and RNG Generation with Mixed HSW organic slurry Addition Scenario Estimates

Scenario	Annualized Scenario Savings [$]	GHG Reduction [MT CO_2e]	Total Project Cap Ex	Diesel Gallon Equivalents/ Day
1.3. 'Enhanced Baseline'	$21,000	221	$0	-
3.5 'No Slurry - all D3 RNG'	$497,000	1,853	$3,318,000	818
5.1 'No Slurry - all D3 RNG and LCFS'	$532,000	1,709	$3,318,000	818
3.3 'Slurry to both DIGs - all D5 RNG'	($233,00)	4,886	$14,213,800	1,722
5.2 'Slurry to both DIGs - all D5 RNG and LCFS'	$192,000	4,886	$14,213,800	1,722

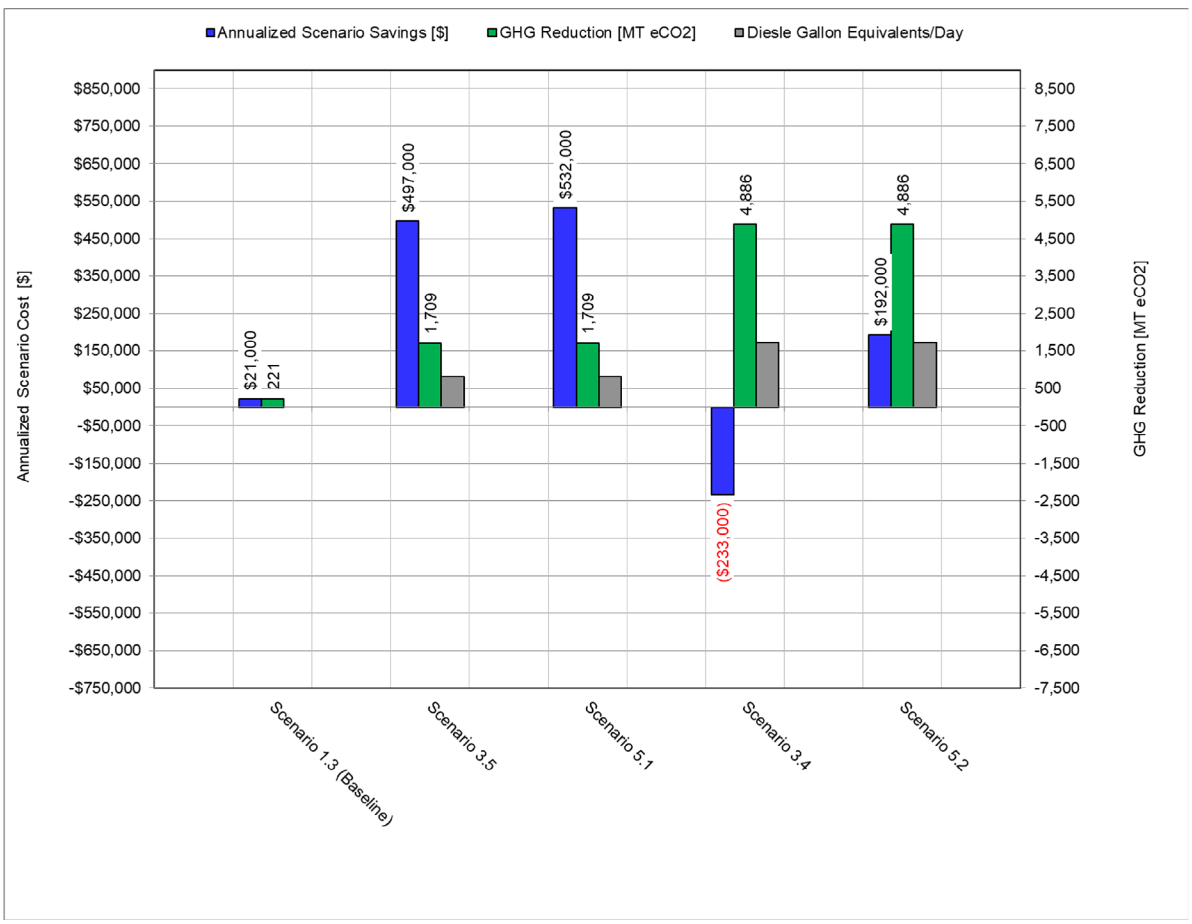


Figure 21. Participation in the Low Carbon Fuel Standard (LCFS) Program Scenario Comparison

7 RISK CONSIDERATIONS

In this section, the risks that co-digesting could potentially expose NWWRP to are evaluated. The chief risks identified include the risk of extended peak flows, upsets to the digestion process, and nutrient recycling. For reach risk identified both the likelihood of occurrence and any necessary mitigating operating procedures were assessed. To mitigate risk of digester upset a detailed breakdown of the start-up, operational and monitoring procedures for the digester has been included in this section.

7.1 Extended Peak Flows at NWWRP

Historic NWWRP flow data suggests that the plant rarely experiences extended periods of peak flows. Peak flows were identified at flows higher than 2 standard deviations above the average flow. To mitigate the risk of overloading the digesters without disrupting the operation at the Center Street Yard Organics Pre-processing Facility. The pre-processing facility will be designed with at least 2-days of storage as well. Additionally, slurry equalization at NWWRP in the PS Wet Well repurposing, there will be almost 2-days of storage availability on-site.

7.2 Digester Offline

The egg-shaped digester design at NWWRP is ideally shaped to minimize material build-up in the digester, while actively volume of the digester, and ultimately reducing the out-of-service time for maintenance. It has been reported that some egg-shaped digesters have been in service for 20 years without needing to be cleaned (Volpe et. Al. 2004).

If NWWRP needs to take a digester offline, the total amount of sludge will be sent to one digester. Under this scenario, it is expected that an average of 69,600 gpd of thickened sludge will be sent to the digester, equating in a 12.6-day SRT. Since this retention time is below the minimum recommended 15-day SRT, during periods in which one digester is offline, OSW and FOG addition must cease.

7.3 Nutrient Recycling

Under the proposed HSW loading rates, it is projected that NH_4-N concentrations in the digester will increase from approximately 550 mg/L to 1,100 mg/L, entailing a 100% increase in NH_4-N concentrations in the digester. This increase in ammonium concentration is not anticipated to be problematic for NWWRP since dewatering centrate will not be recycled to the plant headworks and instead will be sent to 91st Ave WRP for treatment.

7.4 Digester Stability

Increasing COD loading to the digester has the potential to upset digester if equalization is not provided to prevent batch loading and if the digester is not gradually acclimated to the increased

COD loads. The following recommendations for digester operations, start-up, and monitoring should be implemented to ensure digester stability with co-digestion.

Digester Monitoring

The ASU bench co-digestion study analyzed the parameters for both digesters that performed stably during co-digestion and those that soured as a result of HSW addition; as part of this analysis, several key parameters for evaluating the operational stability of a digester during co-digestion were highlighted. Those parameters are summarized as follows:

Blend Tank

- pH
- Volatile Fatty Acid Concentrations
- Alkalinity
- Feed Rate
- Volatile Solids

Digester Monitoring

- pH
- Volatile Fatty Acid Concentrations
- Alkalinity
- Volatile Solids

NWWRP will have approximately 3 days of HSW storage on-site at the recommended HSW loading rates. This allows sufficient time for testing of HSW prior to injection into the digesters. This will allow NWWRP to purge HSW that has parameters that would be problematic for digester stability. It is recommended that HSW that cannot be sent to the digester be sent to the facility headworks for treatment.

Laboratory safety

The above recommended monitoring parameters are all parameters that NWWRP already performs laboratory testing for. It is recommended that NWWRP continue to follow the same laboratory safety protocol that it currently follows since no new laboratory safety hazards are being introduced under the recommended digester monitoring.

HSW Start Up

In order to minimize the risk of souring during co-digestion start up, it is important to gradually increase HSW load rates to the digester in order to allow the digester to progressively acclimate to the increase in volatile solids loading. During this start up period, it is important to have a Digester Loading Schedule in which the digesters are carefully monitored to understand the effects of the food waste and FOG. A recommended loading schedule for a single digester is provided in Table 32 below.

Table 32. Single Digester Loading Schedule

Months	Loading	HSW Slurry Composition	Mixed Slurry Injection
1-2	25% of Goal ~1,750 lbs VS day	5,000-gal FOG (1,500 lbs VS/day) 1 tpd of food waste slurry (500 lbs VS/day)	~4,000 gpd at 6.5% TS
3-4	50% of Goal ~3,500 lbs VS day	5,000-gal FOG (1,500 lbs VS/day) 7 tpd of food waste slurry (2,250 lbs VS/day)	~5,000 gpd at 11% TS
5-6	75% of Goal ~5,250 lbs VS day	5,000-gal FOG (1,500 lbs VS/day) 11 tpd of food waste slurry (4,000 lbs VS/day) 500 gpd of dilution water	~6,000 gpd at 12% TS
7- Onward	100% of Goal ~7,000 lbs VS day	5,000-gal FOG (1,500 lbs VS/day) 16.5 tpd of food waste slurry (5,750 lbs VS/day) 1,700 gpd of dilution water	~7,700 gpd at 12% TS

8 SUMMARY AND RECOMMENDATIONS

The following section summarizes the report findings and recommendations for maintaining digester stability from co-digestion start up and onwards. Recommendations made in this section include imported waste limits, necessary digestion parameter monitoring protocol and instrumentation, co-digestion ramp up schedule, and all related biogas end use equipment sizing.

8.1 Digestion Capacity and Mixed HSW organic Slurry Loading

- Based on the limiting digestion capacity factor of 35% imported organic loading by mass fraction, the recommended amounts of each organic waste stream to be imported to NWWRP were set as follows:
  - Feeding 1 digester: 22 tpd of OSW slurry and 5,000 gallons/day both on a 5 days/week (weekday) basis.
  - Feeding both digesters: 44 tpd of OSW slurry and 10,000 gallons/day both on a 5 days/week (weekday) basis.

  OSW and FOG mixes were set to produce the optimal slurry concentrations in the range of 15% TS without the need for significant dilution water. If greater amounts of OSW and significantly less or no FOG were to be considered, then dilution water considerations must be incorporated into the Center Street Yard Pre-Processing Facility.
- At the above recommended organic waste loading rates, digester SRT is above 20 days and the OLR is approximately 0.175 lb VS/cf/day.
- The decision on whether one, two or zero digesters should be loaded with organic waste is dependent on biogas utilization as RNG and the regulatory outlook involving the accounting for D3/D5 RIN credits resulting from sludge, OSW, and FOG co-digestion.

8.2 Biogas Utilization

- Based on the comparison of model scenarios in which all biogas is sent to RNG versus scenarios where CHP is receiving biogas, it is both economically and operationally favorable to send all available biogas to RNG, even when all biogas is considered for D5 RINs. The CHP engine could still be kept in service and utilized for electric peak shaving with natural gas as the primary fuel.

- The highlighted scenario comparison in Table 33 and Figure 22 below shows the most favorable scenarios together for further examination and evaluation.

Table 33 Highlighted Scenario Comparison

Scenario	Annualized Scenario Savings [$]	GHG Reduction [MT CO_2e]	Total Project Cap Ex	Diesel Gallon Equivalents/ Day
1.3. 'Enhanced Baseline'	$21,000	221	$0	-
2.4 'HSW to both DIGs – CHP at 100%	($349,000)	562	$10,895,800	-
2.5 'HSW to both DIGs – Expanded CHP at 100%'	($336,500)	1,303	$12,220,800	-
3.3 'HSW to both DIGs – All D5 RNG'	($233,00)	4,886	$14,213,800	1,722
3.1b 'HSW to 1 DIG – D3/D5 RNG + PSA Upgrading Skid' '	($245,000)	3,333	$14,213,800	1,291
4.3 'HSW to both DIGs – CHP at 100% + RNG'	($236,000)	4,789	$14,213,800	1,665
4.5 'No HSW – all D3 RNG + NG Peak CHP'	$512,000	1,622	$3,318,000	818

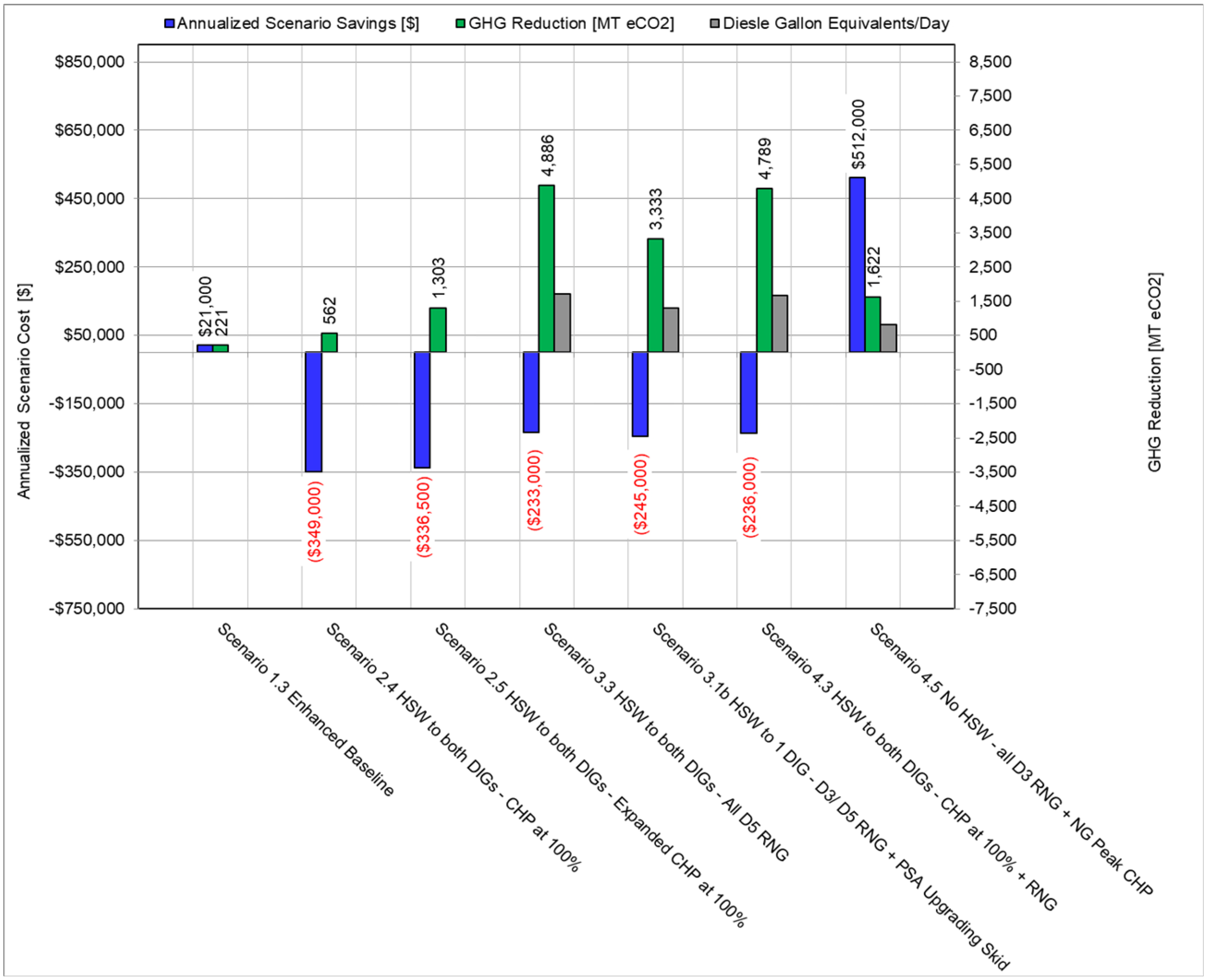


Figure 22. Highlighted Scenario Comparison

- Based on current EPA accounting for D3 and D5 RINs, the most economically favorable alternative for Mesa would be to not accept mixed organic slurry at NWWRP and retain D3 RIN status for all biogas generated from plant digesters. This would also avoid capital cost involved with constructing and operating an organic waste extraction system at the Center Street Yard Facility. However, this option does not align with the City's sustainability and project goals. See Scenario 4.5 above in Figure 22.

- Based on current EPA accounting for D3 and D5 RINs, the second most desirable alternative would be to send mixed HSW organic slurry to both digesters to maximize biogas production and keep digester feeding operations relatively simplified. This configuration better aligns with the project's sustainability and overall goals compared to not digesting imported organic waste. There did not appear to be an economic benefit to accepting less HSW to only one digester to retain partial D3 RIN classification on biogas from 1 digester.

- There are current legislative and lobbying efforts underway to amend the RFS to allow mass fraction accounting of D3 and D5 RINs based on organic loading fractions to the digesters. If this amendment occurs, the value of accepting mixed HSW organic slurry at NWWRP increases significantly, with annual savings over baseline in excess of $600 thousand if both digesters receive mixed HSW organic slurry. In this scenario maximizing slurry to the digesters becomes the most economically favorable option.

- Based on the above conclusions, a phased approach is recommended. An RNG upgrading system should be installed as quickly as feasible in order to maximize the more lucrative D3 RIN revenue potential prior to commencement of co-digestion. Once the HSW organic slurry receiving and injecting system have been installed in the subsequent phase, NWWRP can convert to a co-digestion and D5 RIN generation configuration.
- The RNG upgrading system should be sized for the maximum mixed HSW organic slurry loading scenario, which was approximately 274 scfm. This gas flow equates to approximately 1,800 DGE/day of RNG, which matches closely with the current vehicle fleet usage rate. The system included in the conceptual design has a design capacity of 400 scfm which provides sufficient capacity to both capture peak generation rates and allow for future expansion to the co-digestion/RNG configuration if possible.

CITATIONS

1. Parkin, Gene; Owen, William. *Journal of Environmental Engineering/Volume 112 Issue 5,* 1986. Fundamentals of Anaerobic Digestion of Wastewater Sludges.
2. Rittmann, Bruce; McCarty, Perry. *Environmental Biotechnology: Principles and Applications*, 2001.
3. Lossie, U.; Pütz, P. Targeted Control of Biogas Plants with the Help of FOS/TAC; Laboratory Analysis, Titration FOS/TAC; Hach-Lange Maroc Sarlau: Casablanca, Morocco, 2001.
4. Jeffrey Peirce; Ruth F. Weiner; P. Aarne Vesilind. *Environmental Pollution and Control (Fourth Edition)*, 1998. “Chapter 9 - Sludge Treatment, Utilization, and Disposal.”

APPENDIX A

Air Quality Permit Analysis

AIR QUALITY PERMIT

The Air Quality Permit to operate and//or construct at Northwest Water Reclamation Plant was issued by Maricopa County Air Quality Department (Permit # 990546).

The specific conditions of the site outline the maximum allowable emission in pounds per year. NWWRP is not permitted to exceed any of the limits as provided in Table 1. The calculation of the 12-month rolling total emission is calculated by summing the monthly emissions over the most recent 12 calendar months. The 'historic maximum' represents the highest sum of a 12-month period which ended sometime in 2018; therefore, representing the worst-case conditions for each pollutant. It should be noted that NWWRP exceeded the 12-month rolling permit limit for SOx for the first 6-months of 2018.

Table 1. Historic Maximum vs. Permitted Facility-Wide Allowable Emissions

Pollutant	Historic Maximum 12-Month Rolling Total Emission	Permit 12-Month Rolling Total Emission Limit	Unit
Carbon Monoxide (CO)	13,378	39,206	lbs
Nitrogen Oxide (NOx)	14,371	69,097	lbs
Sulfur Oxides (SOx)	2,334	2,248	lbs
Particulate Matter <10 Micron Diameter (PM10)	2,035	2,986	lbs
Particulate Matter <2.5 Micron Diameter (PM2.5)	2,035	2,986	lbs
Particulate Matter (TSP)	2,035	2,986	lbs
Volatile Organic Compounds (VOC)	5,444	29,948	lbs

Arcadis evaluated the potential increase in emissions due to the changes recommended above. The major concerns regarding the permitted limits are the scenario 'Expanded CHP Generation with Additional Engine'. The potential increase is shown below; However, a majority of the additional emissions can be mitigated by expanding post-combustion engine exhaust equipment to include an oxidation catalyst.

Table 2. Estimated vs. Permitted Facility-Wide Allowable Emissions

Pollutant	Estimated Emissions with Expanded Cogeneration	Permit 12-Month Rolling Total Emission Limit	Unit	Meets Limit?
Carbon Monoxide (CO)	52,693	39,206	lbs	NO
Nitrogen Oxide (NOx)	36,510	69,097	lbs	YES
Sulfur Oxides (SOx)	2,334	2,248	lbs	NO
Particulate Matter <10 Micron Diameter (PM10)	2,259	2,986	lbs	YES
Particulate Matter <2.5 Micron Diameter (PM2.5)	2,259	2,986	lbs	YES
Particulate Matter (TSP)	2,259	2,986	lbs	YES
Volatile Organic Compounds (VOC)	7,967	29,948	lbs	YES

APPENDIX B

Gas Quality Tariff Specification

TRANSMISSION PIPELINE GAS QUALITY TARIFF SPECIFICATION

Components	Renewable Natural Gas
Hydrogen Sulfide H_2S	0.25
H_2O (Water Vapor)	7
CO_2 (Carbon Dioxide)	3%
N_2 (Nitrogen)	-
O_2 (Oxygen)	0.2%
Diluents	4%
Heating Value Gross	No Specification
Hydrocarbon Dew Point	20^{o}F @ 600 psig
Hydrocarbon GPM	No Specification
Hydrocarbon Liquids	shall be free at point of Delivery
Flowing Temperatures	50^{o}F - 120°F
Mercaptan (RSH)	0.30
Organic Sulfur (OS)	0.50
Total Sulfur (TS)	0.75
Dust, Gums, Solid Matter	Commercially Free
Deleterious Substances	shall not contain in concentrations that are hazardous to health, pipeline or merchantability
Liquids (Water & Hydrocarbons)	Free of at Delivery temperature and pressure

APPENDIX C

CENTRYSIS Pondus Thermochemical Hydrolysis Process Quote

NUMBER: 09451

DATE: 01/28/19

TO: Northwest Mesa, AZ WWTP
960 N. Riverview
Mesa, AZ 85211-1466
Attn: Roy Van Leeuwen
Ph: (480) 644-5873

REF.: PONDUS TCHP Process

Budget Proposal
Northwest Mesa, AZ WWTP
PONDUS Thermochemical Hydrolysis Process

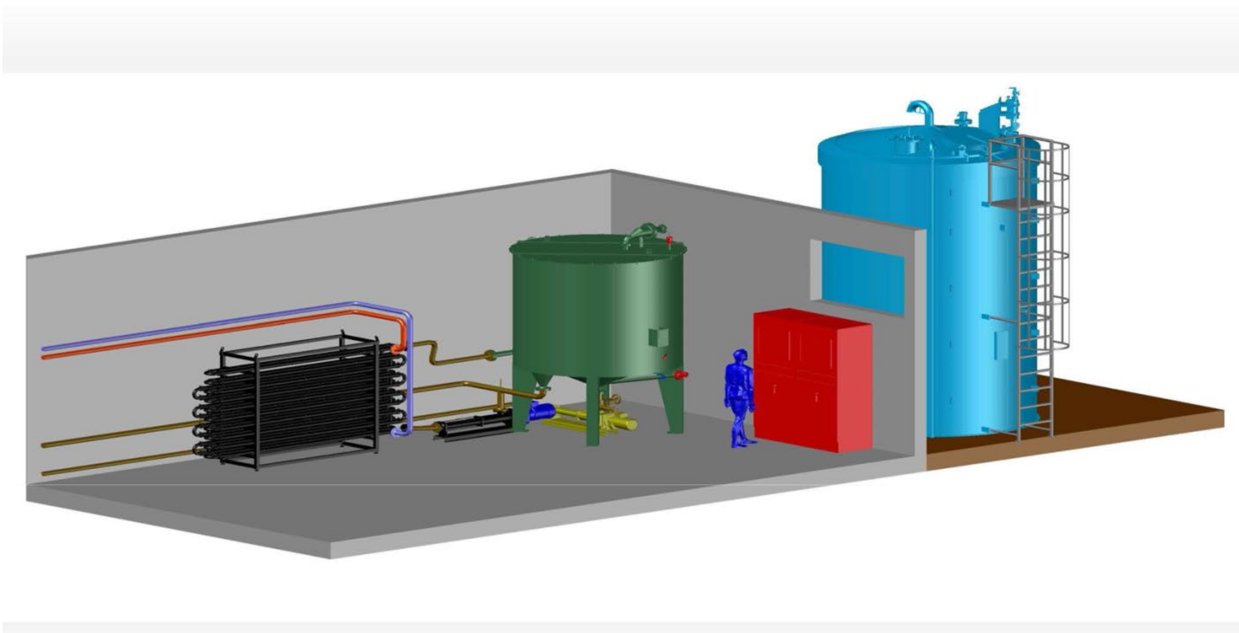
Centrisys Contacts
Jerod Swanson
Regional Sales Manager
9586 58th place
Kenosha, WI 53144
Ph: (262) 654 6006
Direct: (612) 401 2006
Email: Jerod.swanson@centrisys.us

Sanjeev Verma
Regional Sales Manager
Direct: (262) 612 9318
Email: Sanjeev.verma@centrisys.us

Centrisys Representative
John Deogracias
Goble Sampson
1745 So. Alma School Rd, Suite 275
Mesa, AZ 85215
Ph: (480) 969-3667
Email: jdeogracias@goblesampson.com

CNP is pleased to offer a budgetary proposal for the following system:

PONDUS THERMOCHEMICAL HYDROLYSIS PROCESS – WAS-ONLY, CLASS B PROCESS



System Description:

Thickened Waste Activated Sludge (TWAS) is mixed with a small dose of caustic soda before the Pondus reactor recirculation line. The chemically treated TWAS is mixed with recirculated hydrolyzed sludge and heated to around 150F, using waste heat from the cogeneration process or other heat source. The combination of heat and caustic soda destroy the cell membrane of the WAS.

During the hydrolysis process, organic acids are released. These organic acids are now converted more quickly during the anaerobic digestion process – producing approximately 30% more biogas in the anaerobic digester. The process results in at least a 5-fold reduction of dynamic viscosity of TWAS. Therefore, more solids can be process in the digester with less energy required to heat, pump, and mix. The hydrolyzed sludge generates dryer cake and lowers the polymer consumption during dewatering (lower dewatering and disposal costs).

Benefits:

- Improved efficiency of anaerobic digestion
    i. Enhance biogas production between 20-30%
    ii. Improve volatile solids reduction ratio
    iii. Reduction or elimination of digester foaming
- Reduced sludge viscosity by up to 60%
    i. Less energy for heating, pumping, and mixing
    ii. Increased solids in the digester
    iii. Less digester retention time
- Improved digested sludge dewaterability
    i. Dryer cake – DS improvement of 3-6%
    ii. Polymer usage reduction up to 10%
    iii. Reduction of dewatering and disposal costs
- Optional – Class A biosolids

ITEM 1 DESIGN PARAMETERS

Our design calculations are based on the hydrolysis of thickened activated sludge:

Parameter	Unit	Value
Digested sludge flow rate to PONDUS TCHP	gallon/min	16.5
Total Solids % of feed sludge	%	6
50% w/w NaOH solution consumption (24 hr/d operation)	gallon/day	35.7
Estimated annual NaOH dosing cost (@$1.8/gal)	$/year	23,455
O&M Labor requirements	hours/day	<1

ITEM 2 SCOPE OF SUPPLY

ITEM	QUANTITY	DESCRIPTION
1	1	PONDUS TCHP reactor
2	2 (1 duty, 1 standby)	Feed pump
3	2 (1 duty, 1 standby)	Recirculation pump
4	2 (1 duty, 1 standby)	Reactor discharge pump
5	1	Heat water heat exchanger
6	1	NaOH solution dosing system
7	1	NaOH solution storage tank
8	1	Instrumentation and controls
9	1	Start-up and commissioning services

CNP Technology – Water and Biosolids Corp.
9535 58th Place, Kenosha, WI 53144 · Phone: +1 (262) 654 6006

ITEM 3 SYSTEM PERFORMANCE

Reduce TWAS viscosity	up to 80%
Enhance biogas production	up to 30%
Improve volatile solids reduction ratio	up to 6%

ITEM 4 SERVICES

4.A Drawings and Installation, Operation and Maintenance (IO&M) Manuals:

1. Submittal Drawings: One (1) electronic copy; prints by request
2. Final Drawings: Two (2) prints & One (1) electronic copy included
3. O&M Manuals: Two (2) prints & One (1) electronic copy included

4.B Start-Up Assistance:

CNP will furnish one factory representative to assist in installation inspection, start-up supervision, and operator training. Dates of service to be scheduled upon Buyer's written request.

BUDGET PRICE:

All of the above for .... $**1,266,400** USD

F.O.B. Kenosha-WI, freight included, taxes excluded.

PAYMENT TERMS:

30% with order; 60% upon shipment; 10% after startup not to exceed 90 days after shipment.

ITEM 5 TIMETABLE

Submittal phase: 6-8 weeks after the order receipt

Approval phase: 4 weeks for the customer to approve the drawings

Shipment phase: 32-34 weeks following receipt of the Approval drawings

Additional on-sit installation time (by others): 3 weeks after delivery

Dates are subject to confirmation upon receipt of written Purchase Order.

ITEM 6 WARRANTY

One (1) year from the equipment start up or eighteen (18) months from delivery.

BUYER/OWNER RESPONSIBILITY:

- Any site preparation work including surveying and soil sampling
- Civil works such as the foundation plate for the system or the building
- Pipes and piping (except from the outside flange of the reactor the aeration ring inside the reactor)
- Sludge holding or storage tanks for sludge equalization
- We have assumed that all components except the storage tank will be installed underneath the reactor in the associated machine room. The storage tank with the filling station will be installed at a distance of max. 15 m (45 ft) from the building.
- Supply lines (water and electricity) as well as building services (lighting, water supply / sink) in the office building
- Concrete work and core drill holes
- Permits
- Building and building plans (Centrisys provides only the layout drawings without any responsibility of updating any plans or building)
- Building modifications
- Structural and Civil engineering labor
- All utilities that are required for operation
- Unloading, uncrating, installation and installation supervision. Installation will, at minimum, require a forklift and possibly a crane/hoist.
- Readiness of the Equipment before requesting start-up service. Non-readiness may incur additional charges.
- Compatibility of Equipment materials of construction with process environment.
- Any other auxiliary equipment or service not detailed above.

Issued by

Zach Mazur
Applications Engineer

Date: 01/28/19

APPENDIX D

AIR LIQUIDE MICROBIOGAS™ System for Biogas Quote

CONFIDENTIAL

January 21, 2019

Eric Auerbach/Andrew Deur
Arcadis

Subject: Air Liquide MicroBiogas™ System for Biogas – **100, 450, 700, 900 SCFM**

Dear Eric/Andrew:

Air Liquide is a leader in the supply of membrane based systems and has a portfolio of membranes unmatched in the industry. For biogas upgrading, we have provided over 60 units to date. Units range widely in size (largest is over 10,000 SCFM) and we have recognized the market need for a low cost, small system. We have scaled down our system for smaller flows while taking advantage of the range of membranes that Air Liquide manufactures.

For the small system we incorporate the membranes on the compressor skid (100 SCFM) and for moderately sized systems (450, 700, 900 SCFM we offer a simplified membrane skid and a compressor skid that sits close to the membrane skid. Interconnecting piping by others is required. The membranes applied are unique in the ability to highly selectively reject H2S and they also reject water, CO2 and some O2.

For your feed, we designed for feed rates of 100, 450, 700 and 900 SCFM. The process flow assumes compression and then routing of the 150 ppm H2S gas through a H2S scavenger. The gas is then processed by the membrane after chilling. Some of our customers assume that the reject gas can then be vented and thus a thermal oxidizer is avoided.

Alternately, we can remove the H2S with the membrane system (thus no H2S scavenger). If that were the case the reject stream would be routed to a thermal oxidizer (not included).

Design Material Balance:

	Design Basis Feed (wet)	Product	Tail Gas to Thermal Oxidizer
Case #1, Flow SCFM	100	55	42
Case #2, Flow SCFM	450	247	189
Case #3, Flow SCFM	700	384	293
Case #4, Flow SCFM	900	493	377
Pressure, psig	0	140	1
Temperature, F	100	~100	~100
Composition, Mol%			
C1	55.00	97.45	3.94
CO2	40.40	1.00	95.15
O2	0.30	0.18	0.48
N2	0.80	1.37	0.11
H2S	150 ppm – removed with scavenger	4 ppm	~ 10 ppm
H2O	3.50	<7lb./MMSCF	0.32
HHV BTU/FT3		984	40

Note:

1. The design methane recovery rate is 97%.
2. Tail gas is lean in heating value and assumed routed to a thermal oxidizer (supplemental pipeline natural gas would be required).
3. Condensed water from compression is about 25, 105, 165 or 210 Gallons per day. The condensed water removed is the reason the product and tail gas flow rates do not add to the feed flow rate.

EQUIPMENT:

One feed compressor with inlet separators, gas and oil coolers, required skid instrumentation, compression with electric motor and direct drive plus membrane skid/modules are included. A compressor discharge air fan cooler is provided.

A separate membrane skid is provided except for the 100 SCFM where the membranes are mounted on the compressor skid.

An Allen-Bradley PLC with local panel and separate HMI is included. The PLC is mounted on the compressor skid.

The area classification is NEC Class I, Div 2 which is typical for upgrading equipment.

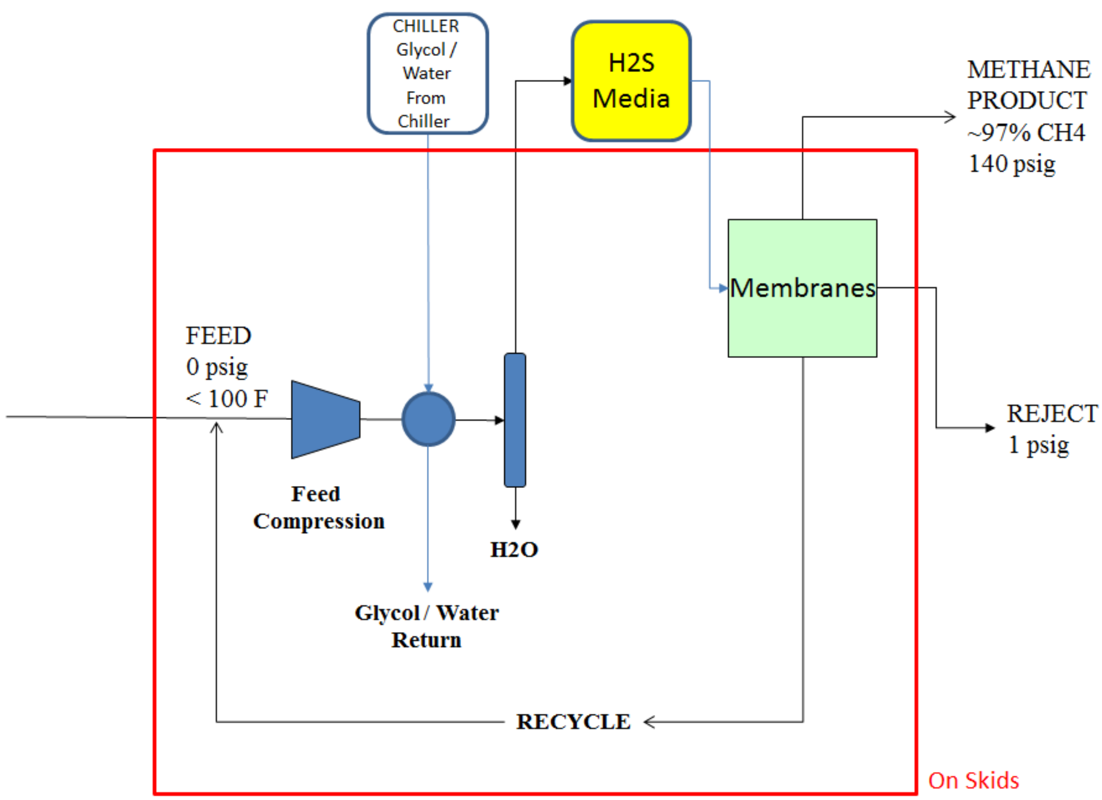
INSTALLATION:

For cases 2, 3, and 4 the installation requires that the compressor and membrane skid be tied together. We would design to minimize the field piping. After compression the product is routed through a polishing vessel for H2S removal to 4 ppm.

Compression requires motor starters (not included) and is the main electrical requirement.

PROCESS FLOW SHEET:

1. Feed plus recycle compression to 200 psig
2. H2S scavenger
3. Membrane treatment to remove water, residual H2S, O2 and CO2.



FEATURES:

- Easy, largely unattended operation with high on-stream factor
- Automatic turndown/turn-up (to < 20%)
- CO2 purity is monitored with a CO2 IR analyzer supplied
- Flexible to changes in the feed composition
- Dry process with no byproducts other than water from feed compression
- Design for easy installation
- Push-button start-up and shutdown
- Capacity regulated by maintaining a fixed pressure in the digester to avoid upsets to the digester operation

SUMMARY & COST:

Case #	1	2	3	4
Feed, SCFM	100	450	700	900
Budgetary Equipment Cost: MicroBiogas system including feed compression, membrane skid, H2S scavenger bed with first load of media. $ EXW USA Shop	**$ 645,000**	**$ 1,380,000**	**$ 1,600,000**	**$ 1,700,000**
Annual media replacement cost, $	**$ 6,000 (first load included)**	**$ 27,000 (first load included)**	**$ 45,000 (first load included)**	**$ 54,000 (first load included)**
Start-up per diem	**$ 1800 per day plus expenses. Assume 7 days for two individuals.**	**$ 1800 per day plus expenses. Assume 7 days for two individuals.**	**$ 1800 per day plus expenses. Assume 7 days for two individuals.**	**$ 1800 per day plus expenses. Assume 7 days for two individuals.**
Adder for thermal oxidizer / Flare	By others if used	By others if used	By others if used	By others if used
Shipping cost (USA)	TBD	TBD	TBD	TBD
Estimated Annual Maintenance Cost	Assume 2% of capital per year. This is conservative. For oil and filter changes.	Assume 2% of capital per year. This is conservative. For oil and filter changes.	Assume 2% of capital per year. This is conservative. For oil and filter changes.	Assume 2% of capital per year. This is conservative. For oil and filter changes.

Note:
• For the design we have assumed that typical national codes are applied (ASME Section III, Div. 1, ANSI B31.3, NEC Class I Div 2).
• Standard mechanical warranty is 12 months from start-up, 15-months from delivery. Product purity of CO2 < 1% is guaranteed.
• Standard payment terms are approx. 1/3rd to start, 1/3rd midway through the project and 1/3rd on delivery
• Minimum ambient temperature: In building, maximum ambient temperature 100 °F
• Elevation assumed as 1300 ft.

SCOPE:

Air Liquide	**Customer**
Feed compression with associated discharge air-fan cooler	Feed gas supply to inlet of the compressor including inlet pressure signal. Supply and installation of feed, product and tail gas piping to/from skid
Membrane skid with membrane modules	Equipment shipping to field and installation including foundation, equipment setting and supply/plumbing of interconnecting piping
Scavenger vessel with first charge of media	Motor starters and electric wiring to/from the skid
Compressor discharge chiller	Labor, material and supplies during installation, start-up and performance testing
Allen-Bradley PLC for control of the equipment with desktop PC HMI interface	Disposal of condensate (from compression/cooling)
Start-up is per diem	Utilities listed below
	Product use and product flow, purity measurement
	Tail gas disposal/flare

MAIN ITEMS THAT ARE NOT INCLUDED:

- Flow meters and analyzers
- Thermal oxidizer or flare
- Installation / buildings
- Field service and hazop attendance is per diem

UTILITIES:

Case #1	**Motor, HP**	**Power, kW**	**Starters**
Feed Compressor	75	43	VFD by others
Air Fan Motor	5	3	VFD by others
Oil Heater		1	Contactor
Chiller		5	Contactor
TOTAL		**52 kW**	

Case #2	Motor, HP	Power, kW	Starters
Feed Compressor	300	190	VFD by others
Air Fan Motor	15	7	VFD by others
Oil Heater		2	Contactor
Chiller		11	Contactor
TOTAL		**210 kW**	

Case #3	Motor, HP	Power, kW	Starters
Feed Compressor	600	314	VFD by others
Air Fan Motor	15	10	VFD by others
Oil Heater		3	Contactor
Chiller		17	Contactor
TOTAL		**344 kW**	

Case #4	Motor, HP	Power, kW	Starters
Feed Compressor	700	378	VFD by others
Air Fan Motor	25	15	VFD by others
Oil Heater		3	Contactor
Chiller		19	Contactor
TOTAL		**415 kW**	

Instrument Air: 5 SCFM @ 60-100 psig, -40F dew point.

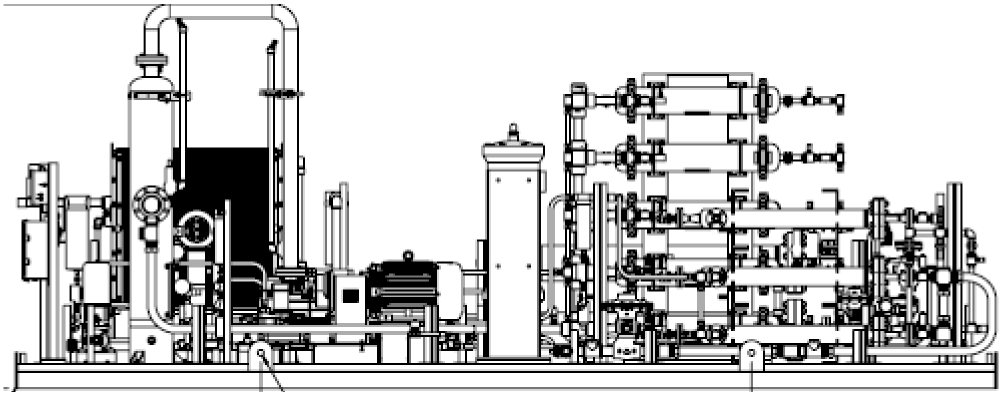
Dry Gas: A six-pack of N2 cylinders should be maintained.

An alternate to the above instrument air and N2 is to add a 1000-gallon buffer tanks for dry gas storage.

DELIVERY TIME:

We expect about 8 months.

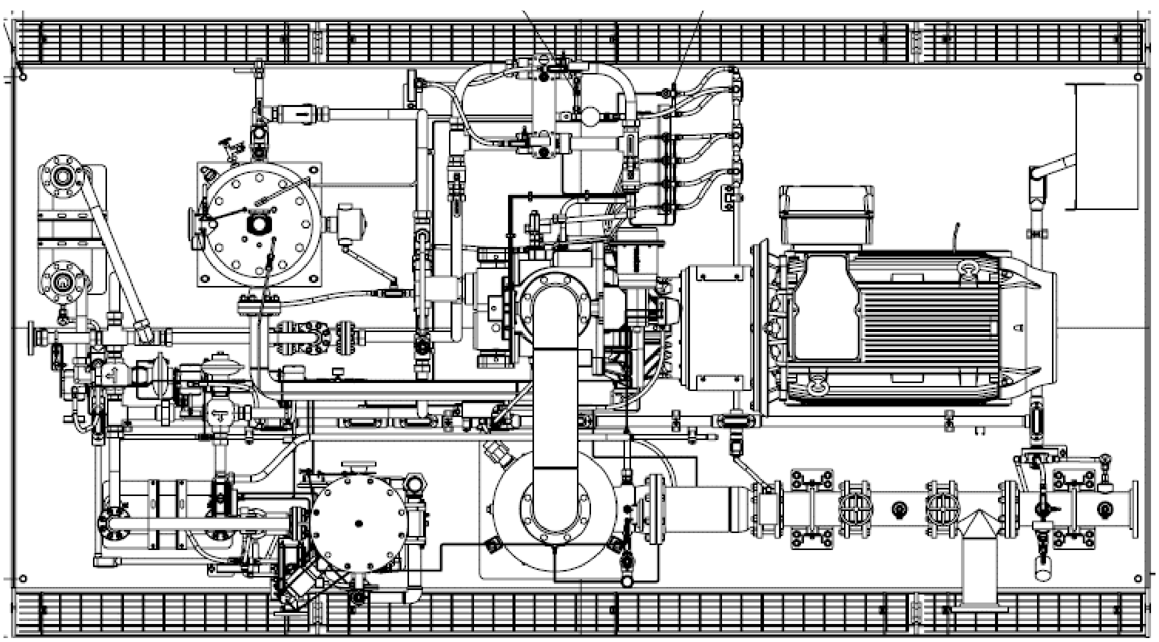
Below Footprint applies to Case #1:



About 20-ft long and 9-ft wide.

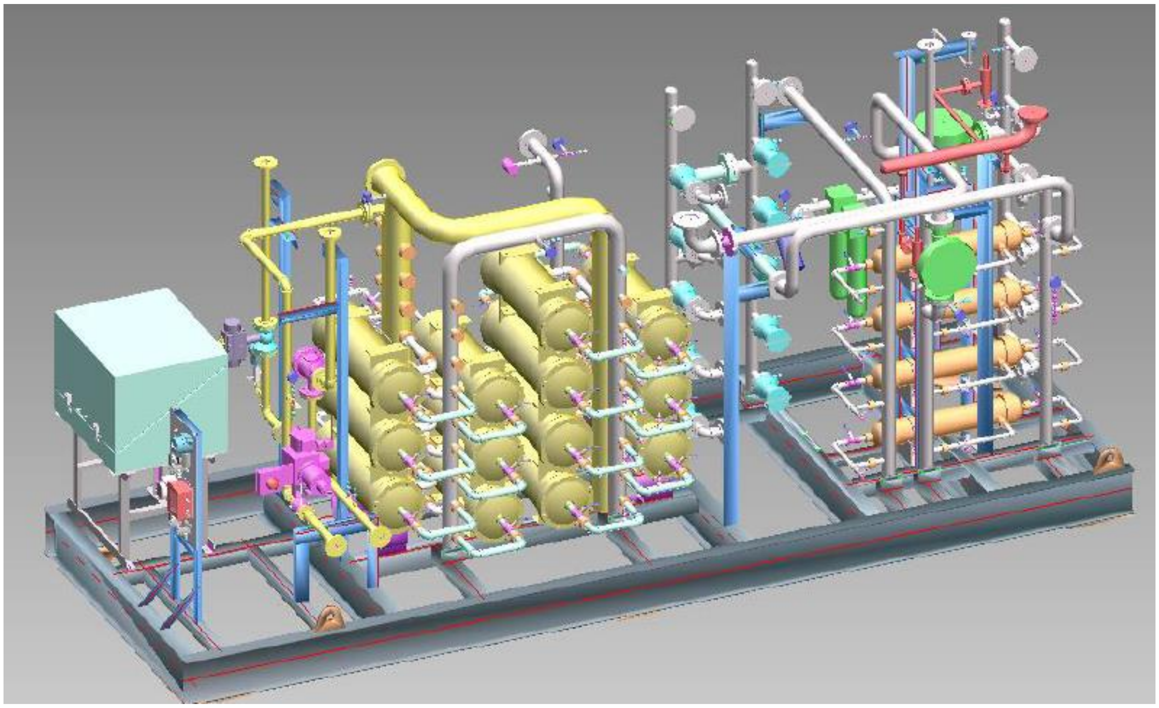
Below Footprint applies to Case #2, 3, 4:

FOOTPRINT – SIMILAR FEED COMPRESSOR:



Air Fan cooler of 12-ft by 15-ft not shown.

FOOTPRINT – SIMILAR MEMBRANE SKID:



We hope the above is helpful for your evaluation.

Joseph P. Bushinsky
Air Liquide Advanced Business & Technologies
Cell: 484-666-9088
E-mail: joseph.bushinsky@airliquide.com

THIS BUDGETARY PROPOSAL IS FOR DISCUSSION PURPOSES ONLY AND DOES NOT CONSTITUTE A BINDING CONTRACT FOR AIR LIQUIDE TO PROVIDE ANY PRODUCTS OR SERVICES. ADDITIONAL DISCUSSIONS BETWEEN THE PARTIES ARE NECESSARY TO FINALIZE DESIGN SPECIFICATIONS AND SCOPE OF SERVICES TO BE PROVIDED BY AIR LIQUIDE. THE FINALIZED SCOPE, DESIGN, TERMS AND CONDITIONS, WARRANTY, PRICES, ETC. WILL BE PRESENTED IN A FINAL, BINDING PROPOSAL AFTER RECEIVING AIR LIQUIDE MANAGEMENT APPROVAL.

EXPERIENCE:

As noted Air Liquide has provided many membrane based biogas units as per the list below.

Biogas upgrading unit- Air Liquide references list					Last update: 20-Jul-15	
N°	Country	City	Year	Project	Raw biogas Nm3/hr	Gas destination
			Europe and Asia			
1	France	Château Renard	2015	Gartinais Biogaz (ALAB)	300	Grid injection
2	Denmark	Roslev	2015	Purac-Puregas	900	Grid injection
3	China	Hangzhou	2015	HEEE	1500	CNG
4	England	Methwold	2015	Future Biogas	900	Grid injection
5	England	Metheringham	2015	Future Biogas	700	Grid injection
6	England	Cumbernauld	2014	Air Liquide UK	900	Grid injection
7	England	Teesside	2014	Air Liquide UK	900	Grid injection
8	Hungary	Kaposvar	2014	Agrana	1,500	Grid injection
9	Germany	Peine	2014	Peine	1,400	Grid injection
10	France	Villeneuve sur lot	2014	Fonroche (ALAB)	800	Grid injection
11	France	Sarreguemines	2014	Methavos (ALAB)	200	Grid injection
12	Wales	Wrexham	2014	Welsh Water Five Fords	900	Grid injection
13	France	Chagny sur Saône	2013	TIRU	1000	Grid injection
14	England	Springlindton	2013	Future Biogas	900	Grid injection
15	England	Hibaldstow	2013	Future Biogas	900	Grid injection
16	England	Holkham	2013	Future Biogas	900	Grid injection
17	France	Saint Pourcin sur Sioule	2013	Sioule Biogaz	70	Grid injection
18	England	Doncaster	2012	Future Biogas	900	Grid injection
19	France	Chaumes en Brie	2012	Bioénergie de la Brie	250	Grid injection
20	France	Forbach	2011	SYDEME	100	Grid injection
21	Sweden	Lidköping	2010	Göteborg Energi	800	Biomethane liquefaction Fuel for vehicle
22	Austria	Vienne	2011	Vienna University	6	Pilot Plant *Axiom with AL membranes*
23	Austria	Wiener Neustadt	2010	Wiener Neustadt	260	Grid injection *Axiom with AL membranes*
24	Germany	Baden-Württemberg	2010	Kißlegg	350	Grid injection *Axiom with AL membranes*
25	Austria	Margarethen am Moos	2007	Margarethen am Moos	70	Fuel for vehicle *Axiom with AL membranes*
26	Austria	Bruck an der Leitha	2007	Bruck an der Leitha	200	Grid injection *Axiom with AL membranes*
			North & South America			
27	Oklahoma	Oklahoma City	2015	Oklahoma City LF	4,200	Grid Injection
28	Chile	Santiago	2015	La Farfana WWTP	3,700	Pipeline system
29	Ohio	Columbus	2014	SWACO	10,000	Grid Injection
30	New York	Seneca Falls	2014	Seneca Meadows	5,000	Grid Injection
31	Illinois	East St Louis	2014	Milam LF	5,800	Grid Injection
32	Brazil	Rio di Janeiro	2013	Novo Gramacho	16,000	Local Industry
33	California	San Diego	2012	Pt Loma	2,400	Grid Injection
34	California	Fresno	2012	Fresno	2400	Local Use
35	Tennessee	Athens	2011	Meadow Branch	4,730	Pipeline system
36	Louisiana	New Orleans	2009	River Birch	10,600	Pipeline system
37	Pennsylvania	Pittsburgh	2009	Seneca	4,730	Grid Injection
38	Washington	Seatle	2009	Cedar Hills	18,900	Grid Injection
39	Georgia	Atlanta	2009	Live Oak	8,268	Grid Injection
40	Tennessee	Church Hill	2008	Carter Valley	2,350	Grid Injection
41	Georgia	Winder	2008	Winder	7,079	Grid Injection
42	Oklahoma	Oklahoma city	2008	Oklahoma	2,350	Pipeline system
43	Pennsylvania	Caimbrock	2007	Shade	4,728	Pipeline system
44	Pennsylvania	Imperial	2007	Imperial	7,079	Pipeline system
45	Pennsylvania	Davidsville	2007	Southem	2,350	Grid Injection
46	Pennsylvania	Kersey	2007	Greentree	14,158	Grid Injection
47	Tennessee	Johnson city	2006	Iris Glen	2,350	Grid Injection
48	Pennsylvania	Raeger mtn	2006	Laurel Highlands	4,728	Grid Injection

APPENDIX E

GUILD Biogas Upgrading Equipment Quote

Guild Associates, Inc.
5750 Shier-Rings Road
Dublin, OH 43016
Phone: (614) 798-8215
Fax: (614) 798-1972

April 23, 2019

Shayla Allen
Arcadis US, Inc.

Quotation 19-B035
Subject: Biogas Upgrading Equipment, Mesa AZ WWTP

1. Introduction

Guild is pleased to present its Molecular Gate^{TM} PSA technology for the purification of digester gas. Our technology uses single step removal of impurities to meet the pipeline specifications that you have outlined. We are offering a fully integrated package that includes feed compression, Molecular Gate PSA system and vacuum compression. This is a combination of new equipment (feed compression) and never-installed Molecular Gate PSA system with vacuum compression refurbished to like-new condition.

Rough Order of Magnitude (ROM) Estimate

This ROM is not an offer to perform a service, it is submitted as an estimate for your budgetary and planning purposes only, and is valid for 90 days. Design and equipment information contained in this document are preliminary and subject to change as systems at this scale are custom engineered to suite your application.

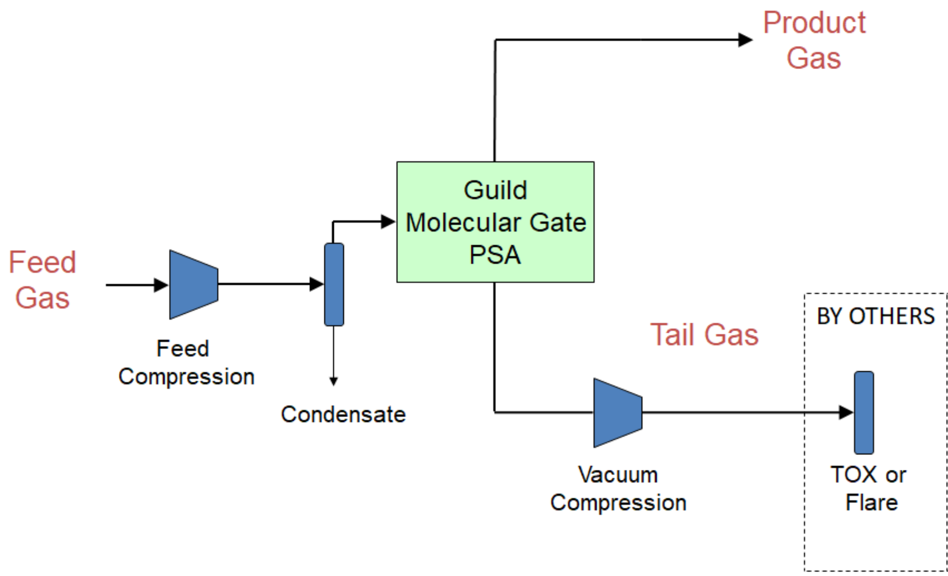
The formal proposal includes a statement of work, pricing, and Guild's terms and conditions.

Compliance to the following factors can and will affect the actual system price and delivery:

- Design specifications including feed composition and flow and product specifications
- Federal, State, and Local Codes/Regulations
- Applicable process, fabrication, and electrical codes/specifications and required certifications
- Documentation requirements

2. Process Flow Sheet

This flow sheet shows a simplified overview of the process.



3. Process Description

1. Feed compression to 100 PSIG
    a. Gas is cooled and condensate is removed
2. Molecular Gate™ PSA treatment to remove contaminants
    a. A Vacuum compressor is used to regenerate the media by removing the contaminants
3. Tail gas to TOX/Flare is required. Guild can provide an equipment and integration solution for this process requirement if requested.

4. Mass Balance Table

This table is simplified to show only the inlet and outlets of the system.

Attribute	Feed Gas (Wet Basis)	Product Gas	Tailgas
Normal Flow (SCFM)	400	223	166
Normal Flow (MMSCFD)	0.6	0.3	0.2
Pressure (PSIG)	2.0	90	2
Temperature (F)	100	120 [3]	180
Composition (Mole %)			
C1[1]	58.18%	96.03%	11.20%
N2	0.80%	1.44%	0.00%
CO2	37.00%	1.99%	86.36%
O2 [2]	0.30%	0.54%	0.00%
H2S (PPM)	150	<0.25 grains / 100SCF	361
H2O	3.70%	< 7lbs/MMSCF	2.40%
HHV (BTU/SCF)	588	970	113

Notes:

1. Typically, small 3-Bed CO_2 rejection plants provide 92% recovery. Actual recovery is based not only on plant performance, but actual gas composition and flow. Our experience is that the gas composition and flow as stated at the time of proposal development may vary from what is present when the plant is commissioned. In addition, once the plant is operational there are likely to be seasonal and year to year variances as well. Based on these factors the actual recovery percentage can only be estimated and not guaranteed.
2. Oxygen in the product gas exceeds the 0.2% limit from the pipeline company. Common good practice in digester operation should result in O_2 not exceeding 0.1% in the feed gas. Guild recommends that the operator pursue good digester practice in the sealing of tarps and barriers against atmospheric infiltration to eliminate the need for O_2 removal equipment.
3. This quotation assumes that air cooling is sufficient for cooling gas to injection temperature. Additional cost and equipment will be necessary if the ambient high temperature does not allow for air fin cooling.

5. SCOPE

Guild supplied:

1. Skid mounted gas processing equipment:
    a. One (1) Feed compressor with on-skid oil/gas cooler
    b. Refurbished Never-Installed Equipment:
        i. Feed flow meter
        ii. Molecular Gate™ PSA system including:
            1. Valve and piping skid which includes:
                a. 3 Adsorber vessels with media
                b. 1 Vacuum compressor with on-skid oil cooler
            2. Tank Skid – 7-high stacking, includes 5 buffer tanks and 2 tail gas tanks
        iii. Tail gas flow controller
2. Thermal insulation of on-skid equipment as required for the process
3. Insulation and heat trace of on-skid equipment as required for freeze protection of condensate
4. Other supplied equipment:
    a. Instrument Air System (10 SCFM, 100 psig, -20 °F dew point, to be located in MCC Building)
5. PLCs for control of Guild equipment and desktop PC HMI interface (with internet allows remote access, HMI to be located in control room)
    a. PLC: Allen Bradley CompactLogix
    b. Programing: RSLogix 5000 by Rockwell Automation
    c. HMI: Citect, now part of Schneider Electric

Customer provided:

1. Feed gas supply to inlet of Guild system
2. Installation of Guild supplied equipment including, but not limited to:
    a. Shipping
    b. Setting equipment
    c. Foundations
    d. Piping to, from and between skids and vessels
    e. Electrical
        i. Wiring to, from, and between skids
        ii. Motor starters
        iii. MCC Building
        iv. MCC interface panel (to be located in MCC building)
        v. Ethernet to, from, and between skids
    f. All labor, material and supplies associated with installation, start up and performance testing

g. Product Gas Flow Meter

3. Lighting, roadways, sidewalks, buildings, and fireproofing as required
4. Condensate disposal system
5. Thermal insulation of off-skid piping and vessels as specified by Guild
6. Insulation and heat trace of off-skid piping as required for freeze protection of condensate
7. Product purity analysis (Guild monitors CO2 Purity only) and product flow measurement as required
8. Thermal Oxidizer (TOX) and/or Flare as required for disposal of tail gas and/or start up/ off spec gas.

6. Utilities

Nitrogen: as required for maintenance purging

Power					
Description	**Motor Size (hp)**	**Voltage[1]**	**Quantity**	**Total Power (kW)[2]**	**Motor Starter[3]**
Feed Compressor	150	460	1	112	VFD
Feed Gas/Oil Cooler	2	460	1	1	VFD
Vacuum Compressor	75	460	1	56	Soft Start
Vacuum Oil Cooler	2	460	1	1	VFD
Total				**171**	**kW**

Notes:

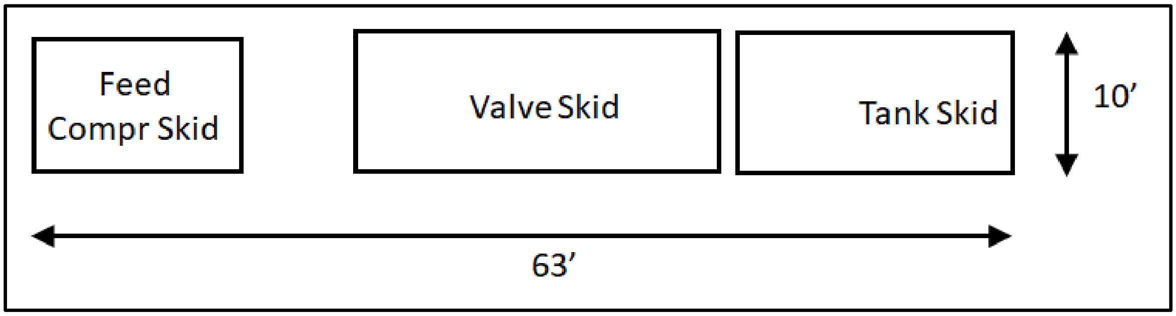
[1] Motor voltage of 460 volts is assumed.

[2] Power consumption calculated above is conservative and is based on motors running at their full nameplate load. Power savings during turndown is noticed through turndown of an individual unit or shutting equipment down if not needed. This function is included in the control system of the plant.

[3] Motor starter type is based off Guild's experience with past projects and are provided by others. We can modify our design based on customer request; however a cost adjustment may be necessary.

7. Equipment Footprint and Site Details

The figure below shows the rough equipment footprint for refurbished equipment.



The picture below shows an installed Valve Skid and Tank Skid

The table below indicates the approximate weights and sizes of the equipment

Item	Ship Weight	Site Weight	Dimensions
PSA Skid	35,000	35,000	25’ x 10’
Bottom 4 Tanks	13,000	21,000	19’ x 10’ x 19’
Top 3 Tanks	8,000	(on Tank Skid)	
Feed Compressor	15,000	15,000	14’ x 9’

8. Experience

Guild has biogas plants in operation at landfills, waste water treatment plants, lagoon digesters and other facilities where the biogas is purified to either pipeline or LNG specifications. Our portfolio of equipment includes: feed compression, pressure swing adsorption (PSA), Temperature Swing Adsorption (TSA), membrane, vacuum compression and product compression. We have standard system offerings or can custom build a package to meet individual customer needs. Guild Molecular Gate™ PSA systems use only regenerable media with our longest running plant in operation since 2004. Tours of operating commercial units in similar scale and application can be arranged upon request. Below is a map of US locations and a summary of our experience to date.

1. Biogas plant locations:
    a. USA
    b. Canada
    c. UK
    d. Brazil
    e. Philippines
2. Feed Flows: 75 to 8,000 SCFM
3. Contaminants removed:
    a. Bulk rejection of:
        i. CO_2- up to 40%
        ii. N_2- up to 17%
    b. Rejection of trace components:
        i. H_2S- up to 1%
        ii. H_2O

iii. O2
iv. VOCs[1]
v. Siloxanes[1]
vi. Heavy Hydrocarbons (C6+)
vii. Ammonia (NH3)

4. Product Compression:
    a. Pressure up to 1,400 PSIG for high pressure interstate pipeline
    b. CNG up to 4,500 PSIG with both slow fill and direct fill

[1] Upon request we can provide gas analysis from an independent 3rd party lab of an operating commercial unit in landfill service to demonstrate removal capabilities of trace organic components and siloxanes.

9. Design Basis

All gas processing equipment is designed for outdoor service in a Class 1 Div 2 area. The plant is design for single operator start up and can run unattended. Automatic turndown and purity control are included standard in our control system. Components are industrially available and are serviceable by local mechanics. Uptime of 98% has been experience for similar facilities. Estimated downtime is 1% for planned maintenance and 1% for unplanned maintenance.

Location: Mesa AZ

Elevation: 1250 ft

Ambient temperature: -20 to 110 °F

10. Design Codes and Standards

<u>Control System</u>

The Guild control system uses Allen Bradley Compact Logix PLCs. The entire Guild package operates together in a seamless manner since all of the logic is authored by Guild. Our system can also accept and transmit signals as desired in order to integrate with other vendor equipment or a Balance of Plant (BOP) SCADA system. A desktop HMI running Citect software is provided to monitor the equipment and for data logging and trending. The plant is fully automated to allow for remote operation, startup and shutdown.

Guild’s standard control philosophy allows for equipment operation without operator input. The system will automatically adjust based on gas flow and product purity setpoints. In the event of a failure of an independent piece of equipment, the system will adjust other operating parameters in order to maintain maximum operating capacity with the remaining operational equipment. Equipment turndown to 25% is standard.

Electrical

Skid mounted electrical equipment such as motors, instrumentation and controls will be suitable for NEC Class 1 Div 2 Group D as required. Instrumentation wiring and power of 120 V and above is run in separate intermediate conduits. Instrumentation wiring is run to the instrument in conduit and uses shielded conductors to prevent erroneous instrumentation readings and thus reduces the likelihood of plant shutdowns. All wiring with in a cabinet is done in wire duct and low power instrumentation is physically separated from 120V and above. Only UL Type 4 cabinets or better are used for the housing the Guild supplied controls.

Painting

All individual piping, frames and vessels are painted before assembly then touched up after assembly. This prevents hardware from being coated with a layer of paint, assuring that any disassembly is less difficult.

All skids are primed, intermediate and final coat painted. All seams are caulked to prevent crevice corrosion. Standard color is window gray (RAL 7040).

Piping

Piping is fabricated in accordance with ASME B31.3, and ANSI B16.5. Both 304 stainless steel and carbon steel piping are used on this system.

Pressure Relief Valves

As required by code relief valves will be provided and are sized in accordance with API RP520. Relief valves internals that are in constant contact with the process are 304 stainless steel or better. As provided the relief valves individually route to atmosphere.

Testing

A factory acceptance test is performed on each skid to ensure the equipment is in good working order. Tests can we witnessed by the customer if desired. Acceptance test tasks vary from skid to skid but can include: leak test, I/O check-out, P&ID inspection, GA dimensional inspection, software checkout (such as shutdowns and operational controls) and run test (for select rotating equipment).

Vessels

All vessels are fabricated in compliance with ASME Section VIII, Division 1. An appropriate pressure and temperature rating are selected based on the service of the vessel.

Adsorber vessels are specifically engineered for PSA service and are fabricated using carbon steel SA-516 Grade 70 (or equivalent). Welds are 100% X-ray inspected and the vessel is post weld heat treated to relieve weld stress. Vessels contain a 304 stainless steel full bed support for proper flow distribution. For more information on PSA vessel design you can refer to “PSA Vessel Technology: An Overview” published by ASME.

11. Price

One Refurbished PSA, New Feed Compressor **$ 995,000**

Commissioning/Startup labor and travel will be separately billed at Guild Associates standard rates. Commissioning (Five days onsite commissioning, two people) is estimated to cost $21,500 per system. Shipping costs are separate and will be paid by the customer.

Price is valid for orders only while systems are available for refurbishment and is also contingent upon acceptance of Guild Associates' terms and conditions.

Warranty for equipment is valid for 15 months from shipment or 12 months from startup, whichever occurs first.

Operating Expense: The majority of the operating cost of the facility will be the power demand for the rotating equipment. Major maintenance costs include annual filter replacements and oil changes, materials cost of a plant of this scale is estimated at 2% of capital cost per year. The Molecular Gate media is fully regenerated in this process and media replacement is not expected during the lifetime of the equipment (20 years).

Estimated Duration: Equipment delivery is dependent on workload at the time order is placed, but is estimated to be between 5 - 7 months from receipt of purchase order.

We appreciate your interest in the technology.

Sincerely,

Paul Baker

Business Development
Phone: 614-760-8013
Email: paulbaker@guildassociates.com

Guild is a licensee of BASF's Molecular Gate™ Adsorbent Technology and is solely responsible for all representations regarding the technology made herein.

APPENDIX F

PERENNIAL ENERGY Thermal Oxidizer Quote

May 1st, 2019

Arcadis

Re: Mesa, AZ 200 SCFM Tail Gas Thermal Oxidizer Unit (TOU)

Attn: Shayla Allen, Andrew Deur

Shayla and Andrew:

Per your request, following and attached please find our **budgetary** quotation to supply the described products and services relative to your project requirements. We appreciate the opportunity to furnish this proposal.

PEI proposes to provide a unitized, modular, ***vertical*** thermal oxidizer (TOU) with a total capacity of **1.64 mmBtu/hr,** with off-loading and installation by others. The unit shall be sized per your request for quotation to handle **Condition #1:** 200 SCFM of waste gas stream at 5 % methane as well as the maximum supplemental fuel stream of **1,26 mmBtu/hr** or **20 SCFM** natural gas at a minimum of 10 PSI, at the **Condition #1** waste gas stream conditions. **Condition #2:** 70 SCFM of waste gas stream at 5% % methane as well as the maximum supplemental fuel stream of **.69 mmBtu/hr** or **11 SCFM** natural gas at a minimum of 10 PSI, at the **Condition #2** waste gas stream condition. TOU stability and economy will be dependent on a steady or slow change rate of waste flow and methane composition.

Connected **480 V motor HP** is: 1 x 3 HP package burner

Properties of the waste gas streams are assumed to be per your RFP.

The Thermal Oxidizer (TOU) shall include two principal sub-systems:

- The Thermal Oxidizer (TOU)
- The Thermal Oxidizer Control System

Not included in this proposal are the following:

- Freight, off-loading, or installation
- Site Civil, Structural, or Electrical Engineering
- Bonds or liquidated damages
- Taxes, permits, fees, etc.
- **Electrical interconnect between unit mounted J-boxes and main PLC cabinet.**

The Thermal Oxidizer(TOU) shall include:

- PEI **1.64 MMBtu/hr** TOU assembly for heat content of Waste Stream and 20 SCFM max natural gas supplemental fuel stream.

1375 County Road 8690 West Plains, MO 65775
Phone (417) 256-2002 Fax (417) 256-2801
www.PerennialEnergy.com PEI@PerennialEnergy.com

- ASTM A-36 carbon steel TOU shell assembly
- Approximate size: 4’ diameter (with reduced diameter stack extension) x 25’ O.A.H.
- Stainless steel protection band around top of TOU shell
- Stainless steel insulation retainer band and weather shield at top of TOU
- **Refractory i**nsulation, installed in overlapping layers. This results in 250 deg F skin temperature.
- Stainless steel retainer pins and keepers (washers) for insulation
- High temperature sealant/fixative solution sprayed on insulation
- Three (3) thermocouples at various heights (for temperature control) in unit shell
- Four (4) source test ports for air quality testing sensor access
- Five (5) view ports . . . one at each thermocouple and two to view main flame and pilot
- OSHA Ladder for access to thermocouples.
- Honeywell UV, self checking flame safeguard sensors
- Honeywell pilot ignition transformer mounted on unit
- Natural gas pilot line with solenoid, valve and pressure gauge
- Engineered structural mounting system
- Four (4) inches of air space beneath unit floor and equipment pad
- One each primary supplemental fuel process heating burner rated **1.26 MMBtu/hr** each. The burner will have a **3 HP** combustion air blower.
- Waste Stream entrance system
- 4” butterfly valve w/pneumatically controlled safety shutoff actuator w/spring assisted shutoff for the waste gas stream. Dry instrument quality compressed (80-100 psig) air supply by others.
- 4” aluminum flame arrester assembly w/ aluminum element. Handles the 90 deg. F max Guild waste gas stream.

Natural Gas Supplemental Fuel Line Valves and Devices:

- Standard natural gas fuel train for the one main power burner
- 1 each Thermal probe flowmeters for supplemental flow to the main burner

The Thermal Oxidizer Control System shall include:

- NEMA 4 control panel w/ NEMA 4 gasketing & 3 point latching
- NEMA 3/3R Weather / Heat radiation protection
- NEMA 3/3R **30 AMP 480** volt three phase Panelboard with branch breakers for all system loads.
- NEMA 3/3R MCC with motor starter for burner blower
- **5 KVA** 240/120 V transformer and low voltage distribution panel
- Control panel lighting
- Allen-Bradley Compact Logix PLC digital and analog logical supervision system with RSLogix 5000 version 20 or later. All specified alarms, shutdowns, and control functions
- C-More Touchscreen 6" Color
- Honeywell Burner Control Systems
- Alarm and shutdown message annunciation (Touch Screen)
- OFF / ON switch for the System
- TEST / CLOSED / AUTO switch for the safety shutdown valves
- TEST / OFF / AUTO switch for the burner control systems.
- Flame failure annunciation for the TOU (Touch Screen)
- Shutdown Valve failure annunciation (Touch Screen) for LFG system
- Flame failure reset (ALARM RESET / LAMP TEST switch)
- 480V three phase, 60 HZ Electrical service required **30 AMPS.**
- AC and DC control voltage surge protection

General:

- **One start up trip** of 3 days of on-site start-up & training services by a factory field services technician/engineer are included. To be accomplished in **one trip.**

- ○ System is priced on an **FOB Factory, West Plains, MO basis**. Freight can be pre-paid and added to invoicing.
- ○ 3 copies of full engineering submittals are included.
- ○ 3 copies of "as-built" Operation & Maintenance Manuals are included.

The system as described above and attached is provided as completely pre-packaged, pre-wired, and factory pre-tested as is possible. ***The system is offered FOB Factory***, with freight billed at 115% of shipping invoice(s).

The pricing does not include any site civil or structural engineering, or site preparation work of any kind. Neither does the price include any local, state or federal taxes, or any permits, or tariffs of any kind. The system as quoted is to be off loaded, set in place, installed and interconnected by others. The system includes only the standard PEI warranty for 18 months from date of shipment or 12 months from date of first service, whichever occurs first. Please see copy of PEI warranty, attached. We are pleased to honor this quotation for 30 days from the date of this document. The pricing is dependent on receiving an approved order that would include industry standard commercial terms. PEI standard terms are:

10% with order
30% with approved submittals
30% with receipt of major components
25% upon shipment
05% upon successful start-up, unless failure to achieve successful start-up is neither the fault nor cause of PEI, then net 60 days of shipment

Budgetary Price……………………………………………………$175,000.00

We anticipate that we could deliver the system in **16-18** weeks from receipt of approved submittals or other irrevocable release to order all materials. Actual shipping estimates will have to be given at time of order. We anticipate that submittals can be provided in **3** to **4** weeks from receipt of an approved order.

Thank you for your consideration of PEI landfill gas products and services. Should you have any questions, or require further information in this regard, please do not hesitate to call.

Respectfully,

Brad Alexander
Perennial Energy
West Plains MO 65775

APPENDIX G

Arcadis Expanded Cost Estimates

Mixed Slurry Offloading, Receiving, and Equalization Station Capital Expenditure Estimate					
Item Description	**Quantity**	**Unit**	**Total Unit Cost**	**nstallation & Labor Cos**	**Total Cost**
General Conditions/Division 1					**$ 31,000**
Truck Unloading					**$ 21,000**
Truck Unloading Goseneck	2	ea	$ 2,000	$ 1,000	$ 6,000
Card Reader and Metering Station	1	ea	$ 10,000	$ 5,000	$ 15,000
Pumps and Equipment					**$ 111,000**
Slurry Recirculation and Mixing Pumps	2	ea	$ 20,000	$ 10,000	$ 60,000
Slurry Recirculation Piping and Valves	1	ls			$ 15,000
Slurry Digester Feed Pumps	2	ea	$ 6,000	$ 3,000	$ 18,000
Level Sensor	1	ea	$ 5,000	$ 2,500	$ 7,500
Flow Meter	1	ea	$ 5,000	$ 2,500	$ 7,500
pH probe	1	ea	$ 2,000	$ 1,000	$ 3,000
Piping, Meterining and Valves					**$ 93,450**
6" Truck Unloading Pipe, DI	100	lf	$ 20	$ 40	$ 6,000
6" Fittings,DI	10	ea	$ 250	$ 400	$ 6,500
6" Knife Gate, DI	2	ea	$ 1,000	$ 500	$ 3,000
6" Recirculation/Mixing Pipe, HDPE	150	lf	$ 15	$ 20	$ 5,250
6" Fittings, HDPE	10	ea	$ 200	$ 400	$ 6,000
6" Plug Valve, DI	4	ea	$ 3,000	$ 1,500	$ 18,000
6" Check Valve, DI	2	ea	$ 3,000	$ 1,500	$ 9,000
4" Digester Feed Pipe, HDPE or PVC	500	lf	$ 20	$ 20	$ 20,000
4" Fittings, HDPE or PVC	20	ea	$ 135	$ 150	$ 5,700
4" Gate Valve	6	ea	$ 1,000	$ 500	$ 9,000
4" Check Valve	2	ea	$ 2,000	$ 500	$ 5,000
Electrical and Instrumentation Controls					**$ 60,000**
Lump Sum Electrical and INC	1	ls	$ 60,000		$ 60,000
Total Project Subtotal					**$ 317,000**
Contingency	30%				$ 95,000
Taxes, Bonds and Insurance	5%				$ 16,000
Overhead and Profit	15%				$ 48,000
Total Conceptual Construction Costs					**$ 476,000**

Low Pressure Compressor Capital Expenditure Estimate					
Item Description	**Quantity**	**Unit**	**Total Unit Cost**	**nstallation & Labor Cos**	**Total Cost**
General Conditions/Division 1					**$ 34,000**
Low Pressure Compressor					**$ 105,000**
2 psig, 200 scfm Compressor	2	ea	$ 30,000	$ 15,000	$ 90,000
Flow Meter	2	ea	$ 5,000	$ 2,500	$ 15,000
Piping, Meterining and Valves					**$ 101,000**
10" Biogas Pipe, SS	150	lf	$ 80	$ 20	$ 15,000
10" Fittings, SS	10	each	$ 1,200	$ 300	$ 15,000
10" Plug Valves, SS	2	each	$ 6,000	$ 2,000	$ 16,000
10" Check Valves, SS	2	each	$ 8,000	$ 2,000	$ 20,000
10" Isolation Valve, SS	2	each	$ 6,000	$ 1,500	$ 15,000
10" Three Way Recycle Valve, SS	2	each	$ 8,000	$ 1,500	$ 19,000
4" NG Pipe, pe	25	lf	$ 20	$ 20	$ 1,000
Gas Blending System					**$ 60,000**
Gas Blending System	1	ls	$ 60,000		$ 60,000
Electrical and Instrumentation Controls					**$ 40,000**
Lump Sum Electrical and INC	1	ls	$ 40,000		$ 40,000
Total Project Subtotal					**$ 340,000**
Contingency	30%				$ 102,000
Taxes, Bonds and Insurance	5%				$ 17,000
Overhead and Profit	15%				$ 51,000
Total Conceptual Construction Costs					**$ 510,000**

RNG Membrane Upgrading System and Pipeline Connection Capital Expense Estiamte							
			Material		Labor/Equipment		
Scope of Work	QTY.	Unit	Unit Rate	Cost	Unit Rate	Cost	Total Cost
General Conditions/ Division 1	1	LS					$ 218,000
Structural							
Concrete Slab for High Btu Skid (25'x10'x1' thick)	10	CY	$ 600	$ 6,000	$ 3,000	$ 3,000	$ 9,000
Mechanical							
Membrane RNG Conditioning System (400 scfm input capacity)	1	EA	$ 1,300,000	$ 1,300,000	$ 150,000	$ 150,000	$ 1,450,000
10" SS Digester Gas Piping	250	LF	$ 60	$ 15,000	$ 80	$ 20,000	$ 35,000
10" SS Digester Gas Fittings, Valves, and Metering	1	LS					$ 20,000
2" Buried HDPE Product Gas Piping	150	LF	$ 20	$ 3,000	$ 25	$ 3,750	$ 7,000
2" Buried HDPE Product Gas Fittings and Valves	1	LS					$ 5,000
Condensate Return and Chiller Piping	1	LS					$ 10,000
RNG to Pipeline Metering Station	1	LS					$ 75,000
Electrical and I&C							
Electrical - 15% of Mechanical Subtotal	15%						$ 240,000
I&C - 10% of Mechanical Subtotal	8%						$ 130,000
Total Project Subtotal							$ 2,197,000
Contingency				30%			$ 659,000
Taxes, Bonds and Insurance				5%			$ 110,000
Overhead and Profit				15%			$ 330,000
Total Conceptual Construction Costs							$ 3,296,000

Membrane System O&M Costs		
Maintenance Item	Annual Cost ($/year)	
Dryer Maintenance oil, grease	$	3,000
Inlet Separator Replace Element	$	1,500
Quarterly Maintenance on Feed Compressor-oil filter, samples	$	10,000
Annual Maintenance on Feed Compressor-add separator elements	$	4,500
Unplanned Maintenance (Estimated as 15% Planned Maintenance)	$	3,000
Total Annual O&M Costs	$	22,000

RNG PSA Upgrading System and Pipeline Connection Capital Expense Estiamte							
			Material		Labor/Equipment		
Scope of Work	QTY.	Unit	Unit Rate	Cost	Unit Rate	Cost	Total Cost
Division 1 Work - 11% of Subtotal	1	LS					$ 177,000
Structural							
Concrete Slab for High Btu Skid (25'x10'x1' thick)	10	CY	$ 600	$ 6,000	$ 3,000	$ 3,000	$ 9,000
Mechanical							
PSA Conditioning System (400 scfm input capacity)	1	EA	$ 995,000	$ 995,000	$ 150,000	$ 150,000	$ 1,145,000
10" SS Digester Gas Piping	250	LF	$ 60	$ 15,000	$ 80	$ 20,000	$ 35,000
10" SS Digester Gas Fittings, Valves, and Metering	1	LS					$ 20,000
2" Buried HDPE Product Gas Piping	150	LF	$ 20	$ 3,000	$ 25	$ 3,750	$ 7,000
2" Buried HDPE Product Gas Fittings and Valves	1	LS					$ 5,000
Condensate Return and Chiller Piping	1	LS					$ 10,000
RNG to Pipeline Metering Station	1	LS				$ -	$ 75,000
Electrical and I&C							
Electrical - 15% of Mechanical Subtotal	15%						$ 200,000
I&C - 10% of Mechanical Subtotal	8%						$ 100,000
Total Project Subtotal							$ 1,786,000
Contingency				30%			$ 536,000
Taxes, Bonds and Insurance				5%			$ 89,000
Overhead and Profit				15%			$ 268,000
Total Conceptual Construction Costs							$ 2,679,000

PSA System O&M Costs		
Maintenance Item	Annual Cost ($/year)	
Dryer Maintenance oil, grease	$	3,000
Inlet Separator Replace Element	$	1,500
Quarterly Maintenance on Feed Compressor-oil filter, samples	$	7,500
Annual Maintenance on Feed Compressor-add separator elements	$	4,000
Vacuum Pump quarterly maintenance-oil filter, oil sample greasing	$	10,000
Unplanned Maintenance (Estimated as 15% Planned Maintenance)	$	4,000
Total Annual O&M Costs	$	30,000

Thermal Oxidizer Capital Expense Estiamte							
Scope of Work	QTY.	Unit	Material		Labor/ Equipment		Total Cost
			Unit Rate	Cost	Unit Rate	Cost	
Division 1 Work - 11% of Subtotal	1	LS					$ 32,000
Structural							
Concrete Slab for TOX Skid (25'x8'x0.5' thick)	4	CY	$ 650	$ 3,000			$ 3,000
Mechanical							
Thermal Oxidizer System (200 scfm capacity)	1	EA	$ 175,000	$ 175,000	$ 50,000	$ 50,000	$ 225,000
Ancillary Piping and Equipment	1	LS				$ -	$ 20,000
Electrical and I&C Subtotal							
Electrical - 12% of Mechanical Subtotal	12%						$ 29,000
I&C - 7% of Mechanical Subtotal	7%						$ 17,000
Total Project Subtotal							$ 326,000
Contingency				30%			$ 98,000
Taxes, Bonds and Insurance				5%			$ 16,000
Overhead and Profit				15%			$ 49,000
Total Conceptual Construction Costs							$ 489,000

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APPENDIX D

Potential Project Incentives vs. Biogas End Uses Memorandum

MEMO

To:

Matthew Adams (Mesa)

Niel Curley (Mesa)

Copies:

File

From:

Matt Tomich (Energy Vision)

Date:

9/13/2019

Arcadis Project No.:

00678068.0000

Subject:

Mesa NWWRP Food to Energy Feasibility Study (CP0870)
Task 6 – FINAL Potential Project Incentives vs. Biogas End Uses Memorandum

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Background

Changing state and federal policies and incentives, combined with an extended period of very low cost geologic natural gas, have made biogas-to-electricity a challenging proposition economically, particularly at wastewater treatment facilities. While renewable electricity production has become less attractive in many jurisdictions, the United States Environmental Protection Agency's (EPA) Renewable Fuel Standard (RFS) has driven a major uptick in interest and investment in projects/facilities "upgrading" biogas to pipeline/vehicle grade renewable natural gas (RNG, also called "biomethane"), largely because the credits generated under this program—Renewable Identification Numbers (RIN)—are particularly valuable for RNG made from wastewater, landfill, and agricultural waste (e.g. dairy or hog manure) derived biogas.

Renewable Natural Gas and the Renewable Fuel Standard: Monetizing Environmental Attributes

Since 2014, RNG made from wastewater, landfill, or livestock manure biogas has been an approved "cellulosic" feedstock for fuel production under the EPA's RFS, making RNG produced from these sources eligible to generate the highest value environmental attributes (i.e., RIN credits). To ensure eligibility and the ability to monetize this resource under the RFS program, where there are dozens of approved "renewable fuel pathways," each new project must include the following three major components:

1. Feedstock: The type of renewable biomass that is converted into renewable fuel.
2. Production process: The type of technology used to convert the biomass.
3. Fuel type: Must be a liquid or a gas derived from renewable biomass resources.

Pathway Approval: To get a project-approved, EPA has three main requirements:

1. **The Biogas production facility must complete an engineering review** by an approved provider once the facility is "mechanically complete" and producing biogas.

2. **RNG must enter a "common carrier system**" to be eligible to generate RINs under the RFS. The definition of "common carrier" by the EPA includes "interstate and intrastate pipelines, and local distribution systems". It now also includes on-site use or "virtual pipeline" fuel delivery. (For projects injecting gas into the gas grid, upgraded biogas must meet local pipeline quality specifications.)

3. **Two pathways must be satisfied to receive EPA approval**

   Physical Pathway – Party(s) must demonstrate a physical (or more often theoretical-physical) pathway that links the biogas production facility with the vehicle fuel producer. The RFS allows for displacement of fossil gas molecules by renewable ones (e.g., it is rare that actual RNG molecules get consumed in a vehicle). More often, it is a matter of matching daily supply with daily fleet demand. One RIN is generated for every 77,000 British thermal units (Btu) of RNG when it is dispensed from a fueling station into a compressed natural gas (CNG)/liquid natural gas (LNG) vehicle.

   Contractual Pathway – Party(s) must prove (via affidavit) the link between the biogas production facility and vehicle fuel producer, and each party that holds title in between, which often includes a gas marketer and/or local distribution company (LDC).

There are several firms specializing in RFS registration, as there are now nearly 70 operational biogas-to-CNG/LNG projects in the United States, including almost 20 municipal wastewater biogas-to-vehicle fuel projects. There are also a growing number of firms specializing in municipal biogas-to-RNG vehicle fuel projects, including all approvals for generation of lucrative environmental attributes and marketing of gas and attributes to fleet users and obligated parties.

Renewable Natural Gas Production Potential Alternatives

As highlighted in the Digestion Capabilities Tech Memorandum (Task 4), NWWRP has a significant excess capacity to handle outside high-strength waste (HSW) beyond the current baseline. While doing so can greatly enhance biogas production, it would also alter both the type and value of the environmental attributes (i.e., RINs) generated by the resulting RNG. That's because wastewater-only biogas generates "cellulosic" (D3) RINs, whereas wastewater biogas produced via co-digestion of other feedstocks—including food scraps, fats/oils/grease (FOG) and other HSW— generates "advanced" (D5) RINs, as shown in Table 1.

Table 1. Biogas as a Cellulosic vs. Advanced Biofuel

Fuel Type	Feedstock(s)	Production Process	D-Code
Renewable CNG/LNG	Landfill Gas, Agricultural Biogas (dairy manure), **biogas from WWTPs**, Separated MSW Biogas (AD post MRF), Cellulosic Feedstocks processed in other waste digesters	Any	**D 3**
Renewable CNG/LNG	Food waste + other "non-cellulosic" feedstocks	Any	**D 5**

This distinction is extremely important from an economic standpoint, given that the value of D3 RINs is considerably greater than D5 RINs, as shown in Figure 1 below.

Figure 1. D3 and D5 RIN Values; 2013-2019

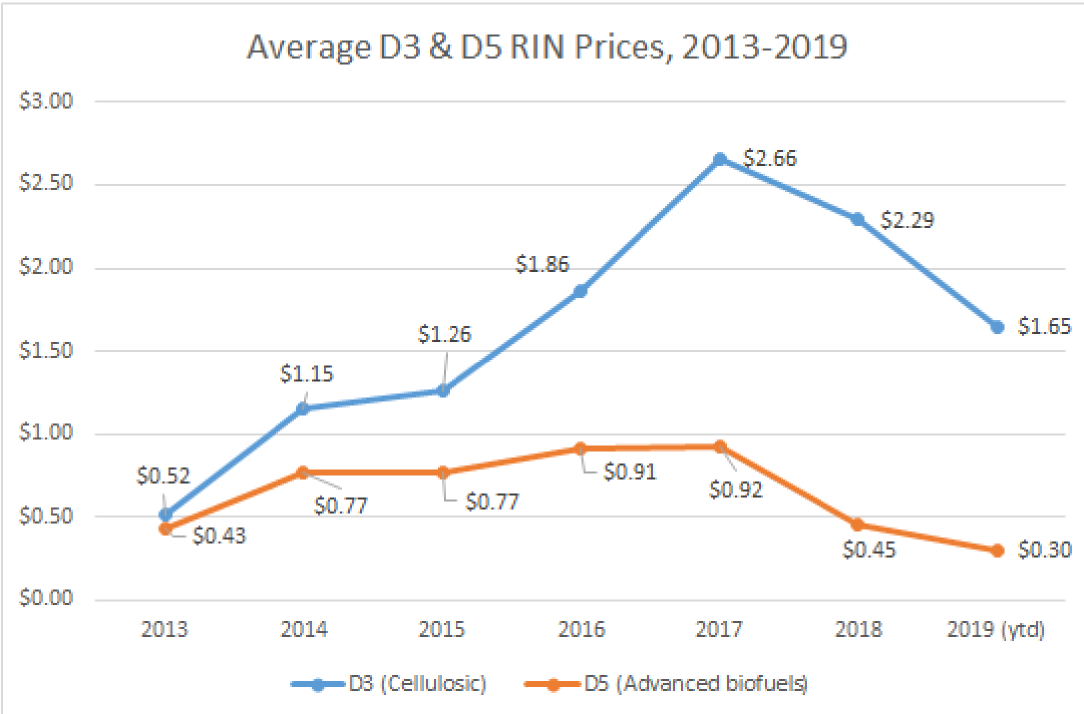


Figure 1 also highlights the historical price volatility associated with RIN credits. As part of EPA's statutory authority to implement the RFS program, EPA sets annual renewable volume obligations (RVO), which effectively determine the RIN credit value based on the subsequent interplay between market supply and demand for a given year. For example, in 2017, EPA set the "cellulosic" (D3) RVO at 311-million gallons, but the total supply was only 298-million gallons, creating a deficit that drove credit prices to an all-time high. To counteract this, for 2018, EPA reduced the D3 RVO to 288-million gallons, but annual RNG production exceeded the RVO, creating more RIN credits than obligations, and exerting downward price pressure.

So far in 2019, a combination of factors has driven RIN pricing down for the following reasons: 1) Because of the 2018 surplus in D3 credits, several obligated parties (oil producers/refiners) carried credits into 2019, extending the surplus; 2) EPA is currently overseeing an RFS "Reset" process, which has created some added price uncertainty, which should resolve itself in the coming months; and 3) Although EPA set the 2019 cellulosic RVO at 418-million gallons—a 45 percent year-over-year increase—monthly production so far has been more than 50 percent higher than 2018 through March, suggesting that there may yet again be a surplus of credits.

However, despite this recent downward price pressure, industry analysts, traders and other market experts indicate that RIN pricing is likely 15-20 percent below expectations. The estimated revenue potential at Mesa's NWWRP is significant and will be described in detail under Task 7, Financial Feasibility Evaluation.

California's Low-Carbon Fuel Standard (LCFS)

The Low Carbon Fuel Standard (LCFS) was adopted in California in 2009 to contribute to state greenhouse gas (GHG) emission reduction goals under the Global Warming Solutions Act of 2006 (AB 32).

The LCFS was designed as a performance-based regulation, such that the program incentivizes adoption of low-carbon transportation fuels based on a given fuel's lifecycle GHG emissions per unit of energy—or carbon intensity (CI) as rated by the program. Carbon intensity is measured as grams of CO2e per megajoule (MJ) of energy.

The regulation initially laid out annually declining CI benchmarks for the average transportation fuel mix from 2011 through 2020. In September 2018, CARB adopted regulatory amendments to extend the LCFS for an additional ten years with a target of an overall 20% CI reduction for all transportation fuels used in the state from 2010 levels by 2030.

Under the program, RNG derived from wastewater biogas is an ultra-low-carbon fuel option with CI scores ranging from low single digits to high teens.

An LCFS system pegs fuels to a carbon intensity benchmark; those with a CI below the benchmark earn more credits the further they get from the benchmark, while those with Cis above the threshold generate deficits that increase as carbon intensity does. (The Cis of fuels are measured and certified by LCFS-accredited verifiers.) To meet their obligations under the standard, providers of higher CI fuels buy credits from producers of lower CI fuels who have a surplus—meaning effectively that producers of higher-CI fuels are funding development of cleaner options. The system emphasizes total carbon reduction, and is more technology agnostic about how reductions are achieved than the Federal RFS. As noted, it also focuses on life cycle emissions, not just tailpipe emissions.

One LCFS credit is generated for every metric ton of reduction of CO2e emissions. Even within RNG produced form wastewater, this produces a range of potential values. By way of example, as of April 4th 2019, LCFS credits were trading at $195 each. For one California WWTP producing RNG with a CI of 7.75 (per CARB's fuel pathways table), this equates to a value of $14.88/MMBTU. For a second California plant producing RNG with a CI of 30.92, it works out to $10.11 per MMBTU.

Long-Term, Non-Transportation RNG Off-Take Alternatives

While the transportation sector is the highest value market opportunity for wastewater biogas today, policy uncertainty around the RFS—and to a lesser extent, the LCFS—continues to create volatility in the market for environmental attributes (RINs + LCFS credits). As a result, as an RNG producer, it can be difficult to secure guaranteed and long-term off-take beyond 5 to 10 years for gas sold into the transportation market. The combination of uncertainty and volatility has led many RNG producers to look for longer-term off-take from non-transportation end-users.

While relatively few and far between to date, there are public and private entities that have or are willing to enter into long-term RNG off-take agreements for non-transportation (primarily thermal) applications. Some recent examples include: L'Oreal, The University of California, Middlebury College, and The Port of Seattle, all of which have committed (or submitted request for proposals (RFP)) for 15- or 20-year RNG procurement contracts.

In addition, a growing number of gas utilities are starting to develop voluntary "green gas" tariffs where commercial or residential customers have the option to pay a premium for RNG. One local example is SoCalGas, which has filed a petition with the CPUC requesting authority to offer RNG to non-fleet customers. If approved, the program would set the utility on a track to procure 5% of its total natural gas from biogas sources over the next 5 years. While specifics have not yet emerged, it appears likely the program will give preference to in-state sources of RNG. Recent discussions with Southwest Gas suggest they may be eyeing a similar voluntary program for Arizona.

While 15- and 20-year RNG off-take contracts are not unheard of, in general, the longer the term, the lower the price point (per MMBtu), which is true for both transportation and non-transportation RNG projects. The importance of working with a trusted gas marketing partner cannot be overstated, given that so much of a project's economic success is rooted in the ability to monetize environmental attributes or other premium pricing options.

Alternatives for Combined Heat and Power (CHP)

As highlighted in the Digestion Capabilities Tech Memorandum (Task 4), NWWRP has an existing CHP engine used for co-generation all seasons during peak and shoulder peak hours. The City is evaluating an alternative for adding a second engine along with associated electrical upgrades for CHP. Currently, there are no attractive Federal- or State-level incentives for CHP as discussed further in the following paragraphs.

Other State/Federal Incentives or Funding Programs for Biogas/RNG

State-level incentives that support biogas production and/or use in Arizona are extremely limited. In fact, State support for municipal biogas/CHP/RNG is not available, and the two CHP programs offered by Southwest Gas do not appear to be relevant to the City of Mesa with its own municipal natural gas utility.

At the federal level, the **Alternative Fuel Excise Tax Credit** appears to be the most relevant incentive to RNG utilization. It is the same program the City of Mesa currently participates in to receive a $.50 per gallon (equivalent) credit for its use of fossil CNG. Use of RNG rather than CNG does not change the City's ability to monetize this credit. Historically, the program has been re-extended on an annual basis, or even retroactively was the case in 2017. It is difficult to assess the likelihood of its continued existence, but as long as it is in place, RNG or CNG will be eligible fuels.

Two other federal bond programs were discontinued by the Trump administration effective January 1, 2018. Since there is a possibility one or both may be reinstated, short summaries of each are included here:

Federal Qualified Energy Conservation Bonds (QECBs): this program allowed state, local and tribal governments to issue bonds to fund certain types of clean energy projects, including anaerobic digestions. These "tax credit bonds," allowed the issuer to 1) repay only principle to bondholders, while the federal government issued bondholders a tax credit as "interest", or 2) receive a payment from the federal government equal to the amount of the afore-mentioned tax credit. Either option gave the bond issuer a lower effective interest rate to repay.

Federal Clean Renewable Energy Bonds (CREBs): these worked in a similar way to the QECBs. The bonds could be issued by local government to fund certain kinds of renewable energy projects, including anaerobic digestion. The bond issuer was required to repay the principle, and interest was paid to bondholders in the form of a federal tax credit.

Two Federal programs that potentially support production of biogas/RNG from wastewater-- one from US DOE and one from USDA -- take the form of loan guarantees, and therefore may not be relevant to the City of Mesa. A third was relevant but has recently been shut down. They include:

US DOE Renewable Energy and Efficient Energy Loan Guarantee (Title 17 Innovative Energy Loan Guarantee Program): This program "finances large-scale, all-of-the-above energy infrastructure projects." A DOE Loan Program Officer, Ed Rios, confirmed that the program would extend to municipalities, and that biogas upgrading was more likely to fall under Title 17 than CHP, as the former is "more innovative". Mr. Rios could not confirm whether the program, which is competitive, would ultimately fund a biogas upgrading project, but said that the Loan Program Office was happy to consult on how best to present an application. He also noted that the program tends to work with larger projects, saying smaller projects tend to fall in the $80 million range, and recalling only a single project that came in below that, in the $20 million range. (https://www.energy.gov/sites/prod/files/2019/02/f59/LPO-renewable-energy-and-ee-final.pdf)

The USDA's "Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program" ("Section 9003 program") provides loan guarantees for up to 80% of total eligible project costs, up to $250 million. Eligible projects include production of "advanced biofuels" made from waste materials and biogas. According to DSIRE, eligible advanced biofuels technologies include "sewage waste treatment gas"; a USDA contact answering questions about the defunct "Repowering Assistance Program" (below) indicated that the 9003 program is "flexible," and could be an option for a wastewater biogas project. (https://www.rd.usda.gov/files/fact-sheet/RD-FactSheet-RBS_Biorefinery.pdf)

The USDA's **"Repowering Assistance Program,"** which provided grants to "biorefineries," is not currently accepting applications, and the main contact confirmed that the program has been shut down for now. This program offered grants for up to 50% of project costs "to eligible biorefineries to replace fossil fuels used to produce heat or power to operate the biorefineries with renewable biomass." It is not clear whether this program will be reinstated in the future.

Table 2 below summarizes the programs/incentives currently relevant to biogas utilization at NWWRP.

Table 2. State/Federal Programs & incentives Relevant to Biogas Utilization

Program / Incentive	Agency	Type of Program	Appropriate End Use(s)	Comments
The Renewable Fuel Standard (RFS2)	US EPA	Federal Regulatory	R-CNG Vehicle Fuel	
California Low Carbon Fuel Standard (LCFS)	CARB	State Regulatory	R-CNG Vehicle Fuel As of 2019, RNG for Industrial Uses also eligible	In 2018, the LCFS was extended through 2030. However, qualifying requires that fuel be sold into the CA market, which would preclude local use of NWWRP RNG.
Alternative Fuel Excise Tax Credit	IRS	Federal Tax Credit	RNG/CNG/LNG Vehicle Fuel	Program historically extended, but often only one year at a time.
Renewable Energy and Efficient Energy Loan Guarantee	US DOE	Loan Guarantee	RNG or CHP; Emphasis on "innovative" technologies	Tends to lend to larger projects, $80 million considered "small".

Program / Incentive	Agency	Type of Program	Appropriate End Use(s)	Comments
Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (“9003 program”)	USDA	Loan Guarantee	CHP or RNG	Program described as “flexible,” but requires significant administrative burden(s) associated with applications, reporting, etc.

While Task 7, Financial Feasibility Evaluation, will review the economic implications of different biogas end use options and the longer term stability of the programs/incentives described herein, it is clear that the LCFS, RFS2 and Alternative Fuel Excise Tax Credit (tangentially) offer the most attractive economic incentives. From a pure financial standpoint, producing RNG (no co-digestion) and sending it to California offers the greatest monetary incentive to NWWRP, as this would allow for production and sale of both RIN and LCFS credits. However, doing so would preclude the City of Mesa from using the clean, carbon-neutral fuel in local fleets.

APPENDIX E

Financial Feasibility Economic Evaluation Memorandum

RAFTELIS

MEMO

To: Brian Bubela, P.E., Arcadis
From: John Mastracchio, P.E. and Steve Gagnon, P.E.
Date: September 16, 2019

Re: Mesa NWWRP Food to Energy Feasibility Study (CP0870)
Task 7 - FINAL Financial Feasibility Economic Evaluation Memorandum

Introduction

Raftelis Financial Consultants, Inc. ("Raftelis") has completed an economic evaluation to support the feasibility assessment of the City of Mesa ("City") to collect high strength waste, such as food waste, and fats, oils, and grease ("FOG") and process this waste at the City's Northwest Water Reclamation Plant ("NWWRP") resulting in the production of biogas. The biogas generated by co-digestion in the anerobic digesters could allow the City to take advantage of existing excess digestion capacity, and the biogas generated could be used for onsite power generation or could be treated to pipeline quality for use in the City's Compressed Natural Gas (CNG) solid waste collection trucks.

The seven process scenarios that were evaluated are shown in the following table. The scenario names are the same as the ones mentioned in Arcadis's Anaerobic Digester Capabilities Concept Memorandum dated September 13,2019. HSW stands for household solid waste, DIG stands for digester and CHP stands for combined heat and power. Attachment 3 cross references the scenarios in this memo with the scenarios in Arcadis's Anaerobic Digester Capabilities Concept Memorandum.

Scenario Number	Scenario Name
Scenario 1	‘All Year On/ Shoulder-Peak’ / ‘Enhanced Baseline’ Scenario
Scenario 2	HSW to both DIGs – CHP at 100%
Scenario 3	HSW to both DIGs – Expanded CHP at 100%
Scenario 4	HSW to both DIGs – All D5 RNG
Scenario 5	HSW to 1 DIG – D3 and D5 RNG
Scenario 6	HSW to both DIGs – CHP at 100% + RNG
Scenario 7	No HSW – all D3 RNG + NG Peak CHP

The economic evaluation for each of the scenarios includes the estimation of life-cycle costs associated with the capital improvements, potential savings or cost avoidance, and incremental costs associated with each scenario. In addition, the economic evaluation includes an estimate of the 20-year net present value (“NPV”), payback period (if applicable), equivalent annual annuity. The equivalent annual annuity calculation annualizes the cost or net savings of each scenario. A sensitivity analysis was completed by adjusting several key estimates and assumptions to present a range of potential economic outcomes associated with each scenario. A summary of the economic evaluation results are presented in Attachment 1. Attachment 2a through 2g shows the economics of each scenario and each scenario is described further below.

Scenario 1 – All Year On/Shoulder Peak/Enhanced Baseline Scenario

The 'Enhanced Baseline' Scenario assumes current operations. Therefore, under this scenario, there is no high-strength waste collected and delivered to the NWWRP. This scenario assumes that the City uses biogas to run the City’s existing engine generator system to generate electricity on-site and peak-shave (both peak- and shoulder peak-periods, all year around). The biogas is used as it is generated and supplemented with biogas stored in the existing storage tank to operate the engine at approx. 60% capacity. Natural gas is fed to the engine when biogas in not available (while the storage tank is being filled). It is assumed that the engine has a 90% annual availability.

Under this enhanced baseline scenario, Arcadis estimates that the City will avoid $148,000 in electricity purchase costs in year one – which would increase each year in line with electricity rates. This cost savings is offset by the incremental cost of operating and maintaining the engine generator, estimated at $62,000 per year, and incremental natural gas cost for digester heating and auxiliary fuel use of approximately $65,000 per year.

The 20-year NPV of this scenario (using a discount rate of 6%) is a savings of $293,000, and the equivalent annual annuity savings estimate is approximately $26,000. With no capital investment needed, this scenario has an immediate payback. Attachment 2 provides a summary of the annual life-cycle cost and economic evaluation results associated with this scenario.

Key assumptions and sensitivity analysis:

The economic results of this scenario are based on several key assumptions, including electricity cost avoidance for the CHP engine of $0.0981 per kWh, escalated at 2.5% per year, and a discount rate of 6%. The NPV of Savings using discount rates of 5% and 7%, and varying electricity cost escalations presented in the following table:

Scenario 1 - Net Present Value Savings (Costs) Sensitivity Analysis

	Electricity Cost Escalation	
Discount Rate	1%	2.5%
5%	$55,000	$321,000
6%	$59,000	$293,000
7%	$61,000	$268,000

Scenario 2 – HSW to both DIGs – CHP at 100%

The 'HSW to both DIGs – CHP at 100%' Scenario assumes that the City will inject HSW slurry (organic solid waste from the City and FOG from outside sources) in both digesters. This scenario assumes that City uses biogas to run the City's existing engine generator system to generate electricity on-site and peak-shave (both peak- and shoulder peak-periods, all year around). The biogas is used as it is generated and supplemented with biogas stored in the existing storage tank to operate the existing engine. Natural gas is fed to the engine when biogas in not available (while the storage tank is being filled). It is assumed that the engine has a 90% annual availability.

The anticipated incremental costs are:

Incremental Capital Costs:

Food waste slurry offloading and receiving station	$476,000
Pre-processing facility and equipment	$10,420,000
Total Capital Cost	$10,896,000

Incremental Operating Costs (per year):

Offloading and receiving station	$5,000
Pre-processing facility and equipment	$15,000
Operating and maintaining the CHP engine generator	$71,000
Additional natural gas costs for digester heating and auxiliary fuel use	$29,000
Sludge Cake Hauling Costs from additional organic solid waste received	$34,000
Total Operating Costs	$154,000

The anticipated revenue, cost savings or cost avoidance would include the following:

Revenue or Cost Savings/Avoidance (per year):

Avoidance of purchase electricity costs from peak shaving	$143,000
Avoidance of solid waste tipping fees from diverted waste from the landfill to the NWWRP	$347,000
Revenue generated from FOG delivered from outside sources	$52,000
Total Revenue or Cost Savings/Avoidance	$542,000

The 20-year NPV of this scenario (using a discount rate of 6%) is net **cost** of approximately $5,469,000, and the equivalent annual annuity cost is estimated to be approximately $477,000. Attachment 2 provides a summary of the annual life-cycle cost and economic evaluation results associated with this scenario.

Key assumptions and sensitivity analysis:

The economic results of this scenario are based on several key assumptions, including solid waste tipping fees of $30.31 per ton, escalated at 2.5% per year, and a discount rate of 6%. The NPV of Savings of this scenario using a discount rates of 5% and 7%, and assuming the solid waste tipping fees are reduced to $20 per ton per year or increased to $60 per ton per year are presented in the following table:

Scenario 2 - Net Present Value Savings (Costs) Sensitivity Analysis

	Solid Waste Tipping Fee		
Discount Rate	$20/ton	$30.31/ton	$60/ton
5%	($6,759,000)	($4,955,000)	$241,000
6%	($7,117,000)	($5,469,000)	($723,000)
7%	($7,431,000)	($5,920,000)	($1,568,000)

Scenario 3 - HSW to both DIGs – Expanded CHP at 100%

The 'HSW to both DIGs – Expanded CHP at 100%' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in both digesters. This scenario assumes that City uses biogas to run the City's expanded engine generator system (existing engine and an additional new 800kW engine) to generate electricity on-site and peak-shave (both peak- and shoulder peak-periods, all year around). The biogas is used as it is generated and supplemented with biogas stored in the existing storage tank to operate the engines. Natural gas is fed to the engine when biogas in not available (while the storage tank is being filled). It is assumed that the engines have a 90% annual availability.

The anticipated incremental costs would include the following:

Incremental Capital Costs:

Food waste slurry offloading and receiving station	$476,000
Pre-processing facility and equipment	$10,420,000
Expanded cogeneration	$1,125,000
H2S media scrubber	$200,000
Total Capital Cost	$12,221,000

Incremental Operating Costs (per year):

Offloading and receiving station	$5,000
Pre-processing facility and equipment	$15,000
Co-gen O&M	$124,000
H2S media scrubber	$23,000
Additional natural gas costs for digester heating net of auxiliary fuel use savings	$109,000
Sludge cake hauling costs from additional organic solid waste received	$34,000
Total Operating Costs	$310,000

The anticipated revenue, cost savings or cost avoidance would include the following:

Revenue or Cost Savings/Avoidance (per year):

Avoidance of purchase electricity costs from peak shaving	$400,000
Avoidance of solid waste tipping fees from diverted waste from the landfill to the NWWRP	$347,000
Revenue generated from FOG delivered from outside sources	$52,000
Total Revenue or Cost Savings/Avoidance	$799,000

The 20-year NPV of this scenario (using a discount rate of 6%) is a net cost of $5,362,000, and the equivalent annual annuity cost is estimated to be $467,000. Attachment 2 provides a summary of the annual life-cycle cost and economic evaluation results associated with this scenario.

Key assumptions and sensitivity analysis:

The economic results of this scenario are based on several key assumptions, including solid waste tipping fees of $30.31 per ton, escalated at 2.5% per year, an electricity price of $0.0981 per kWh, escalated at 2.5% per year, and a discount rate of 6%. A sensitivity analysis of the NPV of this scenario considers discount rates of 5% and 7% and assumes the solid waste tipping fees are reduced to $20 per ton per year or increased to $60 per ton per year, and the electricity price escalator is reduced to 1% per year. The results are presented in the following table as a maximum low and high sensitivity range:

Scenario 3 - Net Present Value Savings (Costs) Sensitivity Analysis

Description	Low	Expected	High
NPV	($8,004,000)	($5,362,000)	$483,000
Tipping Fee	$20/ton	$30.31/ton	$60/ton
Electricity Cost Escalator	1%	2.5%	2.5%
Discount Rate	7%	6%	5%

Scenario 4 – HSW to both DIGs – All D5 RNG
The 'HSW to both DIGs – All D5 RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in both digesters. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is added to both digesters, this scenario generates only D5 RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the existing engine generator system is not operated.

The anticipated incremental costs would include the following:

Incremental Capital Costs:	
Food waste slurry offloading and receiving station	$476,000
Pre-processing facility and equipment	$10,420,000
Pressure swing adsorption system	$2,679,000
Thermal oxidizer	$489,000
RNG Transmission Facilities	150,000
Total Capital Cost	$14,214,000
Incremental Operating Costs (per year):	
Offloading and receiving station	$5,000
Pre-processing facility and equipment	$15,000
Pressure swing adsorption system	$30,000
Thermal oxidizer	$15,000
Additional natural gas costs for digester heating net of auxiliary fuel use savings	$31,000
Additional electrical costs (co-gen is non-operational)	$120,000
Sludge cake hauling costs from additional organic solid waste received	$34,000
Total Operating Costs	$250,000

The anticipated revenue, cost savings or cost avoidance would include the following:

Revenue or Cost Savings/Avoidance (per year):	
Avoidance of solid waste tipping fees from diverted waste from the landfill to the NWWRP	$347,000
Revenue generated from FOG delivered from outside sources	$52,000
Fuel offset for CNG	$289,000
Value of D5 RINs generated	$299,000
Total Revenue or Cost Savings/Avoidance	$987,000

The 20-year NPV of this scenario (using a discount rate of 6%) is a net cost of $3,931,000, and the equivalent annual annuity cost is estimated to be $343,000. Attachment 2 provides a summary of the annual life-cycle cost and economic evaluation results associated with this scenario.

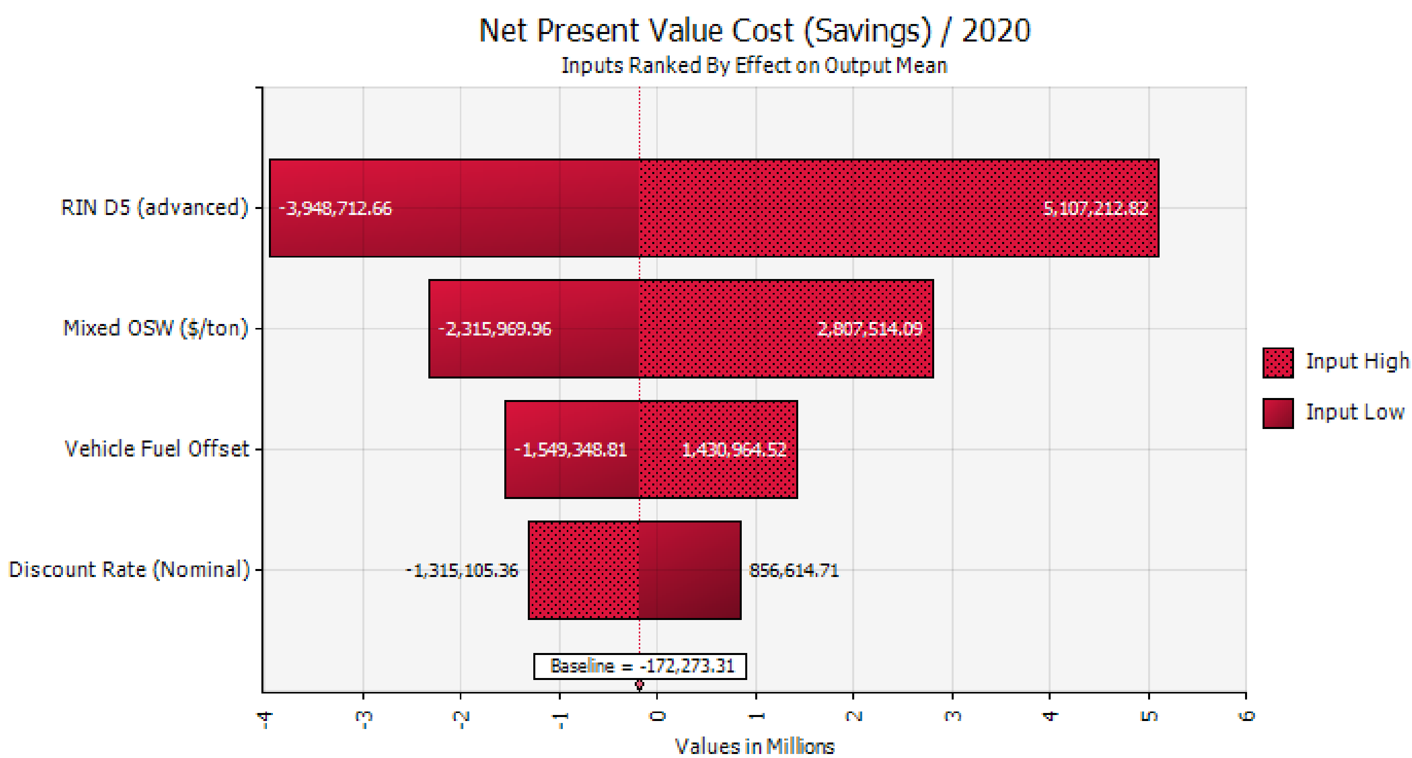
Key assumptions and sensitivity analysis:

The economic results of this scenario are based on several key assumptions, including solid waste tipping fees of $30.31 per ton, escalated at 2.5% per year, a vehicle fuel price of $0.46 per gallon of diesel, a D5 RIN credit price of $0.34 per credit, escalated at 2.5% per year, and a discount rate of 6%. A sensitivity analysis of the NPV of this scenario was prepared using discount rates of 5% and 7%, and assuming the solid waste tipping fees are reduced to $20 per ton per year or increased to $60 per ton per year, and the vehicle fuel offset price decreases to $0.30 per gallon of diesel or increases to $0.75 per gallon of diesel, and the D5 RIN credit price decreases to $0.15 per credit or increases to $1.10 per credit. The results are presented in the following table as a maximum low and high sensitivity range:

Scenario 4 - Net Present Value Savings (Costs) Sensitivity Analysis

Description	Low	Expected	High
NPV	($9,723,000)	($3,931,000)	$15,239,000
Tipping Fee	$20/ton	$30.31/ton	$60/ton
Vehicle Fuel Price	$0.30/gal	$0.46/gal	$0.75/gal
D5 RIN Price	$0.15/credit	$0.34/credit	$1.10/credit
Discount Rate	7%	6%	5%

There is a large swing between the expected NPV and the high NPV, mostly due to the difference between the assumed RINs and tipping fees. To better assess what is driving the change in the NPV for the high scenario, Raftelis prepared a tornado graph shown below. The tornado graph shows the impact on the NPV of each input (tipping fee, D5 RIN price etc.) while holding other inputs constant. The graph shows that the NPV is most sensitive to the assumed D5 RIN price – it shows that when the D5 RIN price varies from $20/ton to $60/ton the NPV varies from -$-4 Million to $+5 Million (the values shown at each end of the red bar). The second most important input is the solid waste tipping fee (Mixed OSW). The table above and the tornado graph below suggests that under expected tipping fees and D5 RINs, Scenario 4 is not favorable, however, should either the D5 RINs increase to greater than $0.66 (while holding other variables constant) and tipping fees increase to more than $55 per ton (while holding other variables constant), Scenario 4 could be reevaluated.



Scenario 5 - HSW to 1 DIG – D3 and D5 RNG

The 'HSW to both DIGs – D3 and D5 RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in one digester. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is added to one digester, this scenario generates both D3 (non-HSW digester) and D5 (w/HSW digester) RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the engine generator system is not operated.

The anticipated incremental costs would include the following:

Incremental Capital Costs:

Food waste slurry offloading and receiving station	$476,000
Pre-processing facility and equipment	$10,420,000
Pressure swing adsorption system	$2,679,000
Thermal oxidizer	$489,000
RNG Transmission Facilities	$150,000
Total Capital Cost	$14,214,000

Incremental Operating Costs (per year):

Offloading and receiving station	$5,000
Pre-processing facility and equipment	$15,000
Pressure swing adsorption system	$30,000
Thermal oxidizer	$15,000
Additional natural gas costs for digester heating and auxiliary fuel use	$29,000
Additional electrical costs (co-gen is non-operational)	$119,000
Additional sludge cake hauling cost	$17,000
Total Operating Costs	$230,000

The anticipated revenue, cost savings or cost avoidance would include the following:

Revenue or Cost Savings/Avoidance (per year):

Avoidance of solid waste tipping fees from diverted waste from the landfill to the NWWRP	$173,000
Revenue generated from FOG delivered from outside sources	$26,000

Fuel offset for CNG	$217,000
Value of D3 RINs generated	$386,000
Value of D5 RINs generated	$153,000
Total Revenue or Cost Savings/Avoidance	$955,000

The 20-year NPV of this scenario (using a discount rate of 6%) is a net cost of $4,074,000, and the equivalent annual annuity cost estimate is $355,000. Attachment 2 provides a summary of the annual life-cycle cost and economic evaluation results associated with this scenario.

Key assumptions and sensitivity analysis:

The economic results of this scenario are based on several key assumptions, including solid waste tipping fees of $30.31 per ton, escalated at 2.5% per year, a vehicle fuel price of $0.46 per gallon of diesel, a D3 RIN credit price of $1.85 per credit and a D5 RIN credit price of $0.34 per credit, both escalated at 2.5% per year, and a discount rate of 6%. A sensitivity analysis of the NPV of this scenario was prepared using discount rates of 5% and 7%, and assuming the solid waste tipping fees are reduced to $20 per ton per year or increased to $60 per ton per year, the vehicle fuel price decreases to $0.30 per gallon of diesel or increases to $0.75 per gallon of diesel, and the D5 RIN credit price decreases to $0.15 per credit or increases to $1.10 per credit. The results are presented in the following table as a maximum low and high sensitivity range. The table below includes a D3 RIN breakeven price for the expected scenario.

Scenario 5 - Net Present Value Savings (Costs) Sensitivity Analysis

Description	Low	Expected	High
NPV	($9,740,000)	($4,074,400)	$10,160,000
Tipping Fee	$20/ton	$30.31/ton	$60/ton
Vehicle Fuel Price	$0.30/gal	$0.46/gal	$0.75/gal
D3 RIN Price	$1.10/credit	$1.85/credit	$2.90/credit
D3 RIN Breakeven Price		$3.25/credit	
D5 RIN Price	$0.15/credit	$0.34/credit	$1.10/credit
Discount Rate	7%	6%	5%

Scenario 6 – HSW to both DIGs – CHP at 100% + RNG

The 'HSW to both DIGs – CHP at 100% + RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in both digesters. This scenario assumes that City sends a small portion to the available biogas to the existing engine generator system to generate electricity on-site and peak-shave ('Max Summer On-Peak' seasonal period). The additional biogas is used in the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is added to both digesters, this scenario generates only D5 RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG).

The anticipated incremental costs would include the following:

Incremental Capital Costs:

Food waste slurry offloading and receiving station	$476,000
Pre-processing facility and equipment	$10,420,000
Pressure swing adsorption system	$2,679,000
Thermal oxidizer	$489,000
RNG Transmission Facilities	$150,000
Total Capital Cost	$14,214,000

Incremental Operating Costs (per year):

Offloading and receiving station	$5,000
Pre-processing facility and equipment	$15,000

CHP O&M	7,000
Pressure swing adsorption system	$30,000
Thermal oxidizer O&M	$15,000
Additional natural gas costs for digester heating and auxiliary fuel use	$31,000
Additional electrical costs from new equipment	$97,000
Additional sludge cake hauling cost	$34,000
Total Operating Costs	$234,000

The anticipated revenue, cost savings or cost avoidance would include the following:

Revenue or Cost Savings/Avoidance (per year):

Avoidance of solid waste tipping fees from diverted waste from the landfill to the NWWRP	$347,000
Revenue generated from FOG delivered from outside sources	$52,000
Fuel offset for CNG	$280,000
Value of D5 RINs generated	$289,000
Total Revenue or Cost Savings/Avoidance	$968,000

The 20-year NPV cost of this scenario (using a discount rate of 6%) is $3,967,000, and the equivalent annuity cost estimate is $346,000. Attachment 2 provides a summary of the annual life-cycle cost and economic evaluation results associated with this scenario.

Key assumptions and sensitivity analysis:

The economic results of this scenario are based on several key assumptions, including solid waste tipping fees of $30.31 per ton, escalated at 2.5% per year, a vehicle fuel price of $0.46 per gallon of diesel, a D5 RIN credit price of $0.34 per credit, escalated at 2.5% per year, and a discount rate of 6%. A sensitivity analysis of the NPV of this scenario was prepared using discount rates of 5% and 7%, and assuming the solid waste tipping fees are reduced to $20 per ton per year or increased to $60 per ton per year, the vehicle fuel price decreases to $0.30 per gallon of diesel or increases to $0.75 per gallon of diesel, and the D5 RIN credit price decreases to $0.15 per credit or increases to $1.10 per credit. The results are presented in the following table as a maximum low and high sensitivity range:

Scenario 6 - Net Present Value Savings (Costs) Sensitivity Analysis

Description	Low	Expected	High
NPV	($9,645,000)	($3,967,000)	$14,775,000
Tipping Fee	$20/ton	$30.31/ton	$60/ton
Vehicle Fuel Price	$0.30/gal	$0.46/gal	$0.75/gal
D5 RIN Price	$0.15/credit	$0.34/credit	$1.10/credit
Discount Rate	7%	6%	5%

Scenario 7 – No HSW – all D3 RNG + NG Peak CHP at 100%

The 'No HSW – all D3 RNG + NG Peak CHP' Scenario assumes that the City will not collect, process, or inject any HSW at NWWRP. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is not added to either digester, this scenario generates only D3 RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the City uses natural gas to run the City's existing engine generator system to generate electricity on-site and peak-shave ('Mild Summer Shoulder-peak' seasonal period). Natural gas is fed to the engine to operate at 100% capacity. It is assumed that the engine has a 90% annual availability.

The anticipated incremental costs would include the following:

Incremental Capital Costs:

Pressure swing adsorption system	$2,679,000
Thermal oxidizer	$489,000
RNG transmission facilities	$150,000
Total Capital Cost	$3,318,000

Incremental Operating Costs (per year):

Co-gen O&M	$43,000
Pressure swing adsorption system	$30,000
Thermal oxidizer	$15,000
Additional natural gas costs for digester heating and auxiliary fuel use	$101,000
Total Operating Costs	$189,000

The anticipated revenue, cost savings or cost avoidance would include the following:

Revenue or Cost Savings/Avoidance (per year):

Avoided electric costs	$24,000
Fuel offset for CNG	$138,000
Value of D3 RINs generated	$772,000
Total Revenue or Cost Savings/Avoidance	$934,000

The 20-year NPV savings of this scenario (using a discount rate of 6%) is $7,084,000, and the equivalent annuity savings estimate is $618,000. The estimated payback period for this scenario is 4.3. Attachment 2 provides a summary of the annual life-cycle cost and economic evaluation results associated with this scenario.

Key assumptions and sensitivity analysis:

The economic results of this scenario are based on several key assumptions, including a D3 RIN credit price of $1.85 per credit, escalated at 2.5% per year, and a discount rate of 6%. A sensitivity analysis of the NPV of this scenario was prepared using discount rates of 5% and 7%, and assuming the D3 RIN credit price decreases to $1.10 per credit or increases to $2.90 per credit. The results are presented in the following table as a maximum low and high sensitivity range:

Scenario 7 - Net Present Value Savings (Costs) Sensitivity Analysis

	D3 RIN Price		
Discount Rate	$1.10/credit	$1.85/credit	$2.90/credit
5%	$3,281,000	$8,069,000	$14,773,000
6%	$2,710,000	$7,084,000	$13,207,000
7%	$2,209,000	$6,220,000	$11,834,000

Conclusions

The results of the economic evaluation indicate that two scenarios are expected to have a net present value savings:

- Scenario #1 – ‘All Year On/ Shoulder-Peak’ / ‘Enhanced Baseline’ Scenario
- Scenario #7 – No HSW – all D3 RNG + NG Peak CHP

Scenario 1 requires no capital investment and results in the lower NPV of savings of the two scenarios. Scenario 7 requires some capital investment and has an expected payback period of approximately 4.3 years but does not achieve the City’s goal of utilizing food waste.

The sensitivity analysis demonstrates that the results of the economic evaluation are highly sensitive to several key variables, including the assumed solid waste tipping fee, the vehicle fuel price, and the D5 RIN credit price. The tornado graph in Scenario 4 shows which variables are most sensitive for that scenario. Given the potential range of possible input values associated with these variables, there is the potential for the NPV of some of the scenarios to be either a net cost or net savings. Scenario 7 produces the highest projected NPV savings under the most favorable sensitivity assumptions, and Scenario 5 produces the highest projected NPV cost under the least favorable sensitivity assumptions, as shown in Attachment 1.

It is worth noting that the economic evaluation was based on the projection of direct costs and cost savings/avoidance associated with each scenario but did not consider or quantify other potential externalities associated with each scenario (e.g. environmental benefits or costs, indirect or induced economic impacts of job creation, favorable public perception / publicity, etc.). As such, the City may find other non-financial benefits to moving forward with one or more of the scenarios even if economic savings are not projected for that scenario.

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Attachment #1: Economic Evaluation Results Summary

	Scenario						
	#1	#2	#3	#4	#5	#6	#7
NPV – Low	$55,000	($7,431,000	($8,004,000	($9,723,000)	($9,740,000)	($9,645,000)	$2,209,000
NPV – Expected	$293,000	($5,469,000)	($5,362,000)	($3,931,000)	($4,074,000)	($3,967,000)	$7,084,000
NPV - High	$321,000	$241,000	$483,000	$15,239,000	$10,160,000	$14,775,000	$14,773,000
Expected Payback Period (years)	0.0	N/A	N/A	N/A	N/A	N/A	4.3
Expected Equivalent Annual Annuity	$26,000	($1,166,400)	($1,390,000)	($343,000)	($355,000)	($346,000)	$618,000
Break-even D5 RIN Price	N/A	N/A	N/A	$0.66	$0.99	$0.67	N/A

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Attachment 2a: Scenario #1 Economic Time Series

Line	Description	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1	Revenues / Benefits																					
2	CGN Fuel Offset	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
3	D3 RINs Generated	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4	D5 RINs Generated	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
5	Tipping Fees Avoided	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
6	FOG Tipping Fee Revenue	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
7																						
8	Operating Expenses																					
9	Media Changeout	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
10	System Backflush	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
12	Chemicals and Water	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	-	$ (62,000)	$ (63,550)	$ (65,139)	$ (66,767)	$ (68,436)	$ (70,147)	$ (71,901)	$ (73,699)	$ (75,541)	$ (77,430)	$ (79,365)	$ (81,349)	$ (83,383)	$ (85,468)	$ (87,604)	$ (89,794)	$ (92,039)	$ (94,340)	$ (96,699)	$ (99,116)
14	Electric Cost	-	$ 147,893	$ 151,591	$ 155,381	$ 159,265	$ 163,247	$ 167,328	$ 171,511	$ 175,799	$ 180,194	$ 184,699	$ 189,316	$ 194,049	$ 198,900	$ 203,873	$ 208,970	$ 214,194	$ 219,549	$ 225,037	$ 230,663	$ 236,430
15	Natual Gas Cost	-	$ (64,938)	$ (66,561)	$ (68,225)	$ (69,931)	$ (71,679)	$ (73,471)	$ (75,308)	$ (77,191)	$ (79,120)	$ (81,098)	$ (83,126)	$ (85,204)	$ (87,334)	$ (89,517)	$ (91,755)	$ (94,049)	$ (96,400)	$ (98,810)	$ (101,281)	$ (103,813)
16	Sludge Cake Hauling Cost	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
17																						
18	Capital Investment	-																				
19																						
20	Total Savings (Cost)	$ -	$ 20,956	$ 21,480	$ 22,017	$ 22,567	$ 23,131	$ 23,709	$ 24,302	$ 24,910	$ 25,533	$ 26,171	$ 26,825	$ 27,496	$ 28,183	$ 28,888	$ 29,610	$ 30,350	$ 31,109	$ 31,887	$ 32,684	$ 33,501
21	Cumulative Savings (Cost)	$ -	$ 20,956	$ 42,435	$ 64,452	$ 87,019	$ 110,150	$ 133,860	$ 158,162	$ 183,072	$ 208,604	$ 234,775	$ 261,600	$ 289,096	$ 317,279	$ 346,166	$ 375,776	$ 406,126	$ 437,235	$ 469,122	$ 501,806	$ 535,307
22	Partial Year		0.0	1.0	1.9	2.9	3.8	4.6	5.5	6.3	7.2	8.0	8.8	9.5	10.3	11.0	11.7	12.4	13.1	13.7	14.4	15.0
23																						
24	**Net Present Value Savings (Cost)**	$ 292,824																				
25	**Payback Period**	0.0	Years																			
26	**Equivalent Annual Annuity**	$25,530																				

Attachment 2b: Scenario #2 Economic Time Series

		0	1	2	3	4	5	6	7	8	9	10
Line	Description	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1	Revenues / Benefits											
2	CGN Fuel Offset	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
3	D3 RINs Generated	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4	D5 RINs Generated	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
5	Tipping Fees Avoided	-	$ 346,746	$ 355,415	$ 364,300	$ 373,408	$ 382,743	$ 392,312	$ 402,120	$ 412,173	$ 422,477	$ 433,039
6	FOG Tipping Fee Revenue	-	$ 52,000	$ 53,300	$ 54,633	$ 55,998	$ 57,398	$ 58,833	$ 60,304	$ 61,812	$ 63,357	$ 64,941
7												
8	Operating Expenses											
9	Media Changeout	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
10	System Backflush	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	-	$ (20,000)	$ (20,500)	$ (21,013)	$ (21,538)	$ (22,076)	$ (22,628)	$ (23,194)	$ (23,774)	$ (24,368)	$ (24,977)
12	Chemicals and Water	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	-	$ (71,000)	$ (72,775)	$ (74,594)	$ (76,459)	$ (78,371)	$ (80,330)	$ (82,338)	$ (84,397)	$ (86,507)	$ (88,669)
14	Electric Savings (Cost)	-	$ 143,171	$ 146,750	$ 150,419	$ 154,180	$ 158,034	$ 161,985	$ 166,035	$ 170,185	$ 174,440	$ 178,801
15	Natual Gas Cost (Savings)	-	$ (28,535)	$ (29,248)	$ (29,979)	$ (30,729)	$ (31,497)	$ (32,285)	$ (33,092)	$ (33,919)	$ (34,767)	$ (35,636)
16	Sludge Cake Hauling Cost (Savings)	-	$ (34,000)	$ (34,850)	$ (35,721)	$ (36,614)	$ (37,530)	$ (38,468)	$ (39,430)	$ (40,415)	$ (41,426)	$ (42,461)
17	Capital Investment	(10,895,800)										
18												
19	Total Savings (Cost)	$(10,895,800)	$ 388,383	$ 398,092	$ 408,044	$ 418,246	$ 428,702	$ 439,419	$ 450,405	$ 461,665	$ 473,207	$ 485,037
20	Cumulative Savings (Cost)	$(10,895,800)	$(10,507,417)	$(10,109,325)	$(9,701,281)	$(9,283,035)	$(8,854,333)	$(8,414,914)	$(7,964,509)	$(7,502,844)	$(7,029,638)	$(6,544,601)
21	Partial Year		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22												
23	**Net Present Value Savings (Cost)**	$ (5,468,745)										
24	**Payback Period**	NA	Years									
25	**Equivalent Annual Annuity**	($476,790)										

		11	12	13	14	15	16	17	18	19	20
Line	Description	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1	Revenues / Benefits										
2	CGN Fuel Offset	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
3	D3 RINs Generated	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4	D5 RINs Generated	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
5	Tipping Fees Avoided	$ 443,865	$ 454,961	$ 466,335	$ 477,994	$ 489,944	$ 502,192	$ 514,747	$ 527,616	$ 540,806	$ 554,326
6	FOG Tipping Fee Revenue	$ 66,564	$ 68,229	$ 69,934	$ 71,683	$ 73,475	$ 75,312	$ 77,194	$ 79,124	$ 81,102	$ 83,130
7											
8	Operating Expenses										
9	Media Changeout	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
10	System Backflush	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	$ (25,602)	$ (26,242)	$ (26,898)	$ (27,570)	$ (28,259)	$ (28,966)	$ (29,690)	$ (30,432)	$ (31,193)	$ (31,973)
12	Chemicals and Water	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	$ (90,886)	$ (93,158)	$ (95,487)	$ (97,874)	$ (100,321)	$ (102,829)	$ (105,400)	$ (108,035)	$ (110,736)	$ (113,504)
14	Electric Savings (Cost)	$ 183,271	$ 187,853	$ 192,549	$ 197,363	$ 202,297	$ 207,354	$ 212,538	$ 217,852	$ 223,298	$ 228,880
15	Natual Gas Cost (Savings)	$ (36,527)	$ (37,440)	$ (38,376)	$ (39,336)	$ (40,319)	$ (41,327)	$ (42,360)	$ (43,419)	$ (44,505)	$ (45,617)
16	Sludge Cake Hauling Cost (Savings)	$ (43,523)	$ (44,611)	$ (45,726)	$ (46,869)	$ (48,041)	$ (49,242)	$ (50,473)	$ (51,735)	$ (53,028)	$ (54,354)
17	Capital Investment										
18											
19	Total Savings (Cost)	$ 497,163	$ 509,592	$ 522,331	$ 535,390	$ 548,774	$ 562,494	$ 576,556	$ 590,970	$ 605,744	$ 620,888
20	Cumulative Savings (Cost)	$(6,047,439)	$(5,537,847)	$(5,015,515)	$(4,480,126)	$(3,931,351)	$(3,368,857)	$(2,792,301)	$(2,201,331)	$(1,595,587)	$ (974,699)
21	Partial Year	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22											
23	**Net Present Value Savings (Cost)**										
24	**Payback Period**										
25	**Equivalent Annual Annuity**										

Attachment 2c: Scenario #3 Economic Time Series

Line	Description	0 2020	1 2021	2 2022	3 2023	4 2024	5 2025	6 2026	7 2027	8 2028	9 2029	10 2030	11 2031	12 2032	13 2033	14 2034	15 2035	16 2036	17 2037	18 2038	19 2039	20 2040
1	Revenues / Benefits																					
2	CGN Fuel Offset	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
3	D3 RINs Generated	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4	D5 RINs Generated	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
5	Tipping Fees Avoided	-	$ 346,746	$ 355,415	$ 364,300	$ 373,408	$ 382,743	$ 392,312	$ 402,120	$ 412,173	$ 422,477	$ 433,039	$ 443,865	$ 454,961	$ 466,335	$ 477,994	$ 489,944	$ 502,192	$ 514,747	$ 527,616	$ 540,806	$ 554,326
6	FOG Tipping Fee Revenue	-	$ 52,000	$ 53,300	$ 54,633	$ 55,998	$ 57,398	$ 58,833	$ 60,304	$ 61,812	$ 63,357	$ 64,941	$ 66,564	$ 68,229	$ 69,934	$ 71,683	$ 73,475	$ 75,312	$ 77,194	$ 79,124	$ 81,102	$ 83,130
7																						
8	Operating Expenses																					
9	Media Changeout	-	$ (15,000)	$ (15,375)	$ (15,759)	$ (16,153)	$ (16,557)	$ (16,971)	$ (17,395)	$ (17,830)	$ (18,276)	$ (18,733)	$ (19,201)	$ (19,681)	$ (20,173)	$ (20,678)	$ (21,195)	$ (21,724)	$ (22,268)	$ (22,824)	$ (23,395)	$ (23,980)
10	System Backflush	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	-	$ (20,000)	$ (20,500)	$ (21,013)	$ (21,538)	$ (22,076)	$ (22,628)	$ (23,194)	$ (23,774)	$ (24,368)	$ (24,977)	$ (25,602)	$ (26,242)	$ (26,898)	$ (27,570)	$ (28,259)	$ (28,966)	$ (29,690)	$ (30,432)	$ (31,193)	$ (31,973)
12	Chemicals and Water	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	-	$ (131,500)	$ (134,788)	$ (138,157)	$ (141,611)	$ (145,151)	$ (148,780)	$ (152,500)	$ (156,312)	$ (160,220)	$ (164,225)	$ (168,331)	$ (172,539)	$ (176,853)	$ (181,274)	$ (185,806)	$ (190,451)	$ (195,212)	$ (200,093)	$ (205,095)	$ (210,222)
14	Electric Savings (Cost)	-	$ 400,357	$ 410,365	$ 420,625	$ 431,140	$ 441,919	$ 452,967	$ 464,291	$ 475,898	$ 487,796	$ 499,990	$ 512,490	$ 525,303	$ 538,435	$ 551,896	$ 565,693	$ 579,836	$ 594,332	$ 609,190	$ 624,420	$ 640,030
15	Natual Gas Cost (Savings)	-	$ (109,247)	$ (110,339)	$ (113,098)	$ (115,925)	$ (118,823)	$ (121,794)	$ (124,839)	$ (127,960)	$ (131,159)	$ (134,438)	$ (137,799)	$ (141,244)	$ (144,775)	$ (148,394)	$ (152,104)	$ (155,906)	$ (159,804)	$ (163,799)	$ (167,894)	$ (172,091)
16	Sludge Cake Hauling Cost (Savings)	-	$ (34,000)	$ (34,850)	$ (35,721)	$ (36,614)	$ (37,530)	$ (38,468)	$ (39,430)	$ (40,415)	$ (41,426)	$ (42,461)	$ (43,523)	$ (44,611)	$ (45,726)	$ (46,869)	$ (48,041)	$ (49,242)	$ (50,473)	$ (51,735)	$ (53,028)	$ (54,354)
17																						
18	Capital Investment	(12,220,800)																				
19																						
20	Total Savings (Cost)	$ (12,220,800)	$ 489,356	$ 503,229	$ 515,810	$ 528,705	$ 541,922	$ 555,470	$ 569,357	$ 583,591	$ 598,181	$ 613,135	$ 628,464	$ 644,175	$ 660,280	$ 676,787	$ 693,707	$ 711,049	$ 728,825	$ 747,046	$ 765,722	$ 784,865
21	Cumulative Savings (Cost)	$ (12,220,800)	$ (11,731,444)	$ (11,228,215)	$ (10,712,405)	$ (10,183,701)	$ (9,641,778)	$ (9,086,308)	$ (8,516,950)	$ (7,933,359)	$ (7,335,178)	$ (6,722,043)	$ (6,093,579)	$ (5,449,404)	$ (4,789,124)	$ (4,112,337)	$ (3,418,630)	$ (2,707,581)	$ (1,978,756)	$ (1,231,710)	$ (465,988)	$ 318,878
22	Partial Year		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.6
23																						
24	**Net Present Value Savings (Cost)**	$ (5,361,961)																				
25	**Payback Period**	19.6 Years																				
26	**Equivalent Annual Annuity**	($467,480)																				

Attachment 2d: Scenario #4 Economic Time Series

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Line	Description	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1	Revenues / Benefits																					
2	CGN Fuel Offset	$ -	$ 288,880	$ 296,102	$ 303,505	$ 311,092	$ 318,869	$ 326,841	$ 335,012	$ 343,388	$ 351,972	$ 360,772	$ 369,791	$ 379,036	$ 388,511	$ 398,224	$ 408,180	$ 418,384	$ 428,844	$ 439,565	$ 450,554	$ 461,818
3	D3 RINs Generated	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4	D5 RINs Generated	-	$ 298,737	$ 306,206	$ 313,861	$ 321,707	$ 329,750	$ 337,994	$ 346,444	$ 355,105	$ 363,982	$ 373,082	$ 382,409	$ 391,969	$ 401,768	$ 411,813	$ 422,108	$ 432,661	$ 443,477	$ 454,564	$ 465,928	$ 477,576
5	Tipping Fees Avoided	-	$ 346,746	$ 355,415	$ 364,300	$ 373,408	$ 382,743	$ 392,312	$ 402,120	$ 412,173	$ 422,477	$ 433,039	$ 443,865	$ 454,961	$ 466,335	$ 477,994	$ 489,944	$ 502,192	$ 514,747	$ 527,616	$ 540,806	$ 554,326
6	FOG Tipping Fee Revenue	-	$ 52,000	$ 53,300	$ 54,633	$ 55,998	$ 57,398	$ 58,833	$ 60,304	$ 61,812	$ 63,357	$ 64,941	$ 66,564	$ 68,229	$ 69,934	$ 71,683	$ 73,475	$ 75,312	$ 77,194	$ 79,124	$ 81,102	$ 83,130
7																						
8	Operating Expenses																					
9	Media Changeout	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
10	System Backflush	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	-	$ (50,000)	$ (51,250)	$ (52,531)	$ (53,845)	$ (55,191)	$ (56,570)	$ (57,985)	$ (59,434)	$ (60,920)	$ (62,443)	$ (64,004)	$ (65,604)	$ (67,244)	$ (68,926)	$ (70,649)	$ (72,415)	$ (74,225)	$ (76,081)	$ (77,983)	$ (79,933)
12	Chemicals and Water	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	-	$ (15,000)	$ (15,375)	$ (15,759)	$ (16,153)	$ (16,557)	$ (16,971)	$ (17,395)	$ (17,830)	$ (18,276)	$ (18,733)	$ (19,201)	$ (19,681)	$ (20,173)	$ (20,678)	$ (21,195)	$ (21,724)	$ (22,268)	$ (22,824)	$ (23,395)	$ (23,980)
14	Electric Savings (Cost)	-	$ (120,287)	$ (123,294)	$ (126,377)	$ (129,536)	$ (132,774)	$ (136,094)	$ (139,496)	$ (142,984)	$ (146,558)	$ (150,222)	$ (153,978)	$ (157,827)	$ (161,773)	$ (165,817)	$ (169,963)	$ (174,212)	$ (178,567)	$ (183,031)	$ (187,607)	$ (192,297)
15	Natual Gas Cost (Savings)	-	$ (31,205)	$ (31,986)	$ (32,785)	$ (33,605)	$ (34,445)	$ (35,306)	$ (36,189)	$ (37,093)	$ (38,021)	$ (38,971)	$ (39,946)	$ (40,944)	$ (41,968)	$ (43,017)	$ (44,092)	$ (45,195)	$ (46,325)	$ (47,483)	$ (48,670)	$ (49,887)
16	Sludge Cake Hauling Cost (Savings)	-	$ (34,000)	$ (34,850)	$ (35,721)	$ (36,614)	$ (37,530)	$ (38,468)	$ (39,430)	$ (40,415)	$ (41,426)	$ (42,461)	$ (43,523)	$ (44,611)	$ (45,726)	$ (46,869)	$ (48,041)	$ (49,242)	$ (50,473)	$ (51,735)	$ (53,028)	$ (54,354)
17																						
18	Capital Investment	(14,213,800)																				
19																						
20	Total Savings (Cost)	$ (14,213,800)	$ 735,871	$ 754,268	$ 773,125	$ 792,453	$ 812,264	$ 832,571	$ 853,385	$ 874,720	$ 896,588	$ 919,002	$ 941,977	$ 965,527	$ 989,665	$ 1,014,407	$ 1,039,767	$ 1,065,761	$ 1,092,405	$ 1,119,715	$ 1,147,708	$ 1,176,401
21	Cumulative Savings (Cost)	$ (14,213,800)	$ (13,477,929)	$ (12,723,661)	$ (11,950,536)	$ (11,158,084)	$ (10,345,819)	$ (9,513,249)	$ (8,659,864)	$ (7,785,144)	$ (6,888,557)	$ (5,969,554)	$ (5,027,577)	$ (4,062,050)	$ (3,072,386)	$ (2,057,979)	$ (1,018,212)	$ 47,548	$ 1,139,953	$ 2,259,668	$ 3,407,376	$ 4,583,777
22	Partial Year		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0	0.0	1.0	2.0	2.9
23																						
24	**Net Present Value Savings (Cost)**	$ (3,931,122)																				
25	**Payback Period**	16.0 Years																				
26	**Equivalent Annual Annuity**	($342,733)																				

Attachment 2e: Scenario #5 Economic Time Series

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Line	Description	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1	Revenues / Benefits																					
2	CGN Fuel Offset	$ -	$ 216,660	$ 222,077	$ 227,628	$ 233,319	$ 239,152	$ 245,131	$ 251,259	$ 257,541	$ 263,979	$ 270,579	$ 277,343	$ 284,277	$ 291,384	$ 298,668	$ 306,135	$ 313,788	$ 321,633	$ 329,674	$ 337,916	$ 346,364
3	D3 RINs Generated	-	$ 386,054	$ 395,705	$ 405,598	$ 415,738	$ 426,131	$ 436,785	$ 447,704	$ 458,897	$ 470,369	$ 482,129	$ 494,182	$ 506,536	$ 519,200	$ 532,180	$ 545,484	$ 559,121	$ 573,099	$ 587,427	$ 602,113	$ 617,165
4	D5 RINs Generated	-	$ 153,104	$ 156,932	$ 160,855	$ 164,876	$ 168,998	$ 173,223	$ 177,554	$ 181,993	$ 186,542	$ 191,206	$ 195,986	$ 200,886	$ 205,908	$ 211,056	$ 216,332	$ 221,740	$ 227,284	$ 232,966	$ 238,790	$ 244,760
5	Tipping Fees Avoided	-	$ 173,373	$ 177,708	$ 182,150	$ 186,704	$ 191,372	$ 196,156	$ 201,060	$ 206,086	$ 211,238	$ 216,519	$ 221,932	$ 227,481	$ 233,168	$ 238,997	$ 244,972	$ 251,096	$ 257,373	$ 263,808	$ 270,403	$ 277,163
6	FOG Tipping Fee Revenue	-	$ 26,000	$ 26,650	$ 27,316	$ 27,999	$ 28,699	$ 29,417	$ 30,152	$ 30,906	$ 31,678	$ 32,470	$ 33,282	$ 34,114	$ 34,967	$ 35,841	$ 36,737	$ 37,656	$ 38,597	$ 39,562	$ 40,551	$ 41,565
7																						
8	Operating Expenses																					
9	Media Changeout	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
10	System Backflush	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	-	$ (50,000)	$ (51,250)	$ (52,531)	$ (53,845)	$ (55,191)	$ (56,570)	$ (57,985)	$ (59,434)	$ (60,920)	$ (62,443)	$ (64,004)	$ (65,604)	$ (67,244)	$ (68,926)	$ (70,649)	$ (72,415)	$ (74,225)	$ (76,081)	$ (77,983)	$ (79,933)
12	Chemicals and Water	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	-	$ (15,000)	$ (15,375)	$ (15,759)	$ (16,153)	$ (16,557)	$ (16,971)	$ (17,395)	$ (17,830)	$ (18,276)	$ (18,733)	$ (19,201)	$ (19,681)	$ (20,173)	$ (20,678)	$ (21,195)	$ (21,724)	$ (22,268)	$ (22,824)	$ (23,395)	$ (23,980)
14	Electric Savings (Cost)	-	$ (118,844)	$ (121,815)	$ (124,860)	$ (127,982)	$ (131,181)	$ (134,461)	$ (137,822)	$ (141,268)	$ (144,799)	$ (148,419)	$ (152,130)	$ (155,933)	$ (159,831)	$ (163,827)	$ (167,923)	$ (172,121)	$ (176,424)	$ (180,835)	$ (185,355)	$ (189,989)
15	Natual Gas Cost (Savings)	-	$ (28,737)	$ (29,455)	$ (30,192)	$ (30,946)	$ (31,720)	$ (32,513)	$ (33,326)	$ (34,159)	$ (35,013)	$ (35,888)	$ (36,785)	$ (37,705)	$ (38,648)	$ (39,614)	$ (40,604)	$ (41,619)	$ (42,660)	$ (43,726)	$ (44,819)	$ (45,940)
16	Sludge Cake Hauling Cost (Savings)	-	$ (17,000)	$ (17,425)	$ (17,861)	$ (18,307)	$ (18,765)	$ (19,234)	$ (19,715)	$ (20,208)	$ (20,713)	$ (21,231)	$ (21,761)	$ (22,305)	$ (22,863)	$ (23,435)	$ (24,021)	$ (24,621)	$ (25,237)	$ (25,868)	$ (26,514)	$ (27,177)
17																						
18	Capital Investment	(14,213,800)																				
19																						
20	Total Savings (Cost)	$ (14,213,800)	$ 725,611	$ 743,751	$ 762,345	$ 781,404	$ 800,939	$ 820,962	$ 841,486	$ 862,523	$ 884,086	$ 906,189	$ 928,843	$ 952,064	$ 975,866	$ 1,000,263	$ 1,025,269	$ 1,050,901	$ 1,077,173	$ 1,104,103	$ 1,131,705	$ 1,159,998
21	Cumulative Savings (Cost)	$ (14,213,800)	$ (13,488,189)	$ (12,744,438)	$ (11,982,093)	$ (11,200,689)	$ (10,399,751)	$ (9,578,789)	$ (8,737,302)	$ (7,874,779)	$ (6,990,693)	$ (6,084,504)	$ (5,155,661)	$ (4,203,596)	$ (3,227,730)	$ (2,227,468)	$ (1,202,199)	$ (151,298)	$ 925,876	$ 2,029,979	$ 3,161,684	$ 4,321,682
22	Partial Year		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1	0.8	1.8	2.7
23																						
24	**Net Present Value Savings (Cost)**	$ (4,074,494)																				
25	**Payback Period**	16.1	Years																			
26	**Equivalent Annual Annuity**	($355,233)																				

Attachment 2f: Scenario #6 Economic Time Series

		0	1	2	3	4	5	6	7	8	9	10
Line	Description	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1	Revenues / Benefits											
2	CGN Fuel Offset	$ -	$ 279,680	$ 286,672	$ 293,839	$ 301,185	$ 308,714	$ 316,432	$ 324,343	$ 332,452	$ 340,763	$ 349,282
3	D3 RINs Generated	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4	D5 RINs Generated	-	$ 288,919	$ 296,142	$ 303,545	$ 311,134	$ 318,912	$ 326,885	$ 335,057	$ 343,433	$ 352,019	$ 360,820
5	Tipping Fees Avoided	-	$ 346,746	$ 355,415	$ 364,300	$ 373,408	$ 382,743	$ 392,312	$ 402,120	$ 412,173	$ 422,477	$ 433,039
6	FOG Tipping Fee Revenue	-	$ 52,000	$ 53,300	$ 54,633	$ 55,998	$ 57,398	$ 58,833	$ 60,304	$ 61,812	$ 63,357	$ 64,941
7												
8	Operating Expenses											
9	Media Changeout	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
10	System Backflush	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	-	$ (50,000)	$ (51,250)	$ (52,531)	$ (53,845)	$ (55,191)	$ (56,570)	$ (57,985)	$ (59,434)	$ (60,920)	$ (62,443)
12	Chemicals and Water	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	-	$ (22,000)	$ (22,550)	$ (23,114)	$ (23,692)	$ (24,284)	$ (24,891)	$ (25,513)	$ (26,151)	$ (26,805)	$ (27,475)
14	Electric Savings (Cost)	-	$ (97,053)	$ (99,479)	$ (101,966)	$ (104,515)	$ (107,128)	$ (109,806)	$ (112,551)	$ (115,365)	$ (118,249)	$ (121,205)
15	Natual Gas Savings (Cost)	-	$ (31,019)	$ (31,794)	$ (32,589)	$ (33,404)	$ (34,239)	$ (35,095)	$ (35,972)	$ (36,872)	$ (37,794)	$ (38,738)
16	Sludge Cake Hauling Savings (Cost)	-	$ (34,000)	$ (34,850)	$ (35,721)	$ (36,614)	$ (37,530)	$ (38,468)	$ (39,430)	$ (40,415)	$ (41,426)	$ (42,461)
17												
18	Capital Investment	(14,213,800)										
19												
20	Total Savings (Cost)	$ (14,213,800)	$ 733,274	$ 751,605	$ 770,396	$ 789,655	$ 809,397	$ 829,632	$ 850,373	$ 871,632	$ 893,423	$ 915,758
21	Cumulative Savings (Cost)	$ (14,213,800)	$ (13,480,526)	$ (12,728,921)	$ (11,958,526)	$ (11,168,870)	$ (10,359,473)	$ (9,529,842)	$ (8,679,469)	$ (7,807,837)	$ (6,914,415)	$ (5,998,656)
22	Partial Year		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23												
24	**Net Present Value Savings (Cost)**	$ (3,967,420)										
25	**Payback Period**	16.0	Years									
26	**Equivalent Annual Annuity**	($345,898)										

		11	12	13	14	15	16	17	18	19	20
Line	Description	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1	Revenues / Benefits										
2	CGN Fuel Offset	$ 358,014	$ 366,964	$ 376,139	$ 385,542	$ 395,181	$ 405,060	$ 415,187	$ 425,566	$ 436,205	$ 447,110
3	D3 RINs Generated	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4	D5 RINs Generated	$ 369,840	$ 379,086	$ 388,563	$ 398,278	$ 408,234	$ 418,440	$ 428,901	$ 439,624	$ 450,614	$ 461,880
5	Tipping Fees Avoided	$ 443,865	$ 454,961	$ 466,335	$ 477,994	$ 489,944	$ 502,192	$ 514,747	$ 527,616	$ 540,806	$ 554,326
6	FOG Tipping Fee Revenue	$ 66,564	$ 68,229	$ 69,934	$ 71,683	$ 73,475	$ 75,312	$ 77,194	$ 79,124	$ 81,102	$ 83,130
7											
8	Operating Expenses										
9	Media Changeout	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
10	System Backflush	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	$ (64,004)	$ (65,604)	$ (67,244)	$ (68,926)	$ (70,649)	$ (72,415)	$ (74,225)	$ (76,081)	$ (77,983)	$ (79,933)
12	Chemicals and Water	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	$ (28,162)	$ (28,866)	$ (29,588)	$ (30,327)	$ (31,085)	$ (31,863)	$ (32,659)	$ (33,476)	$ (34,312)	$ (35,170)
14	Electric Savings (Cost)	$ (124,235)	$ (127,341)	$ (130,525)	$ (133,788)	$ (137,133)	$ (140,561)	$ (144,075)	$ (147,677)	$ (151,369)	$ (155,153)
15	Natual Gas Savings (Cost)	$ (39,707)	$ (40,700)	$ (41,717)	$ (42,760)	$ (43,829)	$ (44,925)	$ (46,048)	$ (47,199)	$ (48,379)	$ (49,588)
16	Sludge Cake Hauling Savings (Cost)	$ (43,523)	$ (44,611)	$ (45,726)	$ (46,869)	$ (48,041)	$ (49,242)	$ (50,473)	$ (51,735)	$ (53,028)	$ (54,354)
17											
18	Capital Investment										
19											
20	Total Savings (Cost)	$ 938,652	$ 962,118	$ 986,171	$ 1,010,826	$ 1,036,096	$ 1,061,999	$ 1,088,549	$ 1,115,762	$ 1,143,656	$ 1,172,248
21	Cumulative Savings (Cost)	$ (5,060,004)	$ (4,097,886)	$ (3,111,714)	$ (2,100,889)	$ (1,064,792)	$ (2,794)	$ 1,085,755	$ 2,201,518	$ 3,345,174	$ 4,517,422
22	Partial Year	NA	NA	NA	NA	NA	NA	0.0	1.0	1.9	2.9
23											
24	**Net Present Value Savings (Cost)**										
25	**Payback Period**										
26	**Equivalent Annual Annuity**										

Attachment 2g: Scenario #7 Economic Time Series

Line	Description	0 2020	1 2021	2 2022	3 2023	4 2024	5 2025	6 2026	7 2027	8 2028	9 2029	10 2030
1	Revenues / Benefits											
2	CGN Fuel Offset	$ -	$ 137,540	$ 140,979	$ 144,503	$ 148,116	$ 151,818	$ 155,614	$ 159,504	$ 163,492	$ 167,579	$ 171,769
3	D3 RINs Generated	-	$ 772,108	$ 791,411	$ 811,196	$ 831,476	$ 852,263	$ 873,569	$ 895,409	$ 917,794	$ 940,739	$ 964,257
4	D5 RINs Generated	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
5	Tipping Fees Avoided	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
6	FOG Tipping Fee Revenue	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
7												
8	Operating Expenses											
9	Media Changeout	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
10	System Backflush	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	-	$ (30,000)	$ (30,750)	$ (31,519)	$ (32,307)	$ (33,114)	$ (33,942)	$ (34,791)	$ (35,661)	$ (36,552)	$ (37,466)
12	Chemicals and Water	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	-	$ (58,000)	$ (59,450)	$ (60,936)	$ (62,460)	$ (64,021)	$ (65,622)	$ (67,262)	$ (68,944)	$ (70,667)	$ (72,434)
14	Electric Savings (Cost)	-	$ 23,730	$ 24,323	$ 24,932	$ 25,555	$ 26,194	$ 26,849	$ 27,520	$ 28,208	$ 28,913	$ 29,636
15	Natual Gas Savings (Cost)	-	$ (100,972)	$ (103,496)	$ (106,084)	$ (108,736)	$ (111,454)	$ (114,240)	$ (117,096)	$ (120,024)	$ (123,024)	$ (126,100)
16	Sludge Cake Hauling Savings (Cost)	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
17												
18	Capital Investment	(3,318,000)										
19												
20	Total Savings (Cost)	$ (3,318,000)	$ 744,406	$ 763,017	$ 782,092	$ 801,644	$ 821,685	$ 842,228	$ 863,283	$ 884,865	$ 906,987	$ 929,662
21	Cumulative Savings (Cost)	$ (3,318,000)	$ (2,573,594)	$ (1,810,577)	$ (1,028,485)	$ (226,841)	$ 594,845	$ 1,437,073	$ 2,300,356	$ 3,185,221	$ 4,092,208	$ 5,021,870
22	Partial Year		NA	NA	NA	NA	0.3	0.7	1.7	2.6	3.5	4.4
23												
24	**Net Present Value Savings (Cost)**	$ 7,083,946										
25	**Payback Period**	4.3	Years									
26	**Equivalent Annual Annuity**	$617,611										

Line	Description	11 2031	12 2032	13 2033	14 2034	15 2035	16 2036	17 2037	18 2038	19 2039	20 2040
1	Revenues / Benefits										
2	CGN Fuel Offset	$ 176,063	$ 180,464	$ 184,976	$ 189,600	$ 194,340	$ 199,199	$ 204,179	$ 209,283	$ 214,515	$ 219,878
3	D3 RINs Generated	$ 988,364	$ 1,013,073	$ 1,038,400	$ 1,064,360	$ 1,090,969	$ 1,118,243	$ 1,146,199	$ 1,174,854	$ 1,204,225	$ 1,234,331
4	D5 RINs Generated	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
5	Tipping Fees Avoided	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
6	FOG Tipping Fee Revenue	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
7											
8	Operating Expenses										
9	Media Changeout	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
10	System Backflush	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
11	System Maintenance	$ (38,403)	$ (39,363)	$ (40,347)	$ (41,355)	$ (42,389)	$ (43,449)	$ (44,535)	$ (45,649)	$ (46,790)	$ (47,960)
12	Chemicals and Water	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
13	General O&M	$ (74,245)	$ (76,101)	$ (78,004)	$ (79,954)	$ (81,952)	$ (84,001)	$ (86,101)	$ (88,254)	$ (90,460)	$ (92,722)
14	Electric Savings (Cost)	$ 30,377	$ 31,136	$ 31,914	$ 32,712	$ 33,530	$ 34,368	$ 35,228	$ 36,108	$ 37,011	$ 37,936
15	Natual Gas Savings (Cost)	$ (129,253)	$ (132,484)	$ (135,796)	$ (139,191)	$ (142,671)	$ (146,237)	$ (149,893)	$ (153,641)	$ (157,482)	$ (161,419)
16	Sludge Cake Hauling Savings (Cost)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
17											
18	Capital Investment										
19											
20	Total Savings (Cost)	$ 952,903	$ 976,726	$ 1,001,144	$ 1,026,173	$ 1,051,827	$ 1,078,123	$ 1,105,076	$ 1,132,702	$ 1,161,020	$ 1,190,046
21	Cumulative Savings (Cost)	$ 5,974,773	$ 6,951,499	$ 7,952,643	$ 8,978,815	$ 10,030,642	$ 11,108,765	$ 12,213,840	$ 13,346,543	$ 14,507,563	$ 15,697,608
22	Partial Year	5.3	6.1	6.9	7.7	8.5	9.3	10.1	10.8	11.5	12.2
23											
24	**Net Present Value Savings (Cost)**										
25	**Payback Period**										
26	**Equivalent Annual Annuity**										

Attachment 3: Cross Reference Table between Scenarios in this Memo and Arcadis's Anaerobic Digester Capabilities Concept Memorandum dated September 13, 2019

	Digestion Memo		
Scenario Number in This Memo	Scenario Number in Digester Memo	Scenario Name	Scenario Description
Scenario 1	Scenario 1.3	'All Year On/ Shoulder-Peak' / 'Enhanced Baseline' Scenario	The 'Enhanced Baseline' Scenario assumes current operations. Therefore, under this scenario, there is no high-strength waste collected and delivered to the NWWRP. This scenario assumes that City uses biogas to run the City's existing engine generator system to generate electricity on-site and peak-shave ('Winter On-peak' seasonal period). The biogas is used as it is generated and supplemented with biogas stored in the existing storage tank to operate the engine at approx. 87.5% capacity. Natural gas is fed to the engine when biogas in not available (while the storage tank is being filled). It is assumed that the engine has a 90% annual availability.
Scenario 2	Scenario 2.4	HSW to both DIGs – CHP at 100%	The 'HSW to both DIGs – CHP at 100%' Scenario assumes that the City will inject HSW slurry (organic solid waste from the City and FOG from outside sources) in both digesters. This scenario assumes that City uses biogas to run the City's existing engine generator system to generate electricity on-site and peak-shave (both peak- and shoulder peak-periods, all year around). The biogas is used as it is generated and supplemented with biogas stored in the existing storage tank to operate the existing engine. Natural gas is fed to the engine when biogas in not available (while the storage tank is being filled). It is assumed that the engine has a 90% annual availability.
Scenario 3	Scenario 2.5	HSW to both DIGs – Expanded CHP at 100%	The 'HSW to both DIGs – Expanded CHP at 100%' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in both digesters. This scenario assumes that City uses biogas to run the City's expanded engine generator system(existing engine and an additional new 800kW engine) to generate electricity on-site and peak-shave (both peak- and shoulder peak-periods, all year around). The biogas is used as it is generated and supplemented with biogas stored in the existing storage tank to operate the engines. Natural gas is fed to the engine when biogas in not available (while the storage tank is being filled). It is assumed that the engines have a 90% annual availability.
Scenario 4	Scenario 3.3	HSW to both DIGs – All D5 RNG	The 'HSW to both DIGs – All D5 RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in both digesters. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is added to both digesters, this scenario generates only D5 RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the existing engine generator system is not operated.
Scenario 5	Scenario 3.1.b	HSW to 1 DIG – D3 and D5 RNG	The 'HSW to both DIGs – D3 and D5 RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in one digester. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is added to one digester, this scenario generates both D3 (non-HSW digester) and D5 (w/HSW digester) RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the engine generator system is not operated.
Scenario 6	Scenario 4.3	HSW to both DIGs – CHP at 100% + RNG	The 'HSW to both DIGs – CHP at 100% + RNG' Scenario assumes that the City will inject HSW slurry (organic solid waste from City and FOG from outside sources) in both digesters. This scenario assumes that City sends a small portion to the available biogas to the existing engine generator system to generate electricity on-site and peak-shave ('Max Summer On-Peak' seasonal period). Tha additional biogas is used in the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is added to both digesters, this scenario generates only D5 RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG).
Scenario 7	Scenario 4.5	No HSW – all D3 RNG + NG Peak CHP at 100%	The 'No HSW – all D3 RNG + NG Peak CHP' Scenario assumes that the City will not collect, process, or inject any HSW at NWWRP. This scenario assumes that City sends all available biogas to the generation of renewable natural gas (RNG). It is assumed that the RNG system has a 95% annual availability. Since HSW is not added to either digester, this scenario generates only D3 RIN credits. The analysis accounts for diesel fuel offset by generating compressed natural gas (CNG). Under this scenario, the City uses natural gas to run the City's existing engine generator system to generate electricity on-site and peak-shave ('Mild Summer Shoulder-peak' seasonal period). Natural gas fed to the engine to operate at 100% capacity. It is assumed that the engine has a 90% annual availability.

APPENDIX F

Total Project Cost Estimates

Thermal Alkaline Hydrolysis Total Project Cost Estimate						
Item Description	**Quantity**	**Unit**	**Total Unit Cost**	**Installation & Labor Cost**		**Total Cost**
General Conditions/Division 1					**$**	**216,000**
Structural					**$**	**18,000**
Concrete Slab on Grate (27'x20'x1' thick)	20	cy	$ 600	$ 300	$	18,000
Mechanical					**$**	**1,662,500**
Pondus System	1	ls	$ 1,250,000	$ 412,500	$	1,662,500
Electrical and Instrumentation Controls					**$**	**282,000**
Electrical - 10% of Mechanical Subtotal	10%				$	166,000
I&C - 7% of Mechanical Subtotal	7%				$	116,000
I&C - 7% of Mechanical Subtotal	7%				$	116,000
Subtotal					**$**	**2,179,000**
Construction Cost Contingency	20%				$	436,000
Contractor Overhead & Profit	8%				$	174,000
Taxes, Bonds and Insurance	5%				$	109,000
Direct Construction Costs					**$**	**2,898,000**
Indirect Construction Costs						
Design						
Design Consultant	6.5%				$	188,000
CMAR Services (Contractor)	1.21%				$	35,000
City Staff	2.50%				$	72,000
Permit	LS				$	1,500
Construction						
Contractor Overhead & Profit	8%				$	232,000
Construction Cost Contingency	20%				$	580,000
Council Award Contingency	5%				$	145,000
Construction Administration (Consultant)	3.25%				$	94,000
Construction Administration (City Staff)	3.50%				$	101,000
Taxes, Bonds and Insurance	5%				$	145,000
Admin Fee & Utility						
CIP Administrative Rate	5%				$	109,000
Total Project Cost Estimate					**$**	**4,600,500**

Mixed Slurry Offloading, Receiving, and Equalization Station Total Project Cost Estimate					
Item Description	**Quantity**	**Unit**	**Total Unit Cost**	**Installation & Labor Cost**	**Total Cost**
General Conditions/Division 1					**$ 31,000**
Truck Unloading					**$ 21,000**
Truck Unloading Goseneck	2	ea	$ 2,000	$ 1,000	$ 6,000
Card Reader and Metering Station	1	ea	$ 10,000	$ 5,000	$ 15,000
Pumps and Equipment					**$ 111,000**
Slurry Recirculation and Mixing Pumps	2	ea	$ 20,000	$ 10,000	$ 60,000
Slurry Recirculation Piping and Valves	1	ls			$ 15,000
Slurry Digester Feed Pumps	2	ea	$ 6,000	$ 3,000	$ 18,000
Level Sensor	1	ea	$ 5,000	$ 2,500	$ 7,500
Flow Meter	1	ea	$ 5,000	$ 2,500	$ 7,500
pH probe	1	ea	$ 2,000	$ 1,000	$ 3,000
Piping, Meterining and Valves					**$ 93,450**
6" Truck Unloading Pipe, DI	100	lf	$ 20	$ 40	$ 6,000
6" Fittings,DI	10	ea	$ 250	$ 400	$ 6,500
6" Knife Gate, DI	2	ea	$ 1,000	$ 500	$ 3,000
6" Recirculation/Mixing Pipe, HDPE	150	lf	$ 15	$ 20	$ 5,250
6" Fittings, HDPE	10	ea	$ 200	$ 400	$ 6,000
6" Plug Valve, DI	4	ea	$ 3,000	$ 1,500	$ 18,000
6" Check Valve, DI	2	ea	$ 3,000	$ 1,500	$ 9,000
4" Digester Feed Pipe, HDPE or PVC	500	lf	$ 20	$ 20	$ 20,000
4" Fittings, HDPE or PVC	20	ea	$ 135	$ 150	$ 5,700
4" Gate Valve	6	ea	$ 1,000	$ 500	$ 9,000
4" Check Valve	2	ea	$ 2,000	$ 500	$ 5,000
Electrical and Instrumentation Controls					**$ 60,000**
Lump Sum Electrical and INC	1	ls	$ 60,000		$ 60,000
Direct Construction Costs					**$ 317,000**
Design					
Design Consultant	6.5%				$ 21,000
CMAR Services (Contractor)	1.21%				$ 4,000
City Staff	2.50%				$ 8,000
Permit	LS				$ 1,500
Construction					
Contractor Overhead & Profit	8%				$ 25,000
Construction Cost Contingency	20%				$ 63,000
Council Award Contingency	5%				$ 16,000
Construction Administration (Consultant)	3.25%				$ 10,000
Construction Administration (City Staff)	3.50%				$ 11,000
Taxes, Bonds and Insurance	5%				$ 16,000
Admin Fee & Utility					
CIP Administrative Rate	5%				$ 16,000
Total Project Cost Estimate					**$ 508,500**

RNG PSA Uprgrading System and Pipeline Connection Total Project Cost Estimate					
Item Description	**Quantity**	**Unit**	**Total Unit Cost**	**Installation & Labor Cost**	**Total Cost**
General Conditions/Division 1					**$ 177,000**
Structural					**$ 9,000**
Concrete Slab for High Btu Skid (25'x10'x1' thick)	10	cy	$ 600	$ 300	$ 9,000
Mechanical					**$ 1,300,000**
PSA RNG Conditioning System (450 scfm input capacity)	1	ea	$ 995,000	$ 150,000	$ 1,145,000
10" SS Digester Gas Piping	250	lf	$ 60	$ 80	$ 35,000
10" SS Digester Gas Fittings, Valves, and Metering	1	ls			$ 20,000
2" Buried HDPE Product Gas Piping	150	lf	$ 20	$ 25	$ 7,000
2" Buried HDPE Product Gas Fittings and Valves	1	ls			$ 5,000
Condensate Return and Chiller Piping	1	ls			$ 10,000
RNG to Pipeline Metering Station	1	ls			$ 75,000
Electrical and Instrumentation Controls					**$ 300,000**
Electrical - 15% of Mechanical Subtotal	15%				$ 200,000
I&C - 8% of Mechanical Subtotal	8%				$ 100,000
Subtotal					**$ 1,786,000**
Construction Cost Contingency	20%				$ 357,000
Contractor Overhead & Profit	8%				$ 143,000
Taxes, Bonds and Insurance	5%				$ 89,000
Direct Construction Costs					**$ 2,375,000**
Indirect Construction Costs					
Design					
Design Consultant	6.5%				$ 154,000
CMAR Services (Contractor)	1.21%				$ 29,000
City Staff	1.16%				$ 28,000
Permit	LS				$ 1,500
Construction					
Council Award Contingency	5%				$ 119,000
Construction Administration (Consultant)	3.25%				$ 77,000
Construction Administration (City Staff)	3.55%				$ 84,000
Admin Fee & Utility					
CIP Administrative Rate	5%				$ 143,000
Total Project Cost Estimate					**$ 3,010,500**

RNG Membrane Uprgrading System and Pipeline Connection Total Project Cost Estimate					
Item Description	Quantity	Unit	Total Unit Cost	Installation & Labor Cost	Total Cost
General Conditions/Division 1					**$ 227,000**
Structural					**$ 5,000**
Concrete Slab for High Btu Skid (25'x10'x0.5' thick)	5	cy	$ 600	$ 300	$ 4,500
Mechanical					**$ 1,680,000**
Membrane RNG Conditioning System (450 scfm input c	1	ea	$ 1,380,000	$ 150,000	$ 1,530,000
10" SS Digester Gas Piping	250	lf	$ 60	$ 80	$ 35,000
10" SS Digester Gas Fittings, Valves, and Metering	1	ls			$ 20,000
2" Buried HDPE Product Gas Piping	150	lf	$ 20	$ 25	$ 7,000
2" Buried HDPE Product Gas Fittings and Valves	1	ls			$ 5,000
Condensate Return and Chiller Piping	1	ls			$ 10,000
RNG to Pipeline Metering Station	1	ls			$ 75,000
Electrical and Instrumentation Controls					**$ 380,000**
Electrical - 15% of Mechanical Subtotal	15%				$ 250,000
I&C - 8% of Mechanical Subtotal	8%				$ 130,000
Subtotal					**$ 2,292,000**
Construction Cost Contingency	20%				$ 458,000
Contractor Overhead & Profit	8%				$ 183,000
Taxes, Bonds and Insurance	5%				$ 115,000
Direct Construction Costs					**$ 3,048,000**
Indirect Construction Costs					
Design					
Design Consultant	6.5%				$ 198,000
CMAR Services (Contractor)	1.21%				$ 37,000
City Staff	2.50%				$ 76,000
Permit	LS				$ 1,500
Construction					
Council Award Contingency	5%				$ 152,000
Construction Administration (Consultant)	3.25%				$ 99,000
Construction Administration (City Staff)	3.50%				$ 107,000
Admin Fee & Utility					
CIP Administrative Rate	5%				$ 152,000
Total Project Cost Estimate					**$ 3,870,500**

Thermal Oxidizer Total Project Cost Estimate					
Item Description	**Quantity**	**Unit**	**Total Unit Cost**	**Installation & Labor Cost**	**Total Cost**
General Conditions/Division 1					**$ 32,000**
Structural					**$ 3,000**
Concrete Slab for TOX Skid	4	cy	$ 650		$ 3,000
Mechanical					**$ 245,000**
Thermal Oxidizer System (200 scfm capacity)	1	ea	$ 175,000	$ 50,000	$ 225,000
Ancillary Piping and Equipment	1	ls			$ 20,000
Electrical and Instrumentation Controls					**$ 46,000**
Electrical - 12% of Mechanical Subtotal	12%				$ 29,000
I&C - 7% of Mechanical Subtotal	7%				$ 17,000
Subtotal					**$ 326,000**
Construction Cost Contingency	20%				$ 65,000
Contractor Overhead & Profit	8%				$ 26,000
Taxes, Bonds and Insurance	5%				$ 16,000
Direct Construction Costs					**$ 433,000**
Indirect Construction Costs					
Design					
Design Consultant	6.5%				$ 28,000
CMAR Services (Contractor)	1.21%				$ 5,000
City Staff	1.16%				$ 5,000
Construction					
Council Award Contingency	5%				$ 22,000
Construction Administration (Consultant)	3.25%				$ 14,000
Construction Administration (City Staff)	3.55%				$ 15,000
Admin Fee & Utility					
CIP Administrative Rate	5%				$ 26,000
Total Project Cost Estimate					**$ 548,000**

Product RNG Pipeline Metering & PRV Station Total Project Cost Estimate					
Item Description	**Quantity**	**Unit**	**Total Unit Cost**	**Installation & Labor Cost**	**Total Cost**
Mechanical					**$ 280,000**
Product RNG Pipeline Metering & PRV Station	1	ls			$ 280,000
Subtotal					**$ 280,000**
Construction Cost Contingency	20%				$ 56,000
Contractor Overhead & Profit	8%				$ 22,000
Taxes, Bonds and Insurance	5%				$ 14,000
Direct Construction Costs					**$ 372,000**
Indirect Construction Costs					
Design					
Design Consultant	6.5%				$ 24,000
CMAR Services (Contractor)	1.21%				$ 5,000
City Staff	1.16%				$ 4,000
Construction					
Council Award Contingency	5%				$ 19,000
Construction Administration (Consultant)	3.25%				$ 12,000
Construction Administration (City Staff)	3.55%				$ 13,000
Admin Fee & Utility					
CIP Administrative Rate	5%				$ 22,000
Total Project Cost Estimate					**$ 471,000**

Low Pressure Compressor Total Project Cost Estimate					
Item Description	**Quantity**	**Unit**	**Total Unit Cost**	**Installation & Labor Cost**	**Total Cost**
General Conditions/Division 1					**$ 34,000**
Low Pressure Compressor					**$ 105,000**
2 psig, 200 scfm Compressor	2	ea	$ 30,000	$ 15,000	$ 90,000
Flow Meter	2	ea	$ 5,000	$ 2,500	$ 15,000
Piping, Meterining and Valves					**$ 101,000**
10" Biogas Pipe, SS	150	lf	$ 80	$ 20	$ 15,000
10" Fittings, SS	10	each	$ 1,200	$ 300	$ 15,000
10" Plug Valves, SS	2	each	$ 6,000	$ 2,000	$ 16,000
10" Check Valves, SS	2	each	$ 8,000	$ 2,000	$ 20,000
10" Isolation Valve, SS	2	each	$ 6,000	$ 1,500	$ 15,000
10" Three Way Recycle Valve, SS	2	each	$ 8,000	$ 1,500	$ 19,000
4" NG Pipe, pe	25	lf	$ 20	$ 20	$ 1,000
Gas Blending System					**$ 60,000**
Gas Blending System	1	ls	$ 60,000		$ 60,000
Electrical and Instrumentation Controls					**$ 40,000**
Lump Sum Electrical and INC	1	ls	$ 40,000		$ 40,000
Direct Construction Costs					**$ 340,000**
Design					
Design Consultant	6.5%				$ 22,000
CMAR Services (Contractor)	1.21%				$ 4,000
City Staff	2.50%				$ 9,000
Permit	LS				$ 1,500
Construction					
Contractor Overhead & Profit	8%				$ 27,000
Construction Cost Contingency	20%				$ 68,000
Council Award Contingency	5%				$ 17,000
Construction Administration (Consultant)	3.25%				$ 11,000
Construction Administration (City Staff)	3.50%				$ 12,000
Taxes, Bonds and Insurance	5%				$ 17,000
Admin Fee & Utility					
CIP Administrative Rate	5%				$ 17,000
Total Project Cost Estimate					**$ 545,500**

High Pressure Dryer Total Project Cost Estimate					
Item Description	Quantity	Unit	Total Unit Cost	Installation & Labor Cost	Total Cost
General Conditions/Division 1					$ 34,000
High Pressure Dryer					
200 psig Dryer	2	ea	$ 50,000	$ 25,000	$ 150,000
Flow Meter	2	ea	$ 5,000	$ 2,500	$ 15,000
Piping, Meterining and Valves					
10" Biogas Pipe, SS	300	lf	$ 80	$ 20	$ 30,000
10" Fittings, SS	15	each	$ 1,200	$ 300	$ 22,500
10" Plug Valves, SS	2	each	$ 6,000	$ 2,000	$ 16,000
10" Check Valves, SS	2	each	$ 8,000	$ 2,000	$ 20,000
10" Isolation Valve, SS	2	each	$ 6,000	$ 1,500	$ 15,000
Electrical and Instrumentation Controls					
Lump Sum Electrical and INC	1	ls	$ 40,000		$ 40,000
Direct Construction Costs					**$ 343,000**
Design					$ -
Design Consultant	6.5%				$ 22,000
CMAR Services (Contractor)	1.21%				$ 4,000
City Staff	2.50%				$ 9,000
Permit	LS				$ 1,500
Construction					
Contractor Overhead & Profit	8%				$ 27,000
Construction Cost Contingency	20%				$ 69,000
Council Award Contingency	5%				$ 17,000
Construction Administration (Consultant)	3.25%				$ 11,000
Construction Administration (City Staff)	3.50%				$ 12,000
Taxes, Bonds and Insurance	5%				$ 17,000
Admin Fee & Utility					
CIP Administrative Rate	5%				$ 17,000
Total Project Cost Estimate					**$ 549,500**

Project Name: Task 3 - Center Street Yard Pre-Processing Facility
Project Number: 30001583
Date: 12/20/2019

Preliminary
Opinion of Probable Cost
FINAL

Line Item No.	Description of Work	Quantity	Unit	Unit Cost ($)	Total Cost ($)	Notes
1	mobilization / demobilization	1	ls	$ -	$ 76,805.19	5% Of items 3 thru 22
2	site preparation	30,976.0	sq. yd.	$ 1.09	$ 33,763.84	clearing and disposal of existing items
3	site grading and subgrade preparation	278,800.0	sq. ft.	$ 2.75	$ 766,700.00	estimated from site plan
4	finish grading	30,976	sq. yd.	$ 1.11	$ 34,383.36	estimated from site plan
5	earthwork	4,700	cu. yd.	$ 0.92	$ 4,324.00	Transfer station and detention ponds
6	asphalt (4 " bituminous asphalt over 8" aggregate base course)	20,497	sq. yd.	$ 27.28	$ 559,158.16	Asphalt $17.07/sq. Yd ABC 10.21/sq. Yd.
7	6" concrete curb	625	lf.	$ 6.10	$ 3,812.50	Parking lot edging
8	sewer lateral (6" dia)	390	lf.	$ 4.36	$ 1,700.40	estimated from site plan
9	sanitary sewer main (8" dia)	528	lf.	$ 6.10	$ 3,220.80	estimated from site plan
10	sanitary sewer manhole (4' dia)	2	ea.	$ 3,076.00	$ 6,152.00	estimated from site plan
11	waterline (C 900 8" Dia.)	1,670	lf.	$ 13.99	$ 23,363.30	Loop from intersection of North Center and Lehi Rd. and project entrance at North Center
12	water service 2"	100	lf.	$ 27.60	$ 2,760.00	estimated from site plan
13	fire hydrant	2	ea.	$ 2,300.00	$ 4,600.00	estimated from site plan
14	roadway asphalt repair from utility installation	721	sq. yd.	$ 27.28	$ 19,668.88	Waterline and sanitary sewer line in Lehi Road
15	valley gutter (4' wide reinforced concrete)	750	lf.	$ 23.73	$ 17,797.50	Concrete valley gutters draining to detention ponds
16	erosion control	1	ls	$ 10,000.00	$ 10,000.00	Lump sum budget item
17	site lighting	1	ls	$ 10,000.00	$ 10,000.00	Lump sum budget item
18	dry utilities (power, fiber)	1	ls	$ 10,000.00	$ 10,000.00	Lump sum budget item
19	signage	1	ls	$ 5,000.00	$ 5,000.00	Lump sum budget item
20	fencing (6' chain link)	1,400	lf.	$ 22.77	$ 31,878.00	Fencing around project perimeter and road to North Center Street
21	fencing (6' block wall)	610	lf.	$ 19.60	$ 11,956.00	Wall along West Lehi Road frontage
22	Landscaping	56,640	sf	$ 0.17	$ 9,628.80	estimated from site plan
23	Scale	2	ea.	$ 70,200.00	$ 140,400.00	Pit less scale, remote reader and printing device, concrete ramps at approach and exit
24	Scale House	1	ea.	$ 27,100.00	$ 27,100.00	10' x 10' pre-engineered / AC / door and window / plug and play wiring and communications
25	Construction Survey				$ 31,397.35	2% of items 2 thru 22
	TOTAL WITHOUT CONTINGENCY				**$ 1,845,570.08**	

Notes: 1.) Based on Concept Site Plan - Fig 5-2
2.) Cost from RS Mean with application of 0.92 cost adjustment for City Index for Mesa AZ

Project Name: Task 3 - Center Street Yard Pre-Processing Facility
Project Number: 30001583
Date: 12/20/2019

ARCADIS Design & Consultancy for natural and built assets

Preliminary
Opinion of Probable Cost
FINAL

Component	Total Cost[1]	Total Cost -30%	Total Cost 50%	Notes
Sitework[2]	$624,000	$436,800	$936,000	33% of Civil/Sitework, incl. one scale.
Pre-Processing Facility Building	$4,582,500	$3,207,800	$6,873,800	incl. 14,300sf interior @ $225/sf, 7,800sf exerior @ $175/sf
Depackaging System	$766,800	$536,800	$1,150,200	vendor quote + installation
Grit Screening	$49,000	$34,300	$73,500	vendor quote + installation
FOG Receiving	$427,700	$299,400	$641,600	vendor quote + installation
Storage, Pumping Systems & Piping (FOG, HSW, etc.)	$250,000	$175,000	$375,000	estimated pumps, tanks, piping
Subtotal	**$6,700,000**	**$4,690,100**	**$10,050,100**	
Construction Cost Contingency **(20%)**	$1,340,000	$938,000	$2,010,000	
Contractor Overhead & Profit **(8%)**	$536,000	$375,000	$804,000	
Taxes, Bonds and Insurance **(5%)**	$335,000	$235,000	$503,000	
Direct Construction Costs	**$8,911,000**	**$6,238,100**	**$13,367,100**	
Indirect Construction Costs				
Design				
Design Consultant **(6.5%)**	$579,000	$405,500	$868,900	
CMAR Services (Contractor) **(1.21%)**	$108,000	$75,000	$162,000	
City Staff **(2.5%)**	$223,000	$156,000	$334,000	
Design Permit	$1,500	$1,500	$1,500	
Construction				
Council Award Contingency **(5%)**	$446,000	$312,000	$668,000	
Construction Administration (Consultant) **(3.25%)**	$290,000	$203,000	$434,000	
Construction Administration (City Staff) **(3.5%)**	$312,000	$218,000	$468,000	
Admin Fee & Utility				
CIP Administrative Rate **(5%)**	$544,000	$380,000	$815,000	5% of Direct + Indirect Subtotals
Total Project Cost Estimate	**$11,414,500**	**$7,989,100**	**$17,118,500**	

[1]The following items are excluded from the Opinion of Probable Construction Cost:

- Geotechnical Investigation & Site Remediation
- Rolling Equipment, Dumpsters, and Misc. Ancillary Items
- Control System Programming

[2]Assumes only sitework for Pre-Processing Facility as stand-alone installation without adjacent similar facilities.

Project Name: Task 3 - Center Street Yard Pre-Processing Facility
Project Number: 30001583
Date: 12/20/2019

ARCADIS Design & Consultancy for natural and built assets

Preliminary
Opinion of Probable Cost
FINAL

Component	Total Cost[1]	Total Cost -30%	Total Cost 50%	Notes
Sitework[2]	$1,221,600	$855,100	$1,832,400	67% of Civil/Sitework, incl. one scale & scale house.
Solid Waste Transfer Station Building	$1,732,500	$1,212,800	$2,598,800	incl. 5,775sf interior @ $300/sf
Subtotal	**$2,954,100**	**$2,067,900**	**$4,431,200**	
Construction Cost Contingency **(20%)**	$591,000	$414,000	$886,000	
Contractor Overhead & Profit **(8%)**	$236,000	$165,000	$354,000	
Taxes, Bonds and Insurance **(5%)**	$148,000	$103,000	$222,000	
Direct Construction Costs	**$3,929,100**	**$2,749,900**	**$5,893,200**	
Indirect Construction Costs				
Design				
Design Consultant **(6.5%)**	$255,000	$178,700	$383,100	
CMAR Services (Contractor) **(1.21%)**	$48,000	$33,000	$71,000	
City Staff **(2.5%)**	$98,000	$69,000	$147,000	
Design Permit	$1,500	$1,500	$1,500	
Construction				
Council Award Contingency **(5%)**	$196,000	$137,000	$295,000	
Construction Administration (Consultant) **(3.25%)**	$128,000	$89,000	$192,000	
Construction Administration (City Staff) **(3.5%)**	$138,000	$96,000	$206,000	
Admin Fee & Utility				
CIP Administrative Rate **(5%)**	$240,000	$168,000	$359,000	5% of Direct + Indirect Subtotals
Total Project Cost Estimate	**$5,033,600**	**$3,522,100**	**$7,547,800**	

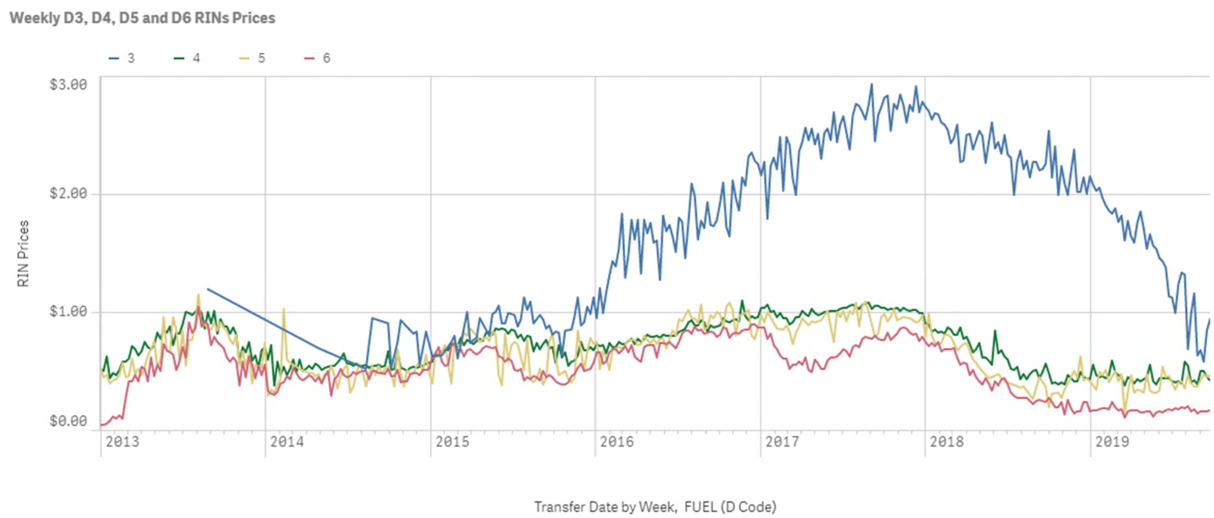
[1]The following items are excluded from the Opinion of Probable Construction Cost:
- Geotechnical Investigation & Site Remediation
- Rolling Equipment, Dumpsters, and Misc. Ancillary Items
- Control System Programming

[2]Assumes only sitework for Solid Waste Transfer Station as stand-alone installation without adjacent similar facilities.

APPENDIX G

Monte Carlo Analysis

As part of Task 4 in Arcadis developed a model to simulate operating conditions at the Northwest Water Reclamation Plant (NWWRP) and Raftelis utilized outputs from that model to conduct a financial analysis to determine the most financially beneficial end use of biogas produced at the NWWRP. The City of Mesa expanded upon the financial analysis developed by Arcadis and Raftelis by conducting a Monte Carlo simulation. The Raftelis financial analysis applied a deterministic model, which assumed RIN prices would increase by 2.5% each year, however RIN prices vary year to year.



The City opted to apply a Monte Carlo simulation to understand the probability of different outcomes due to the variability in RIN prices. The simulation also aids the City in understanding the risk associated with the RIN market.

The City's model was built off the Arcadis and Raftelis model and maintained many of the same cost assumptions. The difference between the models lies in the random generation of RIN prices between an upper and lower bound for each year in the 20-year forecast. Capital costs and operations and maintenance (O & M) costs remained the same and maintained their 2.5% escalation rate. RIN prices were randomly selected for each year in the 20-year forecast then the model calculated the net present value (NPV) of future cash flows, return on investment (ROI), and payback period. The model was run 100,000 times and results were recorded.

The City conducted further analysis on Scenario 4 and Scenario 7 in the Raftelis Economic Evaluation Memorandum. In Scenario 7 the City does not collect food waste and upgrades existing biogas production at the NWWRP to Renewable Natural Gas (RNG). Revenue in these scenarios is from the sale of D3 or D5 RINs and cost savings stem from purchasing less compressed natural gas (CNG) as transportation fuel.

Scenario 4

In Scenario 4 the City would collect and co-digest food waste in the digestors at the NWWRP to generate RNG. Revenue in this scenario is from the sale of D5 Renewable Identification Numbers (RINs). Historically the upper bound for D5 RIN prices is $1.20 per RIN and the lower bound is $0.10 per RIN. The City assumed that RIN prices would fall in the lower half of the historical range over the next twenty years. The model randomly selected a RIN price between the upper and lower bound set by the City for each year in the model.

Assumptions:

- 20-year forecast
- 3% interest rate on debt
- 6% discount rate when calculating net present value
- Costs increase by 2.5% each year
- Equipment life expectancy 15-20 years
- D5 RIN prices between $0.10 and $0.60
- Fueling cost is $0.46 per Diesel Gallon Equivalent (DGE)
- Solid waste tipping fee is $30.31 per ton

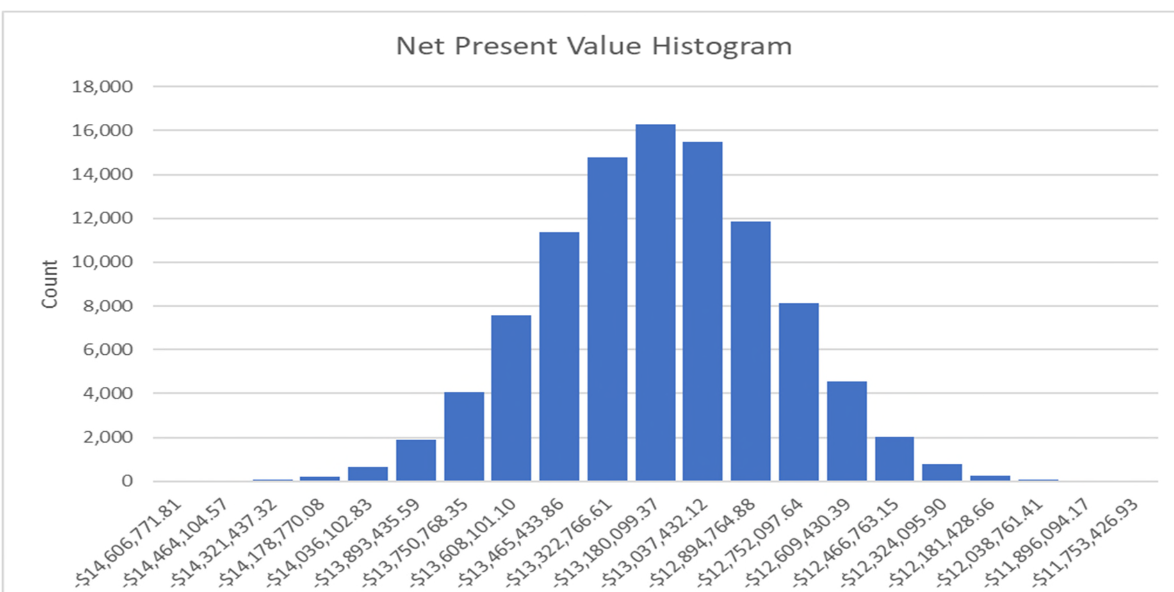
Results

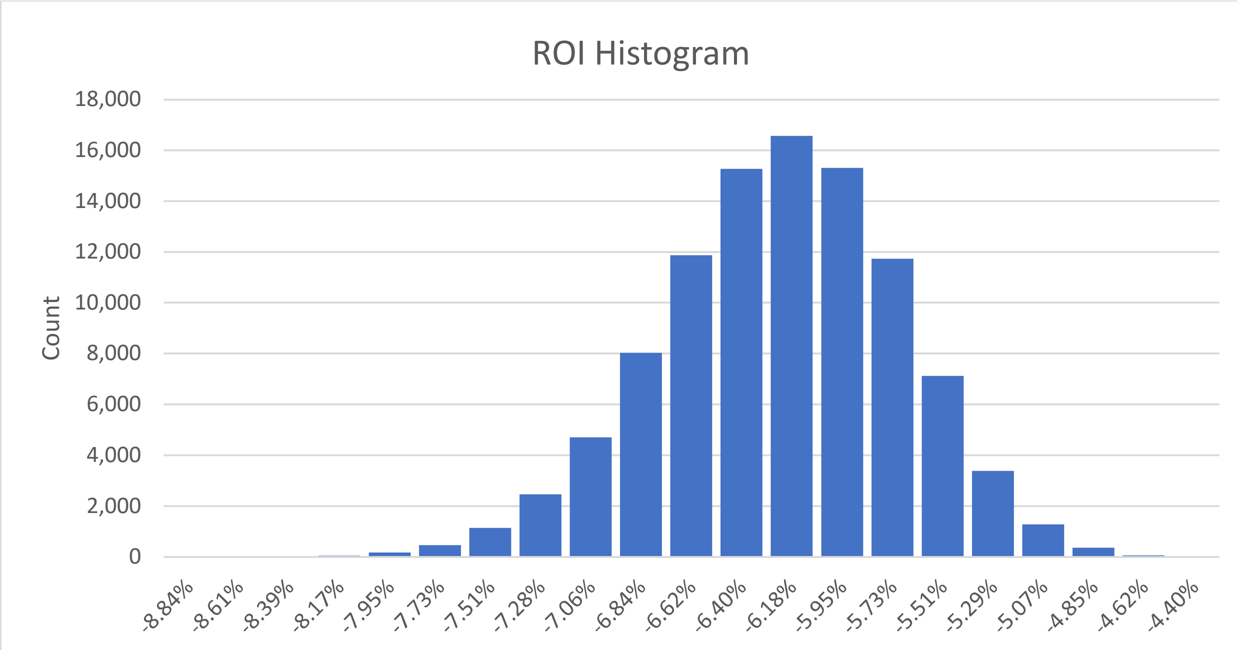
Capital Cost	Expected NPV	Expected ROI	Expected Payback Period
$18,000,000	-$13,000,000	-6.33%	> 20 years

The table below shows the percentile breaks for each financial metric.

Percentile	NPV	ROI
25%	-$13,473,874.37	-6.68%
50%	-$13,240,431.34	-6.32%
75%	-$13,009,769.74	-5.97%
100%	-$11,753,426.93	-4.40%

The graphs below show the distribution of the financial metrics after the model recorded 100,000 simulations.





After 100,000 simulations that randomly generated D3 RIN prices between the upper and lower bounds 5.62% of the simulations resulted in a negative NPV and none of the simulations resulted in a negative ROI.

Negative NPV Percentile	100%
Negative ROI Percentile	100%

Scenario 7

In Scenario 7 the City would capture the existing biogas produced from municipal sludge to generate RNG. Revenue in this scenario is from the sale of D3 RINs. Historically the upper bound for D3 RIN prices is $3.00 per RIN and the lower bound is $0.50 per RIN. The City assumed that RIN prices would fall in the lower half of the historical range over the next twenty years. The model randomly selected a RIN price between the upper and lower bound set by the City for each year in the model.

Assumptions:

- 20-year forecast
- 3% interest rate on debt
- 6% discount rate when calculating net present value
- Costs increase by 2.5% each year
- Equipment life expectancy 15-20 years
- D3 RIN prices between $0.50 and $1.75
- Fueling cost is $0.46 per Diesel Gallon Equivalent (DGE)
- Solid waste tipping fee is $30.31 per ton

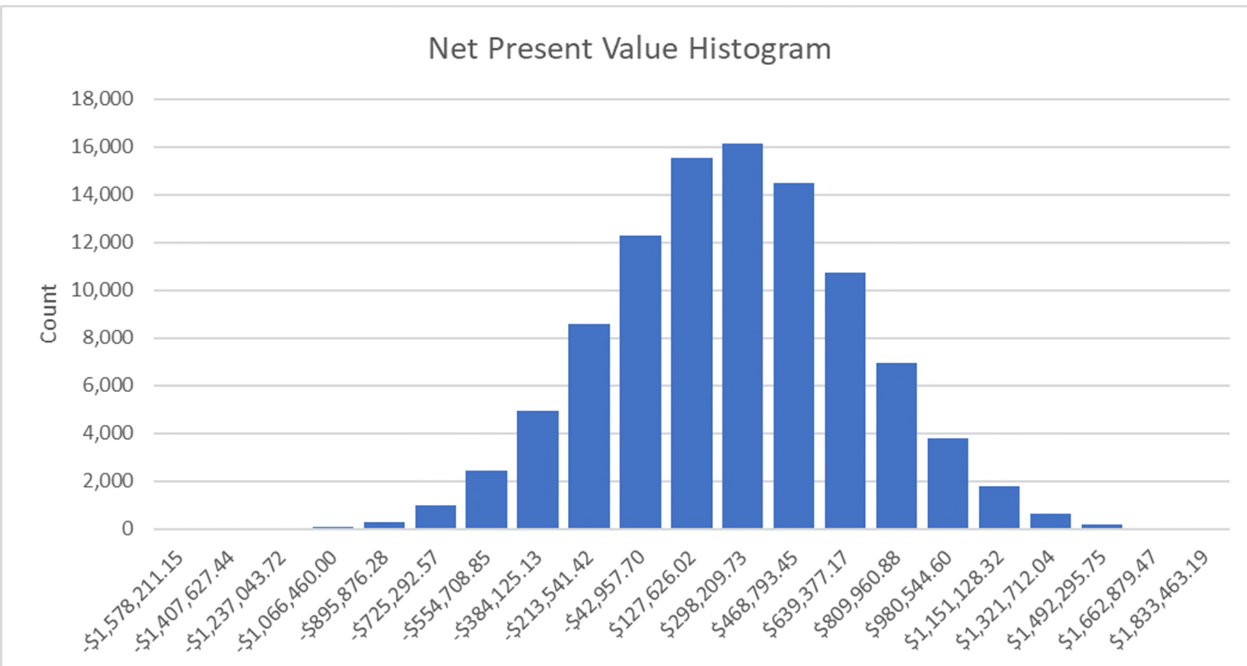
Results

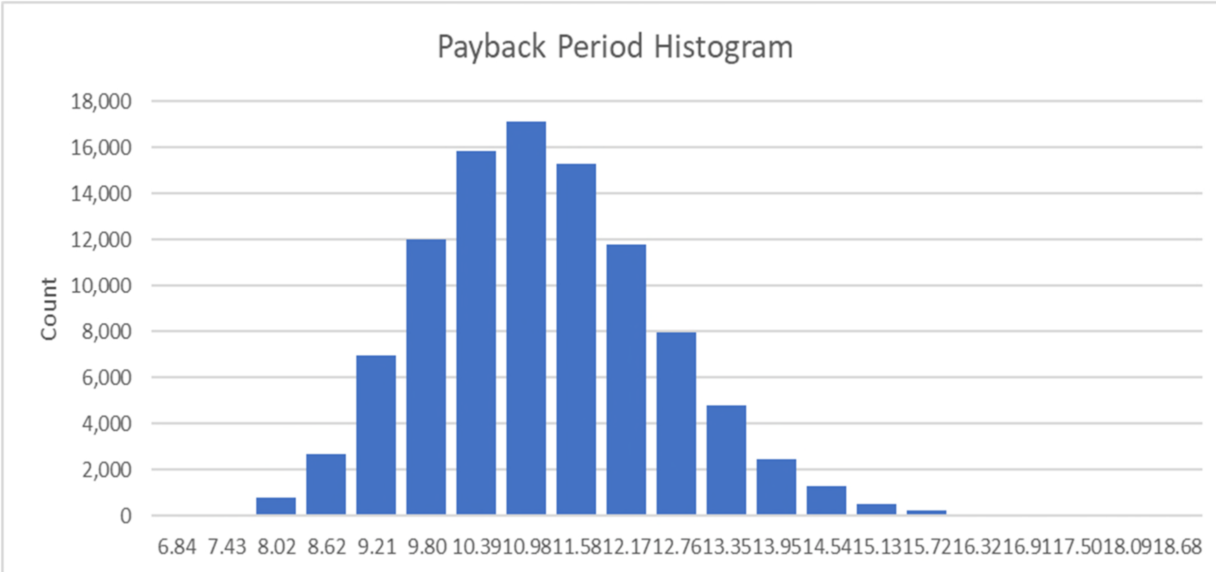
Capital Cost	Expected NPV	Expected ROI	Expected Payback Period
$4,000,000	$180,000	6.55%	10.9 years

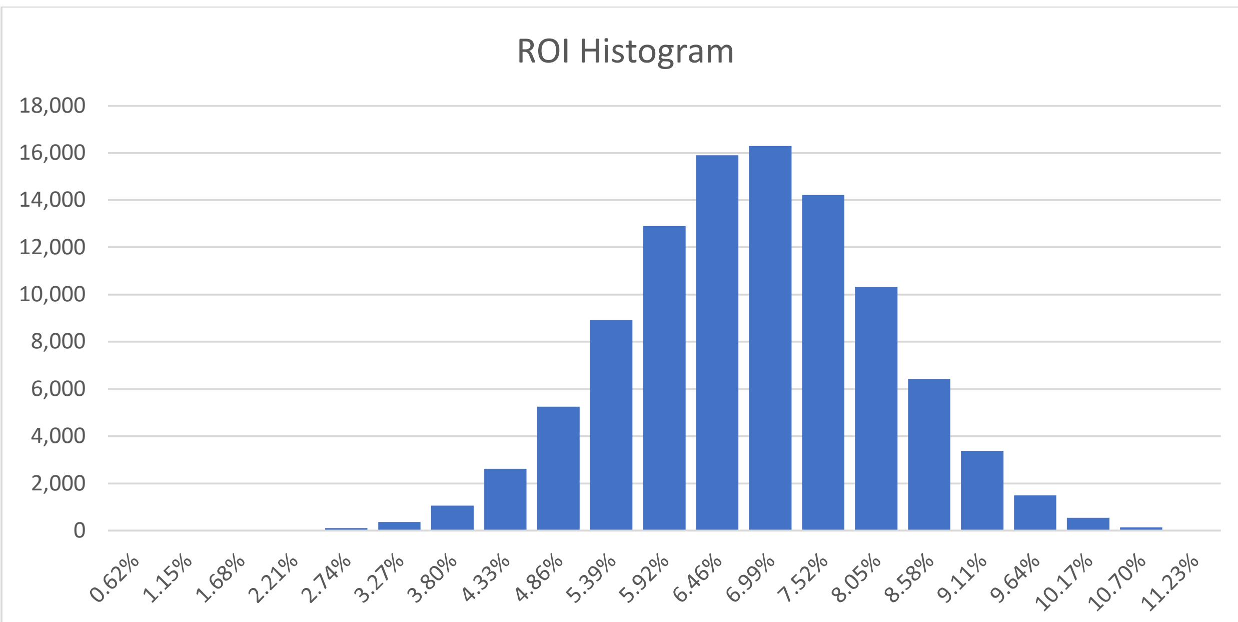
The table below shows the percentile breaks for each financial metric.

Percentile	NPV	Payback Period	ROI
25%	-$101,164.87	9.90 years	5.69%
50%	$177,975.43	10.79 years	6.55%
75%	$458,256.08	11.77 years	7.41%
100%	$1,833,463.19	18.68 years	11.23%

The graphs below show the distribution of the financial metrics after the model recorded 100,000 simulations.







After 100,000 simulations that randomly generated D3 RIN prices between the upper and lower bounds 5.62% of the simulations resulted in a negative NPV and none of the simulations resulted in a negative ROI.

Negative NPV Percentile	33.31%
Negative ROI Percentile	0.00%

Heating Value Scenario

The City also used the model Raftelis and Arcadis created to evaluate the financial benefits of selling the RNG for its heating value. In this scenario the City modified Scenario 4 to reflect revenue from a long term purchase agreement for the RNG. The capital costs and operational costs are the same for this scenario and scenario 4. In this modified model the City would enter into an agreement to sell the RNG to a third party. There is a demand to utilize RNG for its heating value by large organizations that have sustainability goals. The City could co-digest food waste to increase gas production and sell the RNG at a premium to a third party. At the time of this report the market supports RNG prices between $8.00 and $12.00 per MMBtu.

Assumptions:

- 20-year forecast
- 3% interest rate on debt
- 6% discount rate when calculating net present value
- Costs increase by 2.5% each year
- Equipment life expectancy 15-20 years
- RNG sold for $11 per MMBtu for the life of the forecast period
- Fueling cost is $0.46 per Diesel Gallon Equivalent (DGE)
- Solid waste tipping fee is $30.31 per ton

Results

Capital Cost	Expected NPV	Expected ROI	Expected Payback Period
$18,000,000	-$8,800,000	-1.27%	> 20 years

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